Planning for Public Health and Humanitarian Emergencies

Modeling Approaches to Inform Good Decisions




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Key public health threats

TERRORIST ATTACKS

INFECTIOUS DISEASES

NATURAL DISASTERS

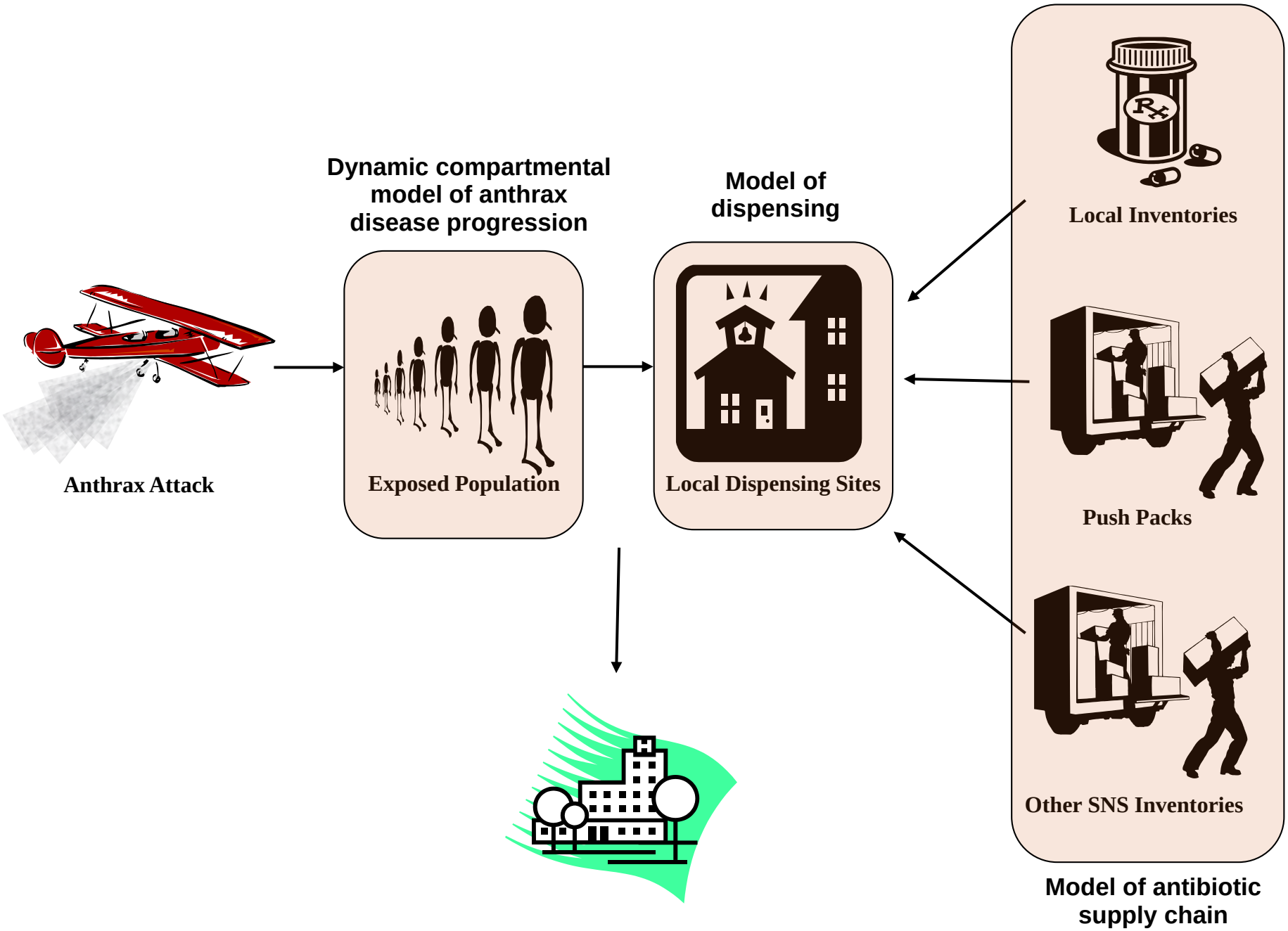
MANMADE DISASTERS

Relevant issues

- Uncertainty about timing and magnitude of events
- Preparedness is essential
  - Supply stockpiling
  - Response plans
- Preparedness budgets are limited
- How can model-based analyses help us make good preparedness plans?

1. Logistics of outbreak response

- Model of anthrax
- Evaluate the costs and benefits of various strategies for stockpiling and dispensing medical and pharmaceutical supplies
- Evaluate the benefits of improved surveillance

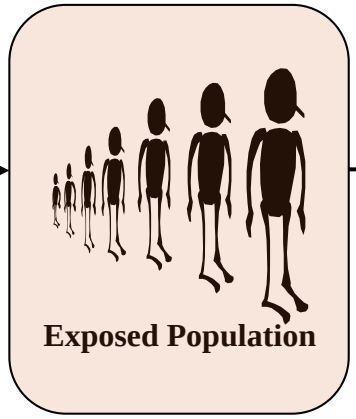

Dynamic compartmental model of anthrax disease progression
Model of dispensing
Local Inventories
Anthrax Attack
Exposed Population
Local Dispensing Sites
Push Packs
Other SNS Inventories
Model of antibiotic supply chain

Key inputs

Anthrax Attack

Chance of attack
Attack size

Costs

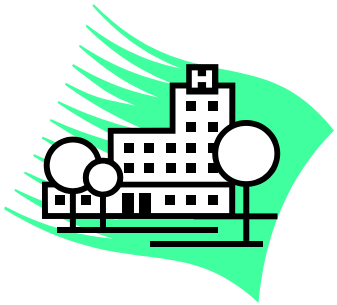


Exposed Population

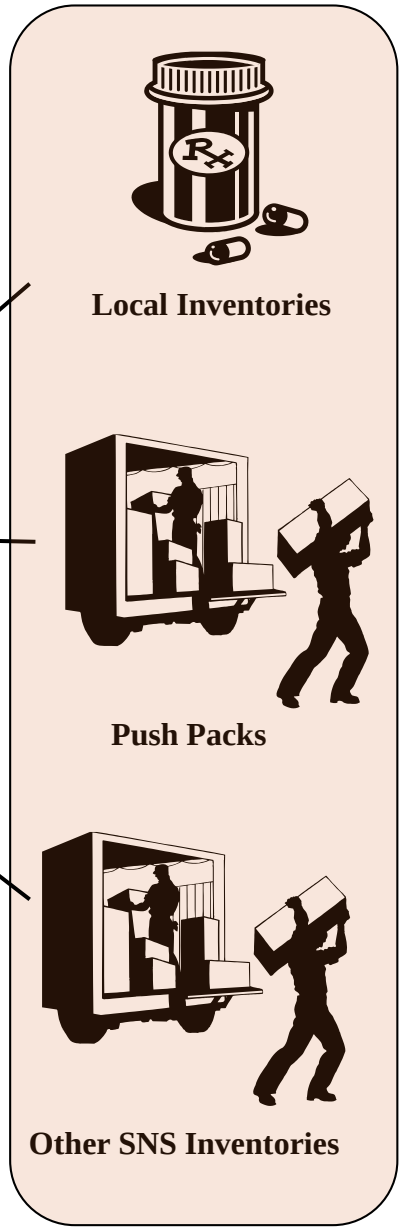
Rate of awareness

Local Dispensing Sites

Dispensing capacity



Hospital capacity



Local inventory levels
Availability of PPs,
other SNS inventories

Model implementation

- Excel spreadsheet
- Difference equations
- Simulate 100 days, in 1-hour time increments
- Used data for a “typical city”
- Calculate costs, deaths, queue lengths, …
- Calculate cost/LY gained

Anthrax Response Planning Model

Initial Conditions	Value
Population size	1000000
Local Inventory Stockpiles	
Local stockpile - Days PEP	64525
Local stockpile - Days IV Abx.	781

Attack Scenario	Value
Exposed	50,000
Not exposed but need prophylaxis	200,000
Not exposed, do not need prophylaxis	750,000
Detection and response times	
Time lag until attack detected	48
Time lag until local supply becomes available	5
Time lag until push packs become available	12
Time lag (after detection) until regional VMI becomes available	36
Time after arrival when Push Pack is ready for distribution	4

Response Scenarios	Value
PEP Regimen	
Length (days) of a complete regimen	60
Length (days) distributed until SNS available	14
Push Pack Contents	
Days PEP Cipro	216,000
Days PEP Doxy	2,502,000
Days IV Abx.	21,492
Vents	100
Rate of Becoming Aware or Seeking Treatment per Day	
General population	33%
First stage/prodromal	33%
Second stage/fulminant	50%

Distribution Capacity	Value
Number of Distribution Centres	20

Cost and Capacity per Center

	Capacity/hour Cost/hour
○ 1,000/ hour, cost from Hupert model	
◉ User defined cost and Capacity	

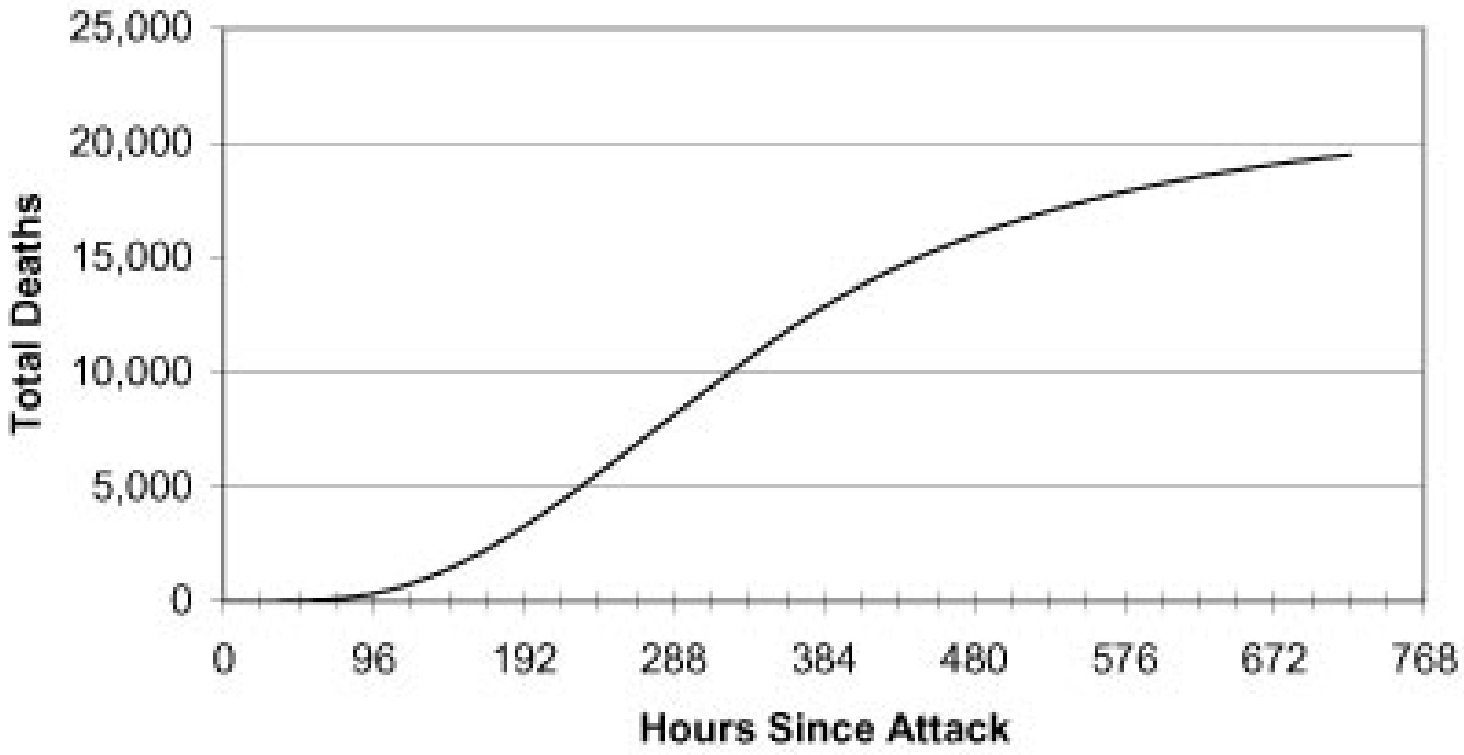
Adherence	Value
PEP Adherence rate	65%

Drug Costs	Value
Cost of doxycycline / 100 mg dose	$0.04
Cost of ciprofloxacin / 100 mg dose	$0.95

Incremental Inventory and Distribution Capacity	Value
Additional Inventory Purchases	
Doxycycline (number of days)	0
Ciprofloxacin (number of days)	0
Additional Distribution Capacity	
Number of Extra Centers	0

Chance of Attack	Value
Annual Probability of Attack	0.10%

Example output



Insights from analyses

- Limiting factor in anthrax response is local dispensing capacity
- Better to rely on regional and national inventories than on local inventories
- Improved surveillance can significantly reduce deaths IF dispensing capacity is adequate

Application to humanitarian logistics

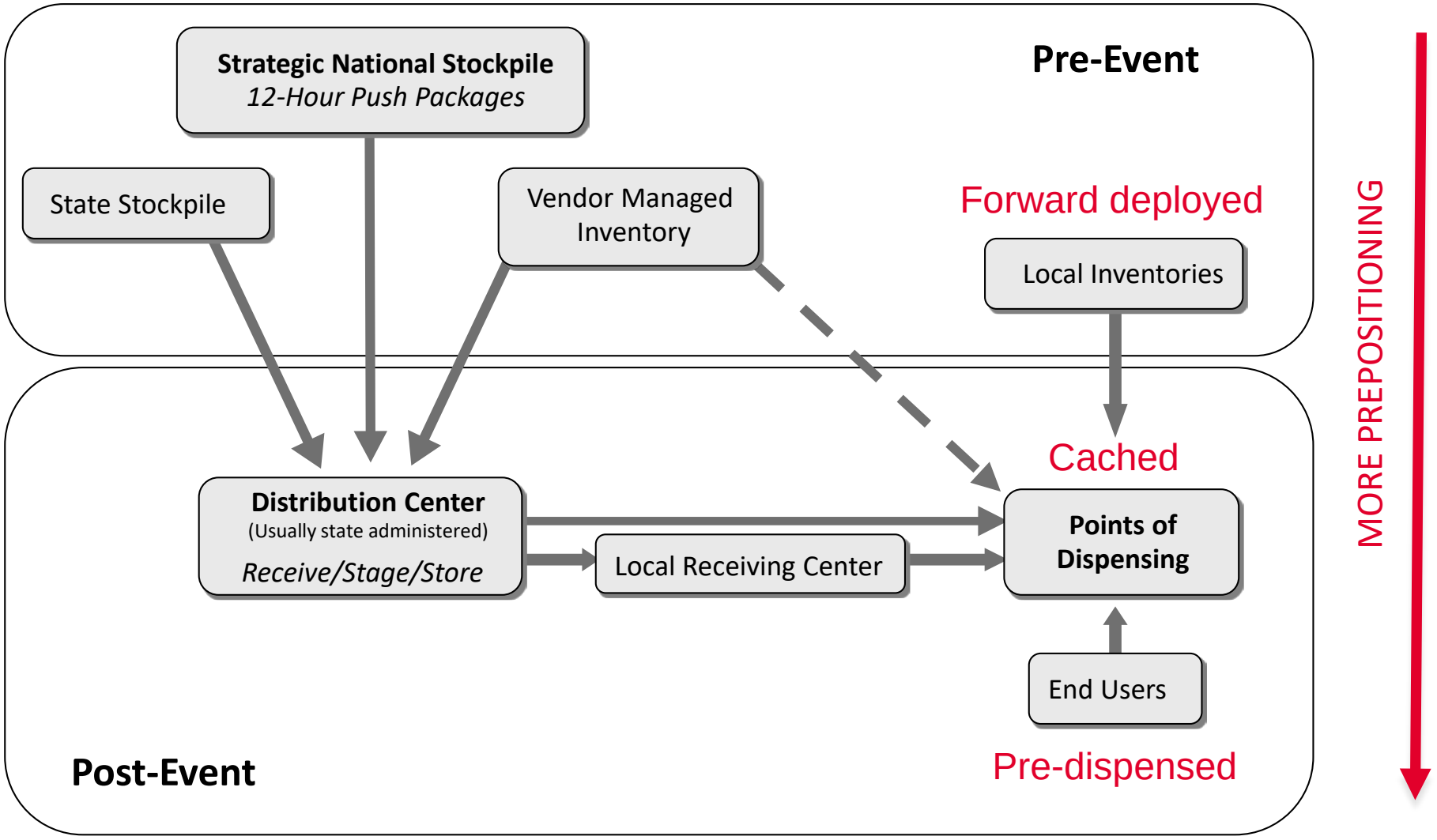
Supply chain model combined with disease model

→ Can assess impact of different stockpiling and response strategies

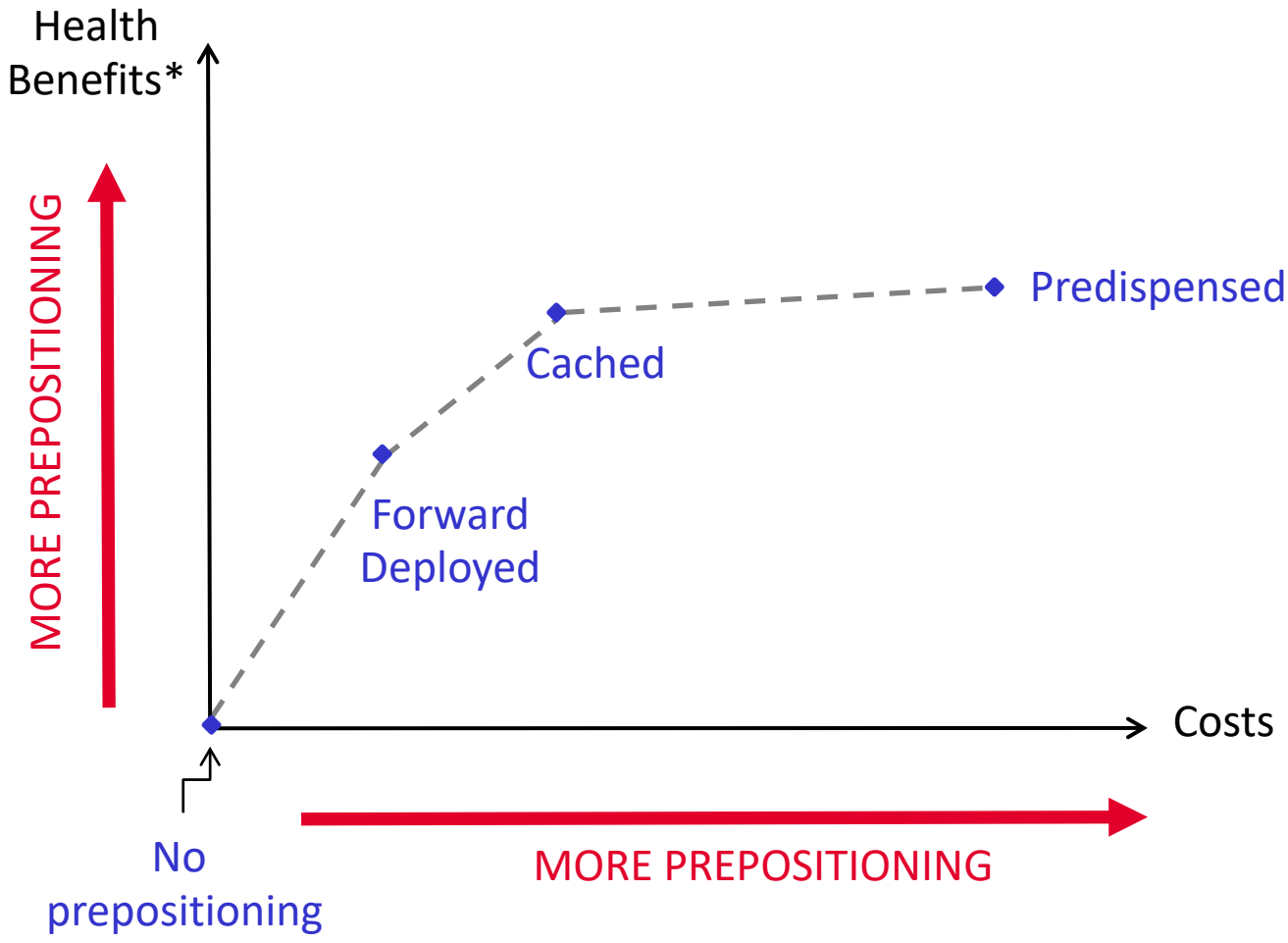
2. Prepositioning of MCMs

- Model of anthrax
- Evaluate the costs and benefits of various strategies for prepositioning medical countermeasures (antibiotics)
  - Costs: initial and ongoing inventory costs
  - Benefits: chance of survival, assuming an event occurs (disease model)

Prepositioning strategies



Cost-benefit tradeoffs



* Assuming an attack occurs

Insights from analyses

- Pre-dispensing is likely to be too expensive compared to its potential benefit in most locales
- One size does not fit all
  - Best strategy depends on attack risk, surveillance capability, current dispensing capacity, etc.
- Forward deployment and local caches may make sense in some locales

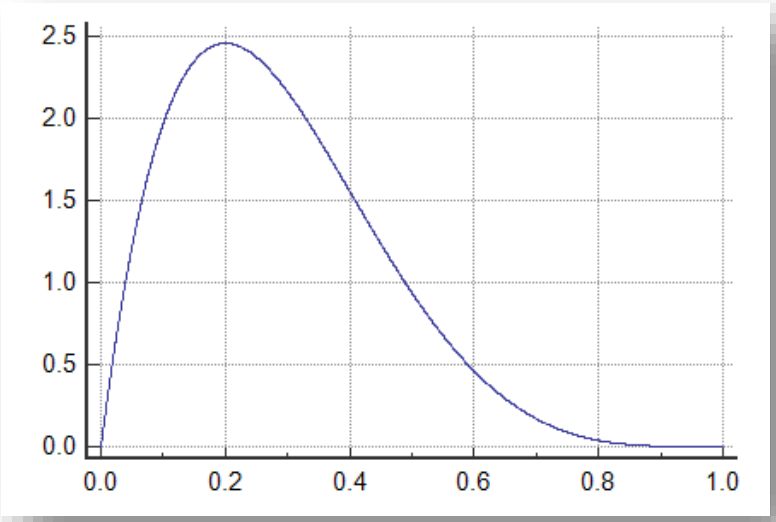
Application to humanitarian logistics

Inventory model combined with disease model

→ Can assess costs and benefits of alternative strategies for prepositioning medical supplies

3. Setting stockpile levels

- Evaluate the costs and benefits of various stockpile levels of needed response items



If pdf of demand is known, can use newsvendor analysis

If pdf of demand is unknown, can use planning scenarios

Example: anthrax vaccine

- Assume an event scenario
  - Probability of an event requiring *n* vaccine doses
- For different levels of doses held, calculate
  - Net present 10-year inventory cost
  - Expected lives saved over 10 years
  - Incremental cost per life saved, compared to next lower stockpiling level

Insights from analyses

- It may not make sense to stockpile tens of millions of doses of anthrax vaccine
- Stockpiling less anthrax vaccine would allow for expenditure on other inventory items

Application to humanitarian logistics

Inventory model combined with risk model

→ Can assess costs and benefits of alternative stockpiling levels

Concluding thoughts

- Preparedness problems are typically complex, with much uncertainty
- Model-based analyses can yield powerful, actionable insights
  - Can combine a logistics model with a model of population health and survival
- Simple analyses can be particularly useful
  - Easy and quick to develop, with modest data requirements

M Brandeau, Public health preparedness: Answering (largely unanswerable) questions with operations research, *Operations Research*, 2019


Thank you