Mathematics of Planet Earth: Sustainable Human Environments

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Sustainable Human Environments

- In 1900, only 13% of the world's population lived in cities.
- By 2050, it is predicted that 70% will.

http://citadel.sjfc.edu/students/rnr00577/e-port/msti260/urban.htm

Sustainable Human Environments

- Rapidly growing urban environments present new and evolving challenges:
  - Growing needs for energy and water
  - Impacts on greenhouse gases
  - Public Health
  - Safety
  - Security

- As rapid city expansion continues, mathematical scientists can play key roles in shaping sustainable living environments – in collaboration with scientists from many fields

Sustainable Human Environments

- Four themes for our cluster activities (so far):

    1. The Role of Data in “Smart Cities”
    2. Anthropogenic Biomes
    3. Security
    4. Urban Planning for a Changing Environment

- One example from each theme

Theme 1: The Role of Data in "Smart Cities"

"With recent advances in technology, we can infuse our existing infrastructures with new intelligence, … digitizing and connecting … [to] sense, analyze and integrate data, and respond intelligently to the needs of their jurisdictions. In short, we can revitalize them so they can become smarter and more efficient."

IBM SmarterPlanet. http://www.ibm.com/smarterplanet/us/en/?ca=v_smarterplanet, 2012.

The Role of Data in "Smart Cities"

- Challenge: Find ways to use data to:
  - Make smarter, more livable cities
  - Understand patterns driving human behavior
  - Understand causes of the state of the urban environment
  - Learn how to optimize our choices.

Smart City: a System of Systems of Systems…

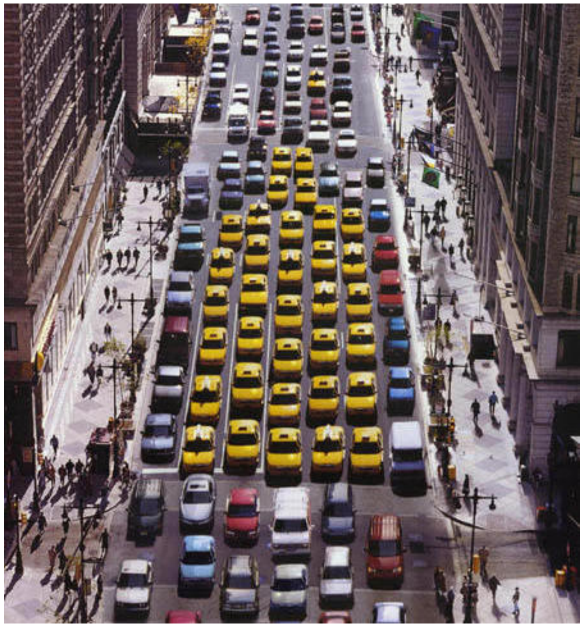
The Role of Data in Smart Cities

- ***Theme 1: The Role of Data In Smart Cities: Math Science Challenges:***
  - Smart systems to reduce congestion and pollution thru traffic prediction and optimization
  - Real-time rerouting of commuting passengers
  - Vehicle sharing systems
  - Energy Management
  - Water Management
  - Health care allocation in emergencies
  - Keeping citizens informed of municipal services (especially during disasters)

The Role of Data in "Smart Cities"

- ***Example: Traffic Management****
- Some math sci challenges: intelligent transportation systems:
  - Integrated fare management
  - Road usage charging
  - Traffic information management

*Most of ideas on traffic management taken from talk "Smart Cities – How can Data Mining and Optimization Shape Future Cities," by Francesco Calabrese of IBM Ireland at DIMACS workshop on Smart Cities, Paris, Sept. 2011



The Role of Data in "Smart Cities"

- Real-time road traffic management:
  - Key role of sensors
  - Monitor actual traffic situation (volumes, speeds, incidents)
  - Control or influence the flow using that information to:
    - ➢ Reduce traffic congestion
    - ➢ Deal with incidents
    - ➢ Provide accurate information to drivers and authorities
    - ➢ Grant proper authority/routing to emergency vehicles

Credit: Francesco Calabrese
Smarter Cities Technical Centre
IBM - Ireland

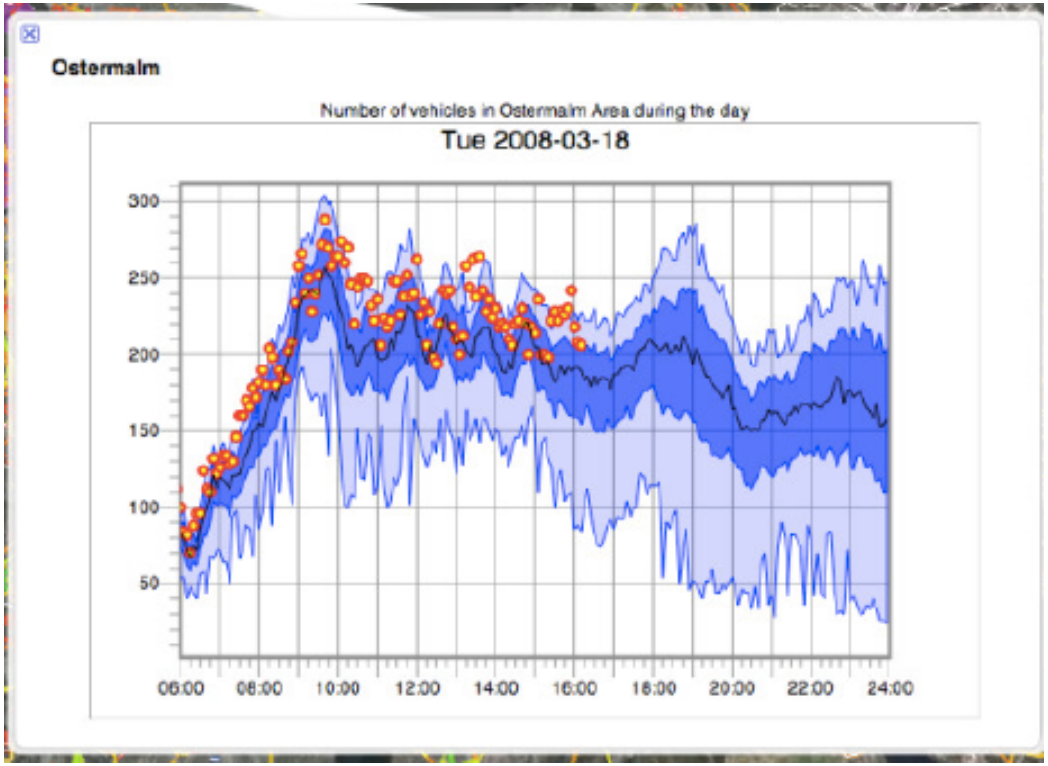
The Role of Data in "Smart Cities"

- Real-time road traffic management: For sensor data, GPS data is key.
- Math Sci challenges:
  - GPS data needs to be related to underlying network (road or rail) by map matching algorithms that are computationally expensive
  - GPS data sampled at irregular intervals, possibly with large gaps – requires advanced analytics to reconstruct GPS trajectories
  - GPS data inaccurate, needs "cleaning"

The Role of Data in "Smart Cities"

- Other sensor data math sci challenges:
  - Real-time speed estimation
  - Estimated heading
  - Real-time traffic information

Credit: Francesco Calabrese
Smarter Cities Technical Centre
IBM - Ireland



The Role of Data in "Smart Cities"

- Understanding human transit demands/needs: for real-time or planning purposes
- Math sci challenges:
  - Analyzing transit needs in short and long term
  - Help citizen to navigate the city
  - Design adaptive urban transportation systems
  - Detect and predict travel demand
  - Offer real-time alternative routings
  - Improving event planning and management: predict effect of an event on urban transportation

Credit: Francesco Calabrese
Smarter Cities Technical Centre
IBM - Ireland

The Role of Data in "Smart Cities"

- Understanding human transit demands/needs: Example: Upcoming Closure of Pulaski Skyway in NJ.
  - Key commuter route into NYC
  - Traffic modeling – NJ Dept. of Transportation
  - Leads to idea of employers shifting work hours
  - Leads to idea of usage of shoulder on NJ Tpk
  - But: need real-time rerouting thru signs, social media, etc.
  - Modeling challenge: what if everyone responds to same routing guidance???
  - Project of CCICADA Center at DIMACS in collaboration with Port Authority of NY/NJ

Credit: Wikipedia

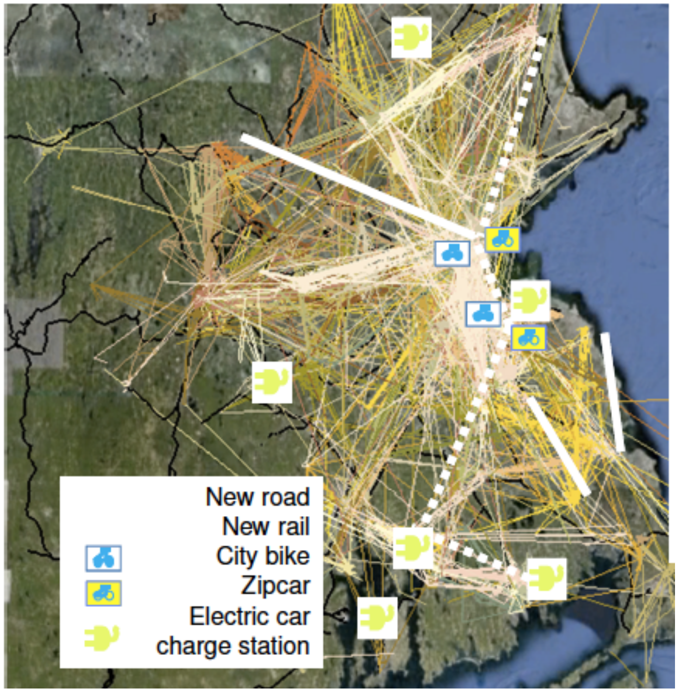
The Role of Data in "Smart Cities"

- Another example: Modeling bike sharing systems
  - How to model spatio-temporal pattern of bike availability
  - Infer correlation between origins and destinations
  - Predict # available bikes, availability of parking spots
  - "Journey advisor" to suggest station to use to minimize travel time and maximize probability of finding a bike

Credit: Francesco Calabrese
Smarter Cities Technical Centre
IBM - Ireland

The Role of Data in "Smart Cities"

- Planning Urban Transportation Systems:
  - What routes to create or expand?
  - Determining route capacities
  - Good combinations of transportation modes
  - Determining location and capacity of stations for bike sharing, zipcars, electric vehicle charging stations
  - How sensitive is plan to origin-destination data?
  - What is effect of population growth?
  - Of changes in built environment?
  - How sensitive is plan to people's transportation mode preferences?



Credit: Francesco Calabrese
Smarter Cities Technical Centre
IBM – Ireland; USDA Farm Service Agency; Mass GIS, Commonwealth of Massachusetts EOEA

Theme 2: Anthropogenic Biomes

- A city can be viewed as a system of systems.
- Considering cities to be like complex, interconnected ecosytems can assist in developing models for interaction of humans and their environment.
- "Biome" an ecological concept – essentially an ecosystem.
- ***Anthropogenic biome***: A biome in which human interaction with natural ecosystems is large and significant.

Anthropogenic Biomes

- ***Theme 2: Anthropogenic Biomes: Math Science Challenges:***
  - Modeling cities as complex, interconnected ecosystems
  - Modeling the interactions of humans and their urban environment
  - Limits to growth
  - Fairness in using and distributing resources
  - Monitoring networks/early warning systems for natural and other hazards
  - Incentives for best practices by citizens
  - Improving paradigms for inclusion and ownership of natural resources
  - Optimizing models for use of networks – physical and social

Anthropogenic Biomes

- *Sustainable* Anthropogenic Biome: What characterizes it?
- Example: compactness
- ***Example: The compact city***

Credit: Francesco Calabrese
Smarter Cities Technical Centre
IBM - Ireland

The Compact City

- In the 1970's two mathematical scientists, George Dantzig and Tom Saaty, developed the notion of a "compact city"
- An idealized city of the future that made effective use of natural resources

- Dantzig, G., and Saaty, T.L., "Compact City: Plan for a Liveable Urban Environment," W.H. Freeman, 1973
- Early version a RAND Corp report in the 1960s.

The Compact City

- George Dantzig:
  - Operations research/management science pioneer
  - Instrumental in establishing the O.R. profession and the foundations of mathematical programming and its applications.
- Tom Saaty
  - PhD in Mathematics
  - Long term faculty member in Business School University of Pittsburgh
  - Pioneer in decision theory, conflict resolution

Tom Saaty
Credit: Wikipedia

George Dantzig
Credit: OR/MS Today, August 2005

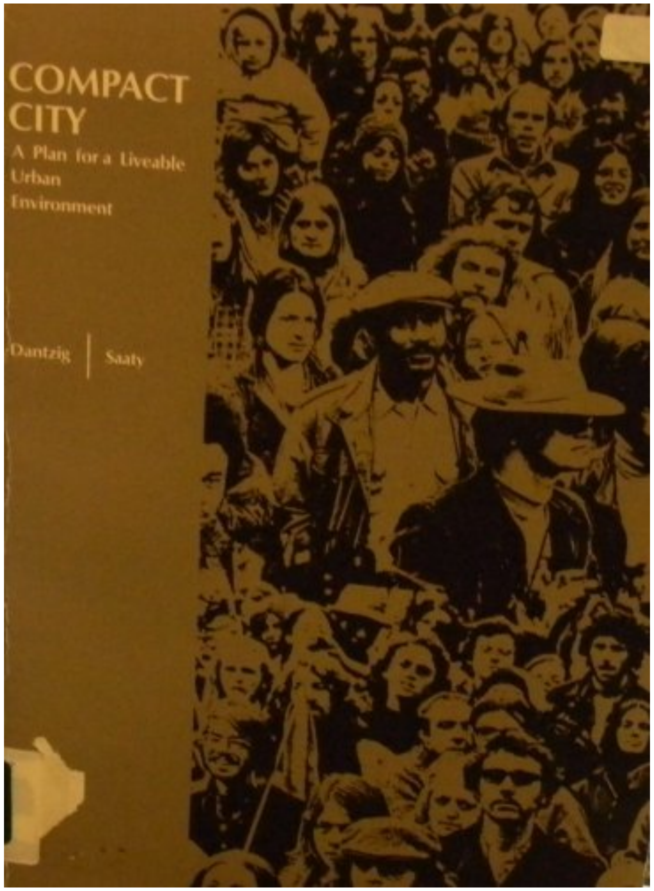
The Compact City

- Dantzig-Saaty compact city:
  - 500,000 people.
  - 5 large skyscrapers surrounded by green space

Credit:
CTBUH Global News
http://www.ctbuh.org/News/GlobalTallNews/tabid/4810/Article/67/language/en-US/view.aspx#!

The Compact City

- Chapters in the Dantzig-Saaty book devoted to specific math-sci problems:
  - Management of vertical traffic
  - Effective use of the time dimension thru round the clock use of facilities
  - Physics of delivering water to top floors
  - Whole chapter on operations research problems



The Compact City: Math Sci Issues*

- Today, concept of compact city is central in urban and regional planning
- Key concepts that need math sci precision/definition/ analysis:
  - Urban containment, separation of settlements, efficiency of land use
  - Viability of public transportation, lower car dependency, lower travel costs and lower climate change emissions
  - Protection of the countryside, land for agriculture, ecological diversity
  - Densification of urban neighborhoods, resulting social cohesion

*This and next 2 slides – thanks to Westerink, et al., "Dealing with Sustainability Trade-offs of the Compact City in Peri-Urban Planning Across European City Regions"

The Compact City: Math Sci Issues

- Should a compact city be monocentric?
- What are advantages of a polycentric city?
- What is the ideal size of a city?
- A compact city loses many advantages if the distance between the core and the fringes is too great. Thus, proximity is important.
- How determine proximity?
  - Metrics?
  - Daily needs of citizens or workers should be in easy walking or cycling distance?
- Proximity replaced by accessibility: Traveling time more important than physical distance

The Compact City: Math Sci Issues

- Density often used as a measure for defining urban gradients
  - But is it # people per acre? # addresses per acre? Average # people per dwelling? Average size of dwelling?
  - How you measure density affects conclusion from your models
- Can you model characteristics of sustainability and of compactness and study whether a compact city is more likely to be sustainable?

Theme 3: Security

- ***Theme 3: Security: Math Science Challenges:***
  - Understanding crime patterns and deploying police
  - Modeling evacuations from large gathering places (stadiums, transportation hubs)
  - Inspection procedures for people entering restaurants, stores, stadiums, transportation hubs
  - Location and optimization of new security initiatives: cameras, barricades, street closures
  - Role of randomization
- ***Example: safety and security at sports stadiums and other large gathering places.***

Credit kitv.com

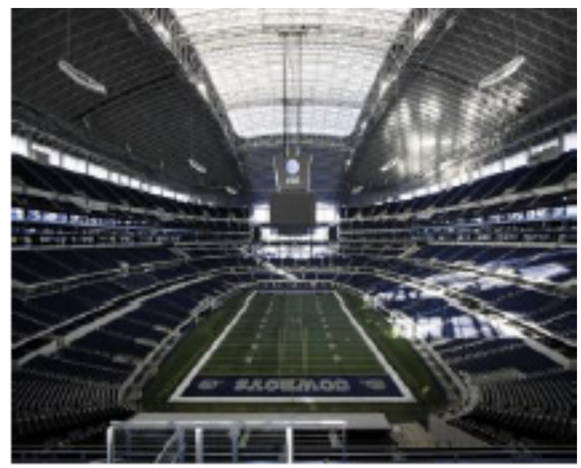
Boston, April 15, 2013

Could mathematical sciences have helped?

Security at Sports Stadiums & Large Gathering Places

- ***Example: safety and security at sports stadiums and other large gathering places.***
- Work of CCICADA Center at DIMACS: modeling and simulation of sports stadium evacuation (in collaboration with Regal Decision Systems)
- Simulations of crowd movement.
- Worked with NFL stadiums.

Lincoln Financial Field
Philadelphia



Cowboys Stadium
Dallas

Security at Sports Stadiums & Large Gathering Places

- ***Example: safety and security at sports stadiums and other large gathering places.***
- Also working with Port Authority of New York and New Jersey on simulation of crowd movements
- Port Authority Bus Terminal in NYC has major crowd movement issues, especially in case of emergencies.

Credit: wnyc.org

Credit: Wikipedia

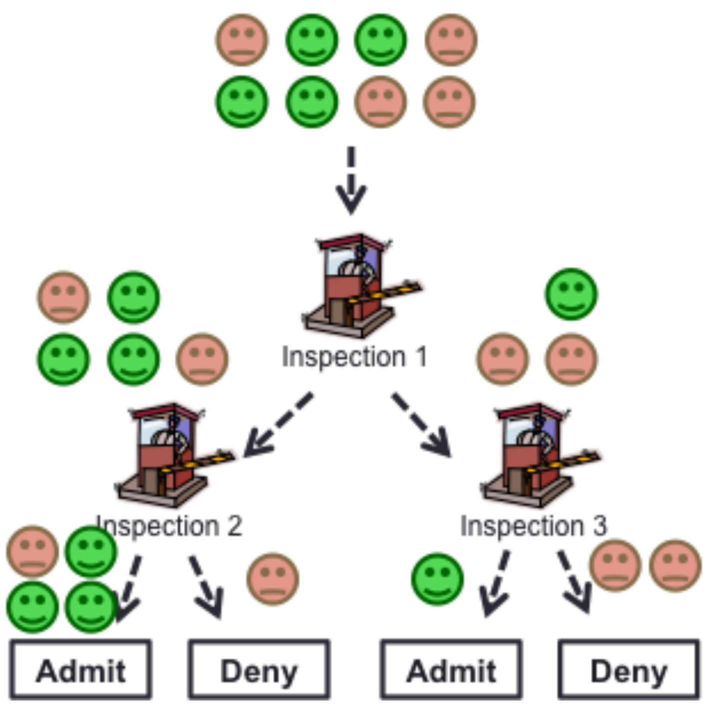
Security at Sports Stadiums & Large Gathering Places

- ***Example: safety and security at sports stadiums and other large gathering places.***
- Work of CCICADA Center at DIMACS: modeling and simulation of sports stadium evacuation (in collaboration with Regal Decision Systems) led us to close collaborations with National Football League security and stadium operators.
  - Worked with 6 NFL stadiums and Indianapolis SuperBowl
  - Work applied during lightning storm at an NFL stadium


PITTSBURGH STEELERS
WORLD CHAMPIONS

Security at NFL Stadiums

- Another challenge: Inspection of entering patrons
  - Modeling
  - Data Analysis
  - Simulation



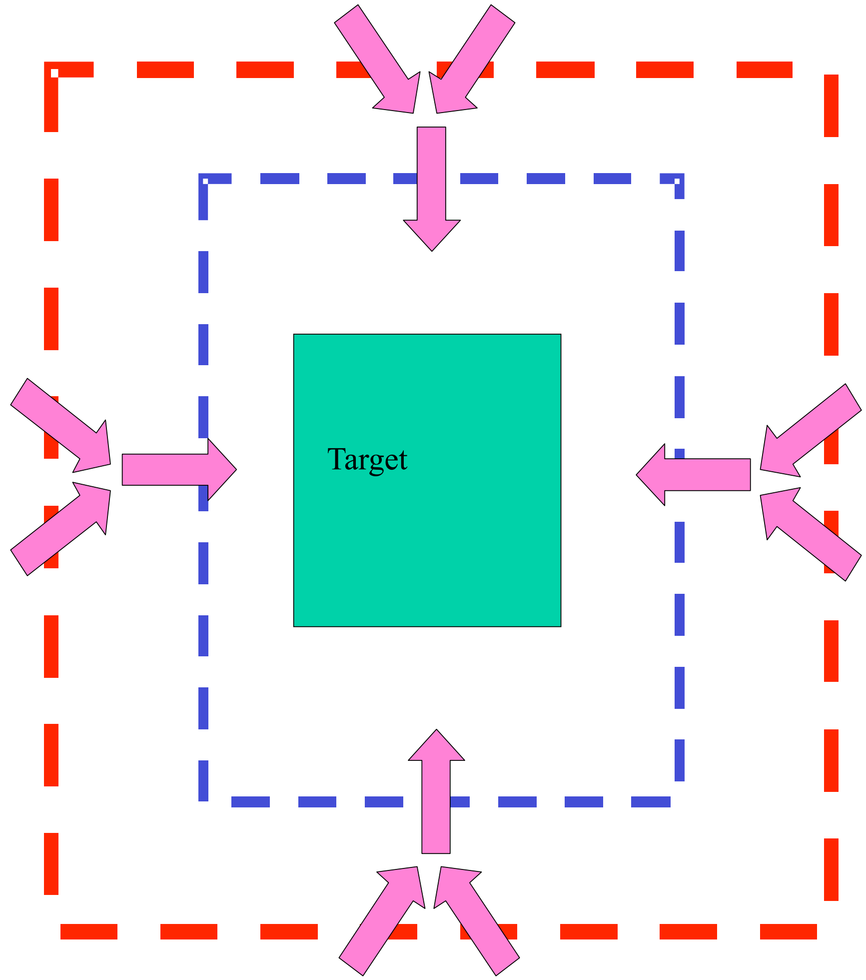
Inspection Models: Layered Defense

- ***Abstract concept of layered defense***
- A model of a "perimeter" defense of the target with several layers of defense:
  - Limited budget for surveillance
  - How much to invest in each layer?
  - Defense at outer layers might be less successful but could provide useful information to selectively refine and adapt strategies at inner layers.
  - Arranging defense in layers so decisions can be made sequentially might significantly reduce costs and increase chance of success.

Layered Defense

Abstract model of layered defense:

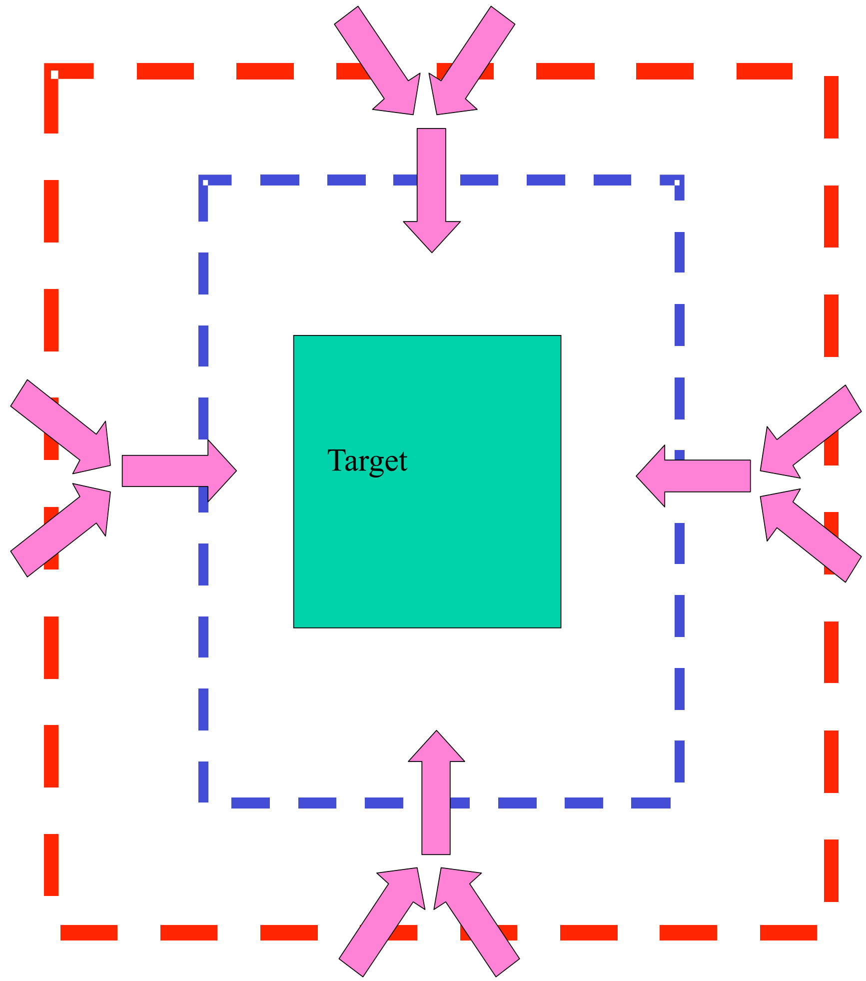
- Target in middle
- Threats arrive via 4 inner channels
- Each combines 2 outer outer flows of vehicles, persons, etc.



Layered Defense

Abstract model of layered defense:

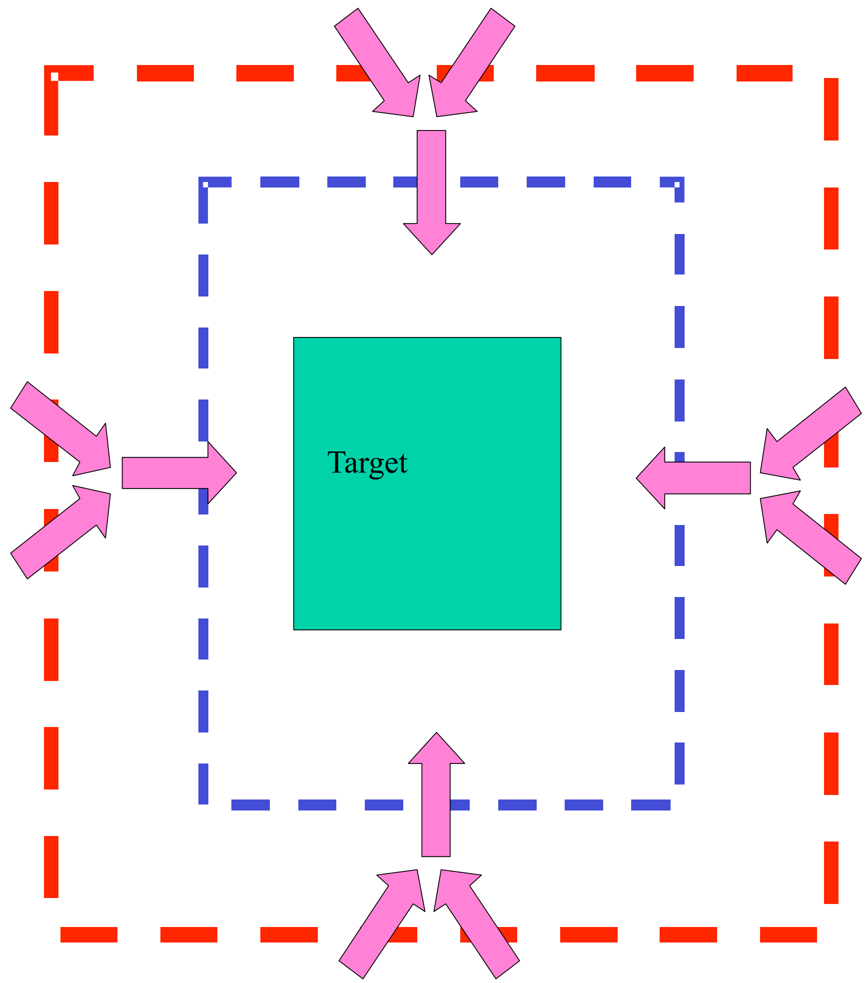
- Fixed budget for outer layer and for inner layer defense
- Can choose among detectors with different characteristics and costs
- How optimize probability of detection?



Layered Defense

Different models for:

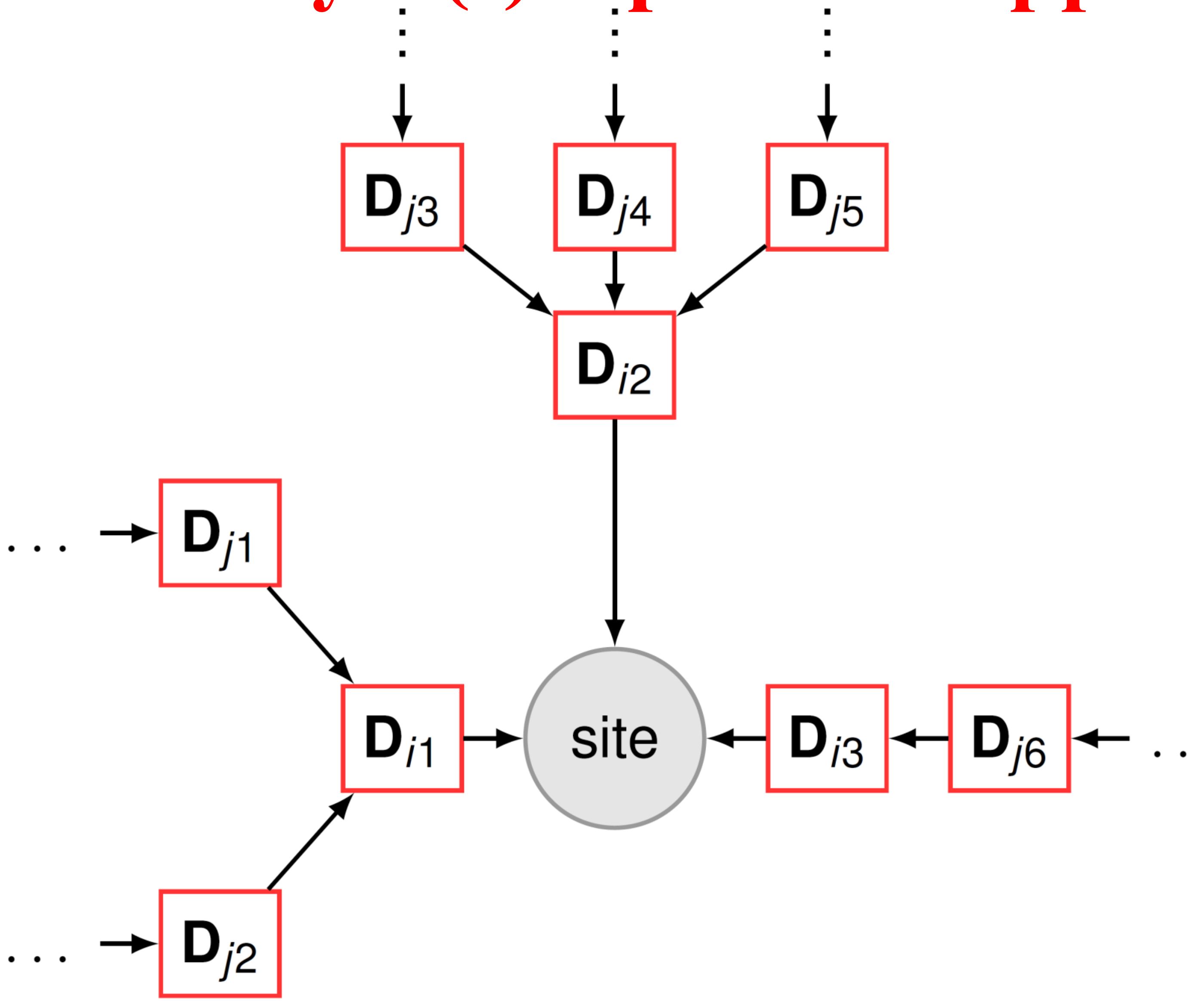
- Flow along different paths
- Prob. of detection at different locations (outer, inner)
- Allocate resources to layers in advance; or allow modifications of inner defense strategies based on outer layer results



Layered Defense

- One can formulate this as an optimization problem of maximizing the probability of detection subject to budget constraints.
- We have developed dynamic programming methods for solving this problem.
- (Asamov, Yamangil, Boros, Kantor, Roberts)

General Formulation: Outer layer(s) plus inner layer(s) – paths of approach



General Formulation: Outer layer(s) plus inner layer(s) – paths of approach

Model Assumptions: First Model:

- Each incoming path u has a dangerous "flow" F_u
- At each sensor k, the probability of detection is a function $D_k(R_k)$ of the resources R_k allocated to that sensor.

General Formulation: Outer layer(s) plus inner layer(s) – paths of approach

Model Assumptions: First Model

Special Case: The Case of Two Layers

- Assume that the outside layers share a limited resource budget and so do the inside layers.
- More subtle models allow one to make decisions about how much budget to allocate between inside and outside.
- ***Goal: Allocate the total outside resources among individual sensors and allocate the total inside resources among individual sensors in order to maximize the illegal flow detected.***

The Case of Two Layers

Dangerous flow captured at outside sensor j

$$\max_{\mathbf{R}} \sum_{i \in InsideSensors} \left\{ \left(\sum_{j \in Neighbors(i)} F_j \cdot D_j(R_j) \right) + D_i(R_i) \left(\sum_{j \in Neighbors(i)} F_j(1 - D_j(R_j)) \right) \right\}$$

$$\text{s.t.} \sum_{i \in InsideSensors} R_i \leq TotalInsideResource$$

$$\sum_{j \in OutsideSensors} R_j \leq TotalOutsideResource$$

$$R_i \geq 0, \forall i \in InsideSensors$$

$$R_j \geq 0, \forall j \in OutsideSensors$$

Dangerous flow not captured at outside sensor j that is captured at inside sensor i

Case of an Adaptive Adversary

- So far, our model assumed a fixed flow of dangerous material on each pathway.
- ***What if we have an adaptive adversary who recognizes how much of a resource we use for sensors on each node and then chooses the path that minimizes the probability of detection?***
- ***To defend against such an adversary we might seek to assign sensor resources so as to maximize the minimum detection rate on any path.***

The Problem for Two Layers with an Adaptive Adversary

$$\max_{\mathbf{R}} \min_{\substack{i \in InsideSensors \\ j \in OutsideNeighbors(i)}} \{D_j(R_j) + D_i(R_i)(1 - D_j(R_j))\}$$

$$\text{s.t.} \sum_{i \in InsideSensors} R_i \leq TotalInsideResource$$

$$\sum_{j \in OutsideSensors} R_j \leq TotalOutsideResource$$

$$R_i \geq 0, \forall i \in InsideSensors$$

$$R_j \geq 0, \forall j \in OutsideSensors$$

Stadium Inspection: Data Issues

- NFL asked all stadium security operators to perform 100% wanding of patrons.
- This didn't always work. Close to kickoff time, lines got too long.
- Met with NFL Security
- Began analysis of security procedures at one stadium

45

Stadium Inspection: Data Issues

- Started by looking at three types of inspection in use at NFL stadiums; later worked with all major sports leagues (MLB, NBA, NHL, MLS, etc.)
  - ***Wanding***
  - ***Pat-down***
  - ***Bag inspection***
- Observed stadium inspections and gathered data about each type of inspection, in particular how long it takes

Stadium Inspection: Data Issues

- Data Collection, Examination, and Analysis of:
  - Efficiency (inspection times) and Effectiveness (detection of contraband).
  - Comparison of pat-down, wanding, and bag check
  - Anonymous comparison of different inspectors
  - Comparison of different gates
  - Physical design of pods
  - Ticket scanning process and related data
  - Arrival patterns of patrons over time

Credit: BigEast.org

Data Analysis - SUMMARY

- We evaluated the ***effect of several important factors on the inspection times***:
  - **Inspection method** (pat-down, wanding, or bag check)
  - **Location** (gate, pod, lane ~ inspector)
  - **Time before event** (early wave vs. late wave)
    - Early wave = from time of gate opening until waiting line is cleared
    - Late wave = from time of crowd accumulation until event start
  - **Type of event/crowd demographics**

Stadium Inspection: Data Analysis

- Since there is a lot of (random) variation, we analyzed the results using statistical methods.

CONCLUSIONS

- Inspection time distributions differ significantly according to
  - Inspection methods; Gates; Times; Events; Inspectors
- ***Statistical analysis shows that the differences are much greater than can be explained by random chance.***

Stadium Inspection: Data Analysis

- Our data analysis and analysis of training procedures helped lead NFL to explore alternatives to the wanding strategy.
- NFL requested 100% walk-through magnetometers.
- Is that feasible?

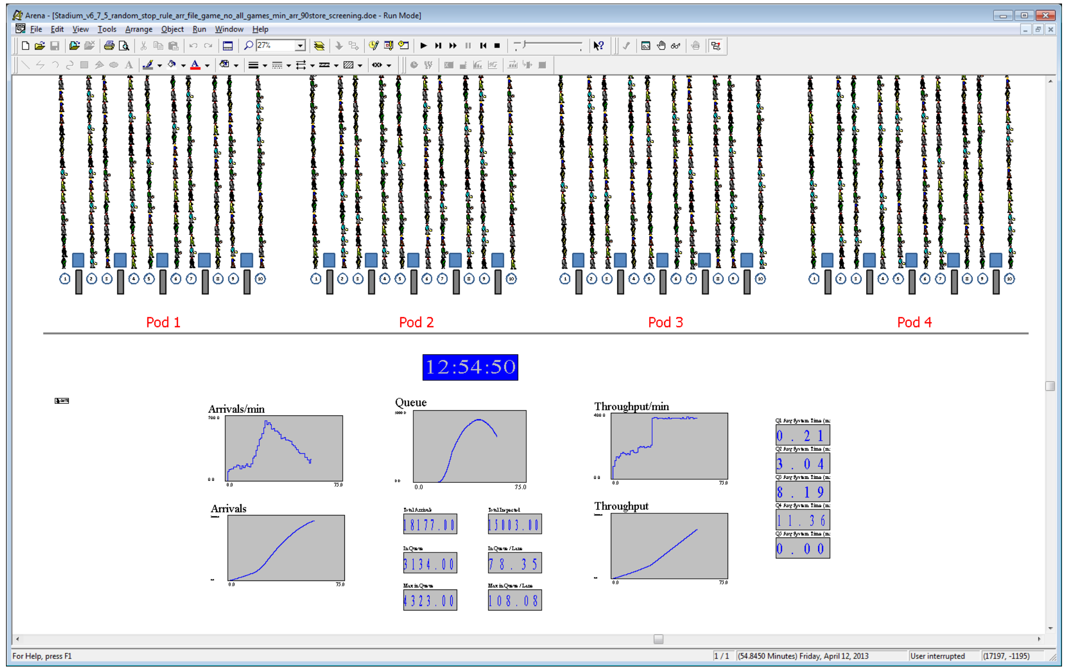
Stadium Inspection: Data Analysis

- We analyzed the strategy of going to 100% magnetometer use
- Issues:
  - ***Project*** number of magnetometers needed to deal with largest expected throughput challenges
  - Observe time required for throughput
  - Model physical location
  - Consider effect of weather on performance

Stadium Security: Simulation as a Planning Tool

- **Simulation modeling – strategic planning:**
  - Based on the information obtained from the data collected during in-person observation and video analysis, we have developed a ***simulation*** of entrance queues.
  - Using the data from actual distributions, we have used the simulation to evaluate the speed and cost of inspection for various alternative policies.

The Simulation Model



Most of the parameters can be obtained by ***choosing a representative game***

- Parameters
  - Arrival rates
  - Number of lanes
  - Wanding times
  - Pat-down times
  - Magnetometer times

- Screening Strategy
  - Switching inspection type (Y/N)
    - Number of patrons in queue to switch the process, or
    - Time of switch
  - Does phase 2 include randomization? (Y/N)
    - Ratio of patrons in each type of inspection in the randomization

The model output file includes:

- **In Queue @ kickoff**
- **Queue clearance time**

- **Max Waiting Time per patron**

Magnetometer Scenarios (Queue Clearance)

No	Game Time	Queue Clearance Times as function of Number of Lanes					
		Base Case (*Wanding & switch to Patdown*)	Magnetometer Scenarios (Number of Lanes)				
		40	20	25	30	35	40
1	9/16/12 1:00 PM	64.65	97.76	83.57	72.18	63.19	56.57
2	10/7/12 1:00 PM	72.79	113.38	95.87	81.07	72.39	64.66
3	10/21/12 1:00 PM	68.67	108.49	92.53	82.13	71.48	65.03
4	11/4/12 4:25 PM	66.80	114.18	94.48	79.75	71.21	61.03
5	11/25/12 8:20 PM	72.40	111.95	94.56	82.52	74.22	65.96
6	12/9/12 4:25 PM	75.40	118.88	99.42	85.81	76.06	67.32
7	12/30/12 1:00 PM	82.67	128.82	108.36	95.27	85.81	76.99
8	9/9/12 1:00 PM	65.46	108.92	89.23	77.64	67.33	58.04
9	9/30/12 1:00 PM	71.33	111.08	94.26	83.39	74.11	65.91
10	10/8/12 8:30 PM	60.80	94.76	76.65	58.19	55.00	55.00
11	10/14/12 1:00 PM	66.50	109.20	91.91	79.01	65.45	55.00
12	10/28/12 1:00 PM	70.82	112.12	93.47	81.09	69.53	61.86
13	11/22/12 8:20 PM	65.94	93.41	79.52	55.12	55.00	55.00
14	12/2/12 1:00 PM	64.45	105.51	91.92	77.06	55.00	55.00

Worse than the Base and does not meet the goal
Similar to Base or better, but does not meet the goal
Meets the goal

Goal: Queue clears by 65 minutes

Future Directions/Next Steps

- ***Simple randomizations and how to implement and test in practice:***
  - When 100% inspection is not feasible, is there a randomized inspection scheme that ensures equal or greater security protection and deterrence benefit?
  - Use our simulation model to help with percentages that can be inspected at each stage before kickoff?
  - Is there a way to implement such a scheme that is practical and not subject to being interpreted as profiling?
    - ➢Random beeper
    - ➢Deck of cards
    - ➢Credit card number to present later in the queue

Stadium Inspection

- **Other Key Security Issues with Math Sci Challenges:**
  - Access control
  - Credentialing
  - Perimeter control
  - Communications
  - Training and exercising
  - Transportation access
  - Cyber security

Boston April 15, 2013

Credit people.com

So would mathematical sciences have helped?

Boston April 15, 2013

Credit people.com

So would mathematical sciences have helped?

- Modeling helped change access policies at NFL and college stadiums following the Boston events: Layered defense!
- Beginning to be used for events with more open access

Theme 4: Urban Planning for a Changing Environment

- ***Theme 4: Urban Planning for a Changing Environment: Math Science Challenges:***
  - Changing climate
  - Sea level rise; salt water inundation
  - Growing number of electrical vehicles
  - Alternative energy systems for heating and cooling
  - Smart grid
  - Social media as aid to urban living
  - Increasing problem of solid waste as city population increases; recycling protocols
  - Availability of potable water
  - Ubiquitous sensors that measure everything from the need to dim street lights and when trash bins are full

Urban Planning for Climate Events

- ***Example: Climate events***: Super Storms, heat, drought, floods – all could be increasing in number and severity.
- What can urban areas do to prepare for them?

Urban Planning for Climate Events

- Sustainable Human Environments cluster: Pre-workshop: Urban Planning for Climate Change, Sept. 2013, at DIMACS-Rutgers University
- *What can urban areas do to prepare for/mitigate changes due to climate and in particular the effect of future climate events?*

Extreme Events due to Global Warming

- We anticipate an increase in number and severity of extreme events due to global warming.
- More heat waves.
- More floods, hurricanes.

Extreme Events due to Global Warming: More Hurricanes

Irene hits NYC – August 2011

Extreme Events due to Global Warming: More Hurricanes

Irene hits NYC – August 2011

Extreme Events due to Global Warming: More Hurricanes

Irene hits NYC – August 2011

Extreme Events due to Global Warming: More Hurricanes

Sandy Hits NJ Oct. 29, 2013

My backyard

My block

Extreme Events due to Global Warming: More Hurricanes

Sandy Hits NJ Oct. 29, 2013

My neighborhood

My block

Extreme Events due to Global Warming: More Hurricanes

Sandy Hits NJ Oct. 29, 2013

NJ Shore – from Jon Miller

Extreme Events due to Global Warming: More Hurricanes

Future Storms

•To plan for the future, what do we need to do?

•How can we use mathematical modeling, simulation, and algorithmic tools of risk assessment to plan for the future?

•To plan for more extreme events

•To plan for rising sea levels

Extreme Events due to Global Warming: More Hurricanes

- Using mathematical modeling, simulation, and algorithmic methods of risk assessment to plan for the future:
  - What subways will be flooded?
  - How can we protect against such flooding?

Extreme Events due to Global Warming: More Hurricanes

•Using mathematical modeling, simulation, and algorithmic methods of risk assessment to plan for the future:

- What power plants or other facilities on shore areas will be flooded?
- Do we have to move them?

Extreme Events due to Global Warming: More Hurricanes

•Using mathematical modeling, simulation, and algorithmic methods of risk assessment to plan for the future:

– How can we get early warning to citizens that they need to evacuate?

– How can we plan such evacuations effectively?

Extreme Events due to Global Warming: More Hurricanes

- Using mathematical modeling, simulation, and algorithmic methods of risk assessment to plan for the future:
  - –How can we plan placement of utility lines to minimize down time?

Extreme Events due to Global Warming: More Hurricanes

- Using mathematical modeling, simulation, and algorithmic methods of risk assessment to plan for the future:
  - –How can we plan for getting people back on line after a storm?

Bringing in help from out of state

Extreme Events due to Global Warming: More Hurricanes

- Using mathematical modeling, simulation, and algorithmic methods of risk assessment to plan for the future:
  - How can we set priorities for cleanup?

Sea Level Rise

- Sectors affected by sea level rise include:
  - Transportation
  - Communications
  - Energy
  - Construction
  - Water supply
  - Waste

- How do we prioritize among them?
- How are they interrelated? E.g., better communications might help us reroute transportation more efficiently.

Photo Source: Updating Maryland's Sea-Level Rise Projections, Maryland Climate Change Commission, June 26, 2013

Logistics: Supply Chains

- What supplies are needed during an emergency?
  - Water, Food, Fuel, Generators, Chainsaws?
- How and where can we stockpile them?
- What are good methods for getting these to those who need them in an efficient way?


Floods

• How do we plan emergency rescue vehicle routing to avoid rising flood waters while still minimizing delay in provision of medical attention and still getting afflicted people to available hospital facilities?

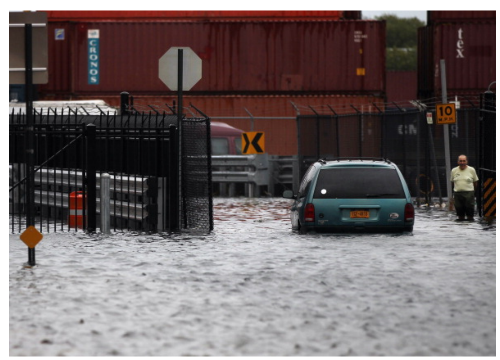
Floods

- Which flood mitigation projects to invest in?
  - Buyouts
  - Better flood warning systems
  - "Green infrastructure" (cisterns & rain barrels)
  - Pervious concrete
  - Etc.

Raritan River flood
Bound Brook, NJ
August 2011

Floods

- Data-driven/Model-driven Decision Support
- Data-driven. Assemble data about:
  - Precipitation (duration, amount)
  - Antecedent conditions (soil moisture content, ground cover, seasonality)
  - River gage levels
  - Flood maps
  - Property damage data – FEMA payouts



Floods

- Data-driven, Model-driven Decision Support
- Model-driven: A CCICADA project with FEMA
  - Hydrological modeling to predict effect on river gage levels of different flood mitigation projects
  - Econometric modeling to predict insurance costs of flood gage levels
  - Combine the two

Extreme Heat Events

•Subject of a DIMACS project.

•Key initial emphasis by CDC's modeling unit

•Result in increased incidence of heat stroke, dehydration, cardiac stress, respiratory distress

•Hyperthermia in elderly patients can lead to cardiac arrest.

•Effects not independent: Individuals under stress due to climate may be more susceptible to infectious diseases

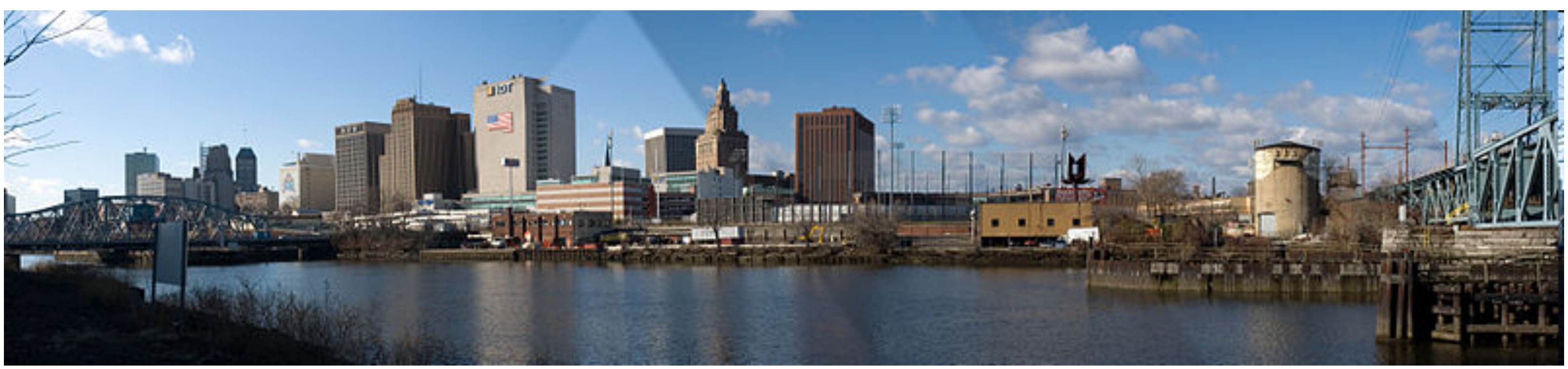
Extreme Heat Events

- One response to such events: evacuation of most vulnerable individuals to climate controlled environments.
- Modeling challenges:

  - Where to locate the evacuation centers?
  - Whom to send where?
  - Goals include minimizing travel time, keeping facilities to their maximum capacity, etc.
  - All involve tools of Operations Research: location theory, assignment problem, etc.
  - Long-term goal in smart cities: Utilize real-time information to update plans

Extreme Heat Events

- The DIMACS project on heat event evacuation was based in Newark, NJ – collaboration with Newark city agencies.
- Data includes locations of potential shelters, travel distance from each city block to potential shelters, and population size and demographic distribution on each city block.
- Determined “at risk” age groups and their likely levels of healthcare needed to avoid serious problems

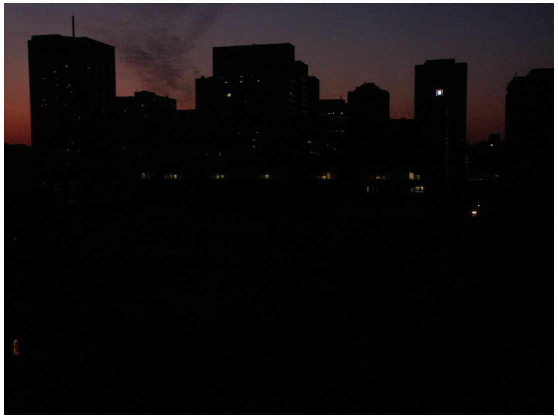


Extreme Heat Events

- DIMACS project was also concerned with computing optimal routing plans for at-risk population to minimize adverse health outcomes and travel time
- Question: Smart cities: Can routing plans be implemented quickly; can we get information to people quickly?
- Can we develop evacuation plans that are quickly modifiable given data from evacuation centers, traffic management, etc.?
- Far from what happens in evacuations today.

Extreme Heat Events

- A side effect of such events: Extremes in energy use lead to need for rolling blackouts.
- Modeling challenges (a DIMACS research project)
  - Understanding health impacts of blackouts and bringing them into models
  - How do we design efficient rolling blackouts while minimizing impact on health?
    - Lack of air conditioning
    - Elevators don't work: vulnerable people over-exertion
    - Food spoilage
  - Minimizing impact on the most vulnerable populations
- Math science challenge: How to utilize "smart grid" to update plans



MPE: Sustainable Human Environments
How can Math Sciences help?
How can we each help?