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DRC Disaster Research Center University of Delaware

Emergency Logistics Issues Impacting the Katrina Response
What went wrong?
How do we avoid a repeat?

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Outline

- Commercial vs. Humanitarian logistics
- The phenomenon of material convergence
- Katrina's logistical debacle or How not to do it
- How do we avoid a repeat?
  - Operations
  - Decision support systems
- The need to reformulate humanitarian logistic modeling
  - Material convergence
  - Considering social costs

Commercial vs. Humanitarian logistics

Characteristic	Commercial logistics	Humanitarian logistics
Objective pursued	Minimization of total logistic costs	Minimization of human suffering
Commodity flows generated	Self-contained	Determined by material convergence
Decision making structure	Structured interactions under control of a decision maker	Non-structured interactions, unknown multiple decision makers
Knowledge of demand	Known with some certainty	Unknown and dynamic
Periodicity and volume of logistic activities	Repetitive, large volumes	One in a lifetime events, smaller volumes
State of supporting systems	Stable system	Impacted and dynamic system

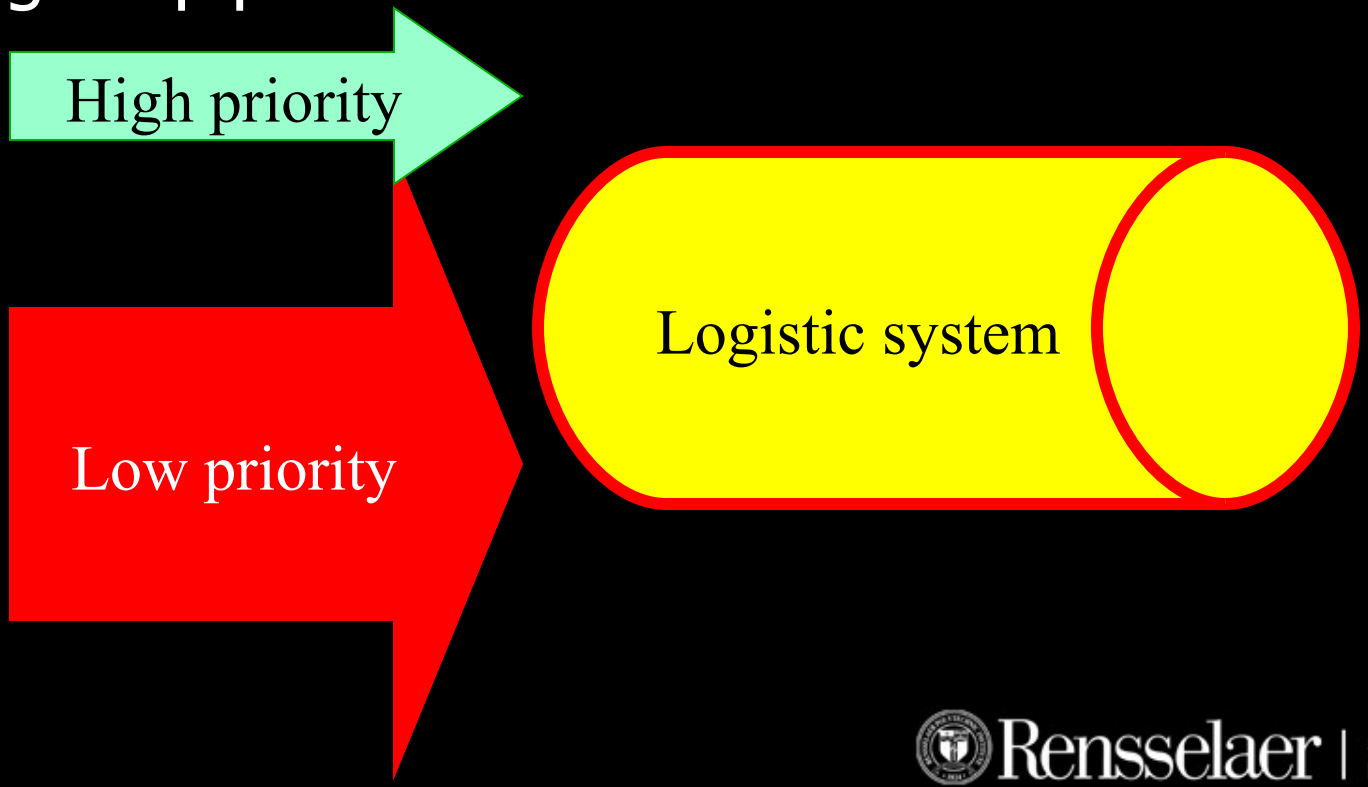
Background on Material Convergence and Humanitarian Logistics

Humanitarian Logistics / Material Convergence

- Fritz and Mathewson (1956) defined convergence as "the movement or inclination towards a point"
- They created a comprehensive:
  - personnel convergence, i.e., movements of individuals;
  - informational convergence, i.e., "movement or transmission of symbols, imageries, and messages…";
  - material convergence, i.e., "…the actual movement of supplies and equipment…"
- Humanitarian Logistics intertwined with Material Convergence
- Not much research in either field

What is the problem?

- The efficiency of the flow of high-priority goods depend on the flow of low priority cargoes
- Equivalent to trying to move two different liquids through a pipe



Is it really that bad?

- Let's take a look at previous experiences
  - 1953 Arkansas tornado
  - 1992 Hurricane Andrew
  - 2001 World Trade Center
  - 2005 Gulf Coast
- Indeed, we could list as examples ALL major disasters

1953 Arkansas tornado

- "… (the day following the tornado) all this clothing and food and all this vast store of supplies started moving into Searcy for distribution to the tornado areas….There was no place to put it … No buildings to put it in ... That created a big problem ... So much was worthless rags. They had some pretty good ones. Somebody sent an old doggone big carton of falsies. We got a tuxedo, a nice one …"
- "…It was coming by Railway Express, by truck, by plane, by freight car… Enormous amount of floor space, but that was filled in two hours—filled ceiling high. One other big building…probably a hundred feet long and sixty feet wide, with 14 feet ceiling… filled in 12 hours." … sixty percent of it was not good; it shouldn't have come to the area at all…" (NORC report No. 52, pp. 281)

1992 Hurricane Andrew

- "Excessive donated clothing created major problems… some of the clothing was not appropriate for the tropical climate of Dade county (e.g., winter coats)….Often, truck drivers with loads of clothes drove straight to severely damaged areas…Upon arrival, they often did not know where to deliver the donated clothes, so they unloaded them on the side of the road. The heat and usual afternoon summer rains quickly turned the piles into heaps of stinking, rotting cloth." … " Excessive food donations created further emergency management problems." (Neal, 1994, pp. 24)

2001 World Trade Center

- "Chris Ward is snaking through a tunnel of cardboard crates, past boxes … past thousands of shampoo containers organized by size….The problem is, very little of it was needed…. little of the cargo reached the intended recipients, as they simply had no use for it…The propensity of Americans to ship stuff to national disasters has become such an overpowering reflex that rescue workers now have to divert considerable resources to ensure the largess does not get in the way. Some even describe the torrent of sundries as a "second tier disaster."" (Newsweek, 2002)
- "[There] were examples of much needed materials, but we also saw donations of unnecessary goods … the five tractor-trailer loads of pumpkins donated to Ground Zero around Halloween that needed to be redirected to public schools …. We heard of people driving machinery and equipment to the site, leaving it for use, and then becoming upset when it was not returned even though the items were never documented, processed, or requested." (Wachtendorf and Kendra, 2004, pp. 5).

2005 Gulf Coast

- “"Donation management is the most difficult part of every disaster," he said of the unsorted mountains of clothes. "We have a little bit of everything."”…. (Caller-Times, 2005).
- “Sometimes generosity can go awry.”….. In Katrina's immediate aftermath…. collection sites along the Mississippi Gulf Coast became “nothing more than dump sites”….” (Times-Piscayune, 2005).

Katrina's logistical debacle or How not to do it

- The findings discussed here are based on dozens of interviews with the individuals directly involved in the logistical response
- JHV and colleagues declared persona non grata by FEMA (and very proud of it!)

1. Magnitude of the event and the requirements

- The largest natural disaster in U.S. history:
  - Devastated 100 miles around the eye
  - Property damages ascending to $96 billion
  - Total economic impact may reach $200 billion
  - One of the deadliest hurricanes to ever hit mainland U.S., with 1,577 confirmed deaths and 226 people still missing as of May 2006
  - Flooded 80% of New Orleans
  - The government federal disaster declarations covered 90,000 square miles, an area almost the size of the United Kingdom

- The American Red Cross (ARC) started preparing:
  - Prepositioned 500,000 meals ready to eat (MREs)
  - Identified 15 sites for large kitchens for mass feeding
  - Opened several shelters in the region
  - Deployed vehicles and staff to the disaster area
  - Raised more than $2 billion, 2/3 of charitable groups
  - Led the efforts of more than 220,000 staff and volunteers
- When New Orleans flooded, ARC was overwhelmed: "…I don't think Red Cross ever had to work with so many outside agencies in coordination…"

2. Collapse of the communication infrastructure

- Nearly three million people without electricity/phone
- 911 emergency call centers were severely impacted
- Out of service: 50% radio stations, 44% of TV stations
- 50,000 utility poles were toppled in Mississippi alone
- "[the] entire infrastructure was wiped out [and] there were no communications…until five days after the storm [when] we got satellite phones."
- "…the main communication came back and forth by helicopter. Sort of like a New Age Pony Express." No one knew "…if things had been delivered, and if they had been delivered, who accepted it."
- The Internet-based inventory system (E-Team) used by the State of Louisiana to process emergency requests collapsed

3. Lack of integration between computer systems

- Local and state governments used a commercial software (E-Team) for procurement and tracking
- FEMA relied on a custom-made system called NEMIS (National Emergency Management Information System)
- E-TEAM and NEMIS did not communicate
- E-Team requests had to be individually read and manually inputted into NEMIS
- Federal staff could not check information on individual requests, local/state staff could not check the status of their requests…

4. Lack of planning for handling of donations

- The volunteers and staff available at staging areas were not enough to manage the large influx of goods received
- "…another thing we need in our plan is donated goods. There needs to be a section within FEMA, or the State, or somebody, besides VOAD in conjunction with VOAD that needs to be responsible for donated goods."

- Volunteers complained that communication with the government was inefficient and that they did not know what the priorities and needs were
- Donations of low-priority goods hampered critical activities: clothing being the most problematic
- Incoming trucks loaded with clothing sometimes dropped their cargo at parking lots

5. Limited asset visibility

- Asset visibility was seriously obstructed at both ends of the supply chain
- Locals could not estimate the quantity and type of critical supplies needed
- FEMA had difficulties determining supplies needed, the resources it had available, and the specific location of a resource at a given point of time
- Because of lack of GPS, nobody knew where trucks were. Example: the Superdome trucks

6. Understaffing and lack of training

- FEMA had around 500 vacancies (20% of the 2500 agency positions) with eight out of its ten regional directors working in an acting capacity
- FEMA turned to other federal agencies to staff positions in Mississippi and Louisiana
- Not all local staff were proficient users of E-Team
- The volunteer groups had problems: "…every time a new group comes in, you have to train [them]
- Few individuals had logistic training

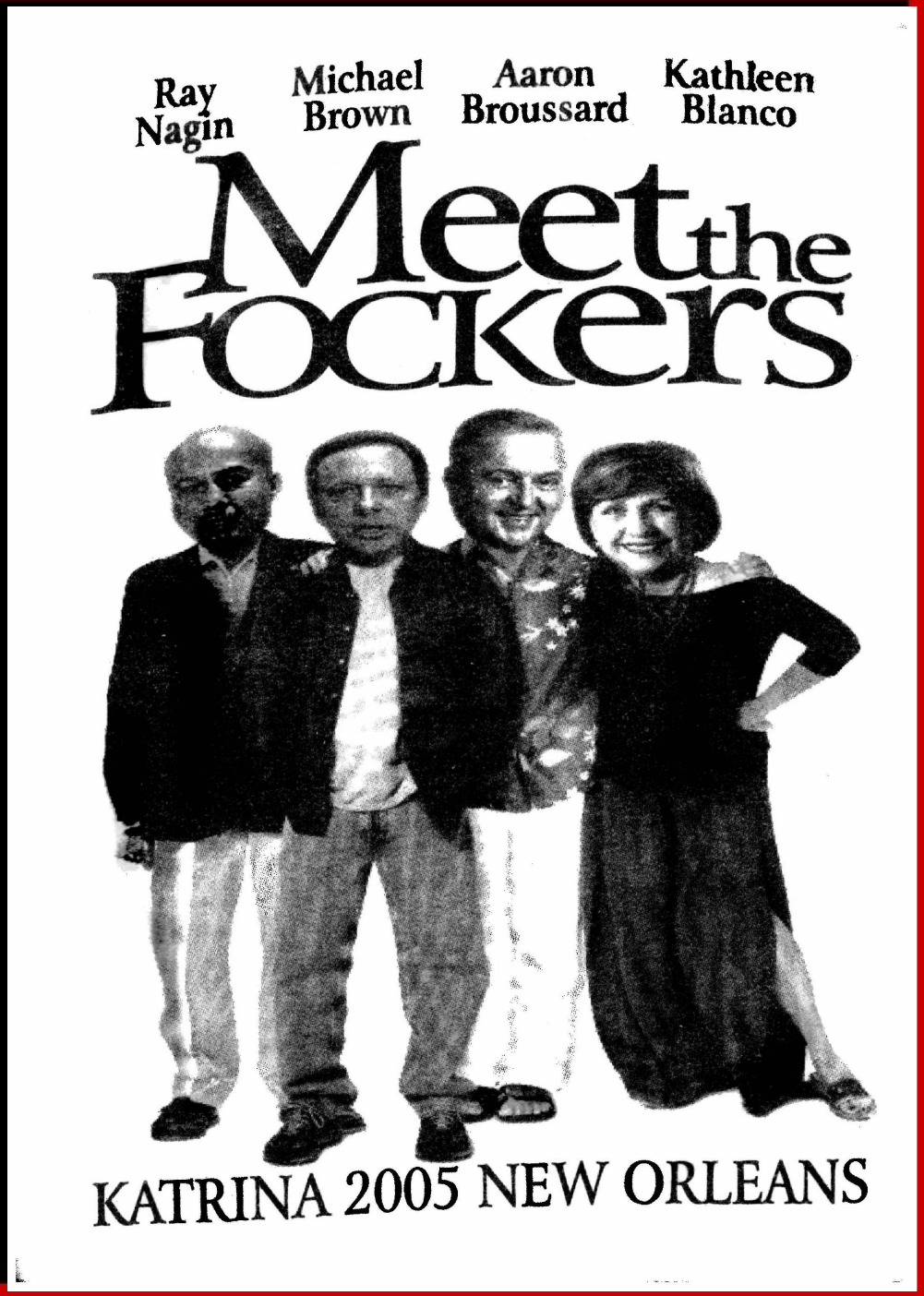
7. Inefficiencies in pre-positioning resources

- Not enough critical supplies were prepositioned
- The locals did not event think about prepositioning
- It was suggested that the state did not preposition the critical supplies called for by its own emergency plan because it was waiting for the Federal emergency declaration to avoid using State funds
- The federal declaration of emergency was issued one day before landfall
- FEMA started to preposition but there was no time. The activities were suspended because of Katrina.

8. Procurement

- Procurement delays may be the single most important factor explaining the slow flow of critical supplies after the initial response
- "…delivery times were horrible. Small quantities were OK [however delivery of] large quantities [was] very bad (two weeks)."
- This same respondent described delivery of large quantities taking 2-6 weeks after requisition, while the delivery of medical supplies took 1-3 weeks as the staff were unfamiliar with the supplies and where to acquire them

Popular wisdom in action …



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Finding: Volunteer organizations saved the day

- Horrendous as it was, the Katrina debacle would been much worse if not by the outstanding work of the volunteer organizations that:
  - pre-positioned supplies
  - sent experienced and motivated leaders
  - demonstrated great creativity, ingenuity and flexibility in the face of disaster
  - 80 million pounds = 2,000 semitrailers

How do we avoid a repeat?
Part I: Operations

Key Recommendations

- Create a Emergency Logistics Training Program
- Train local population / emergency response staff
- Learn to follow the National Response Plan
- Define proper roles for the key agents
- Create a Robust Emergency Logistics Network
- Regional Blanket Purchasing Agreements, RBPA
- Implement Measures to Increase Asset Visibility
- Regional Pre-Positioning/Sharing of Critical Supplies
- Implement Proactive Donation Coordination Plans
- Develop Decision Support Tools

How do we avoid a repeat?
Part II: Decision Support Tools

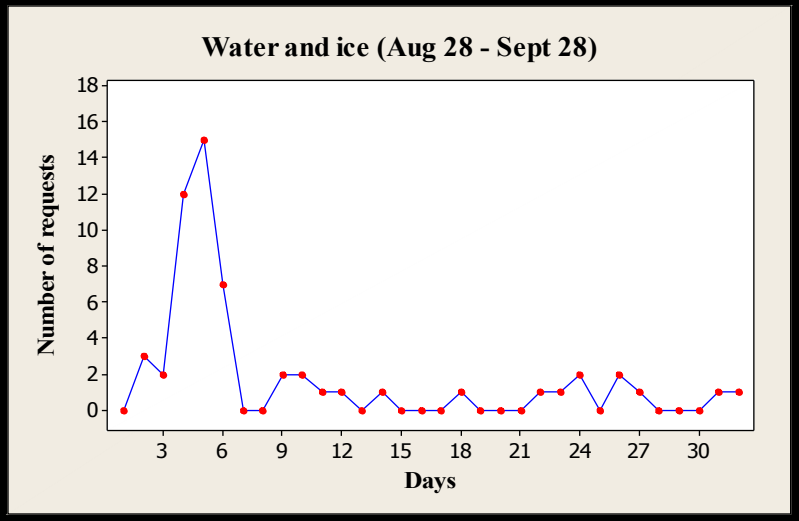
Research in progress at RPI

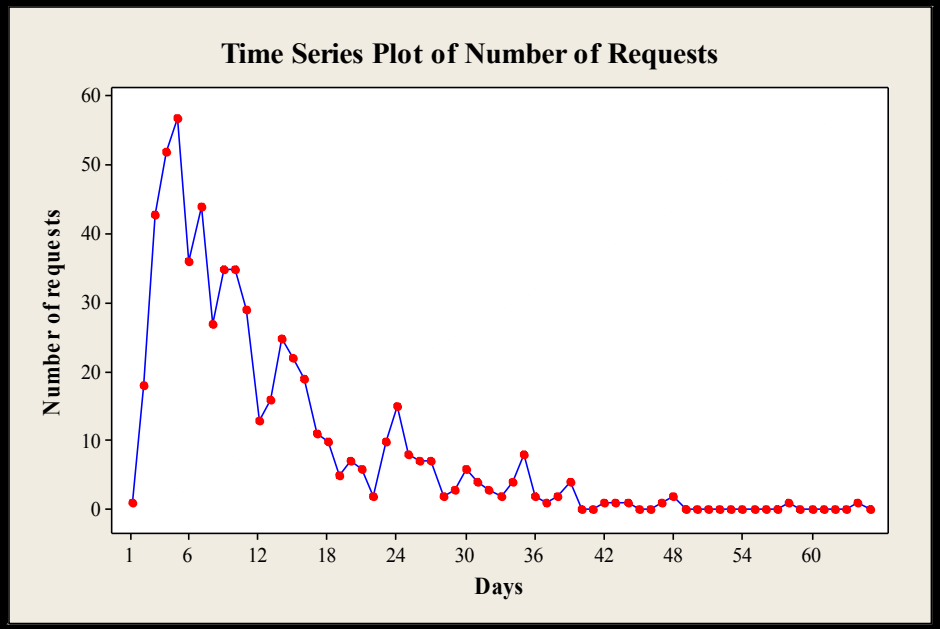
- Diagnosis and characterization:
  - Causes of logistical debacle post-Katrina
  - How humanitarian logistics take place
  - Quantification:
    - Aimed at obtaining empirical estimates
    - Provide support to analytical modeling
    - Immediate resource requirements, donation patterns
- Basic research on analytical modeling
  - To develop new modeling paradigms
  - Considering social costs of logistic actions
  - Incorporating social science concepts

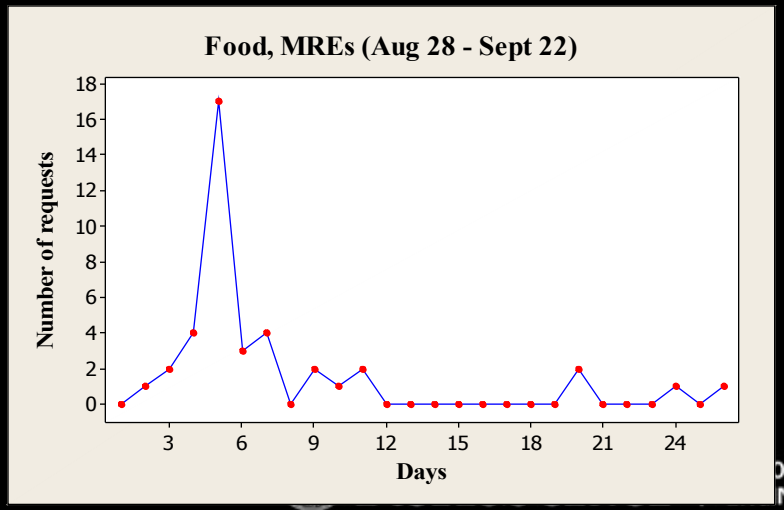
Quantification: IRRs

- Immediate resource requirements (IRRs)
  - Based on processing the Action Request Forms from FEMA, that captured the requests made by responders
  - A total of 1388 forms obtained through a Freedom of Information Act

- Developed models to forecast immediate resource requirements







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Quantification: Material convergence

- We have assembled a database of donations based on post-processing of newspaper articles (now working on Internet)→ to be used for spatial econometric modeling to quantify convergence
- The idea is:
  - Use this data to estimate spatial econometric models
  - If successful, this will enable to get estimates of material convergence and to gain insight into key factors

Typical model

Variable	Name	Coefficient	T-value
Total population	**Population**	**0.581**	**3.59**
Total population for donors that are organization headquarters	HQ*Pop	0.410	14.80
African American population	**Black**	**0.099**	**1.89**
Distance in miles from donation origin to impacted area	**DIST**	**-0.227**	**-2.36**
Distance in miles from donation origin to impacted area for donors that are charitable orgnanizations, NPOs and churches	N*Dist	-0.088	-2.02
Distance in miles from donation origin to impacted area for donors that are schools and libraries	S*Dist	1.243	2.00
Population 25 years and over that are high school graduates	**25+_High school grad**	**-0.804**	**-6.02**
Population 25 years and over educational attainment (high school graduates) for donors that are companies	C*25+HS	-0.145	-4.09
Family income per capita	**Fam_Per capita income**	**0.675**	**3.87**
Family income per capita for donors that are schools and libraries	S*Fam/Capita Inc	-0.947	-2.23
Family income per capita for donations that originated in the North East states	NE*Fam/Capita Inc	-0.625	-3.27
Employed civilian population 16 years and over that are in the public administation industry for type of donors that are local organizations	LOC*Public administrati	0.141	3.14
Median age for type of donors that are associations and clubs	A*Age	-0.543	-5.70
Median age for donations that originated in the North East states	NE*Age	1.721	3.18
Constant	Constant	4.396	2.29
F	56.54		
R-Sq	44.30%		
R-Sq(adj)	43.50%		

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The need to reformulate humanitarian logistic modeling

Two pressing issues

- Considering the social costs of suffering
- Considering material convergence
  - Nasty problem
  - Behavioral foundations of convergence not clear

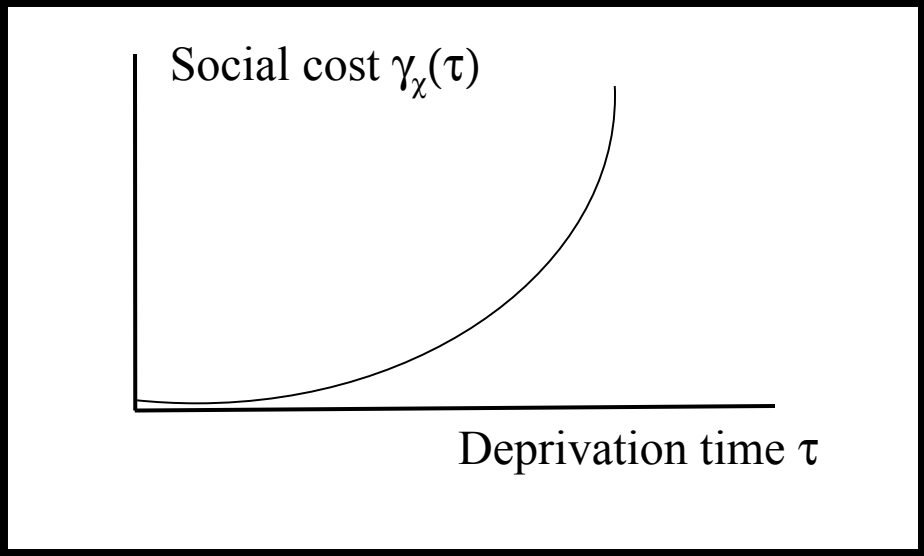
The need to consider human suffering

- Humanitarian supply chains must focus on minimization of human suffering
  - No other objective function captures better the fundamental goal of humanitarian logistics
- None of the current analytical formulations explicitly consider victims' wellbeing (some consider penalty costs as a proxy variable)

How to quantify human suffering?

- Using human suffering as a decision criterion leads to philosophical and ethical dilemmas
  - Ideally no one should be purposely left in peril
  - Controversial to assign economic value to suffering and the loss of lives
- A sensible approach is to use economic valuation
  - An economic measure to evaluate alternatives
  - Able to differentiate and prioritize alternative actions
  - Bypasses the need to subjectively decide levels of service
  - Allows for unbiased tradeoff analysis between social benefits and operational costs

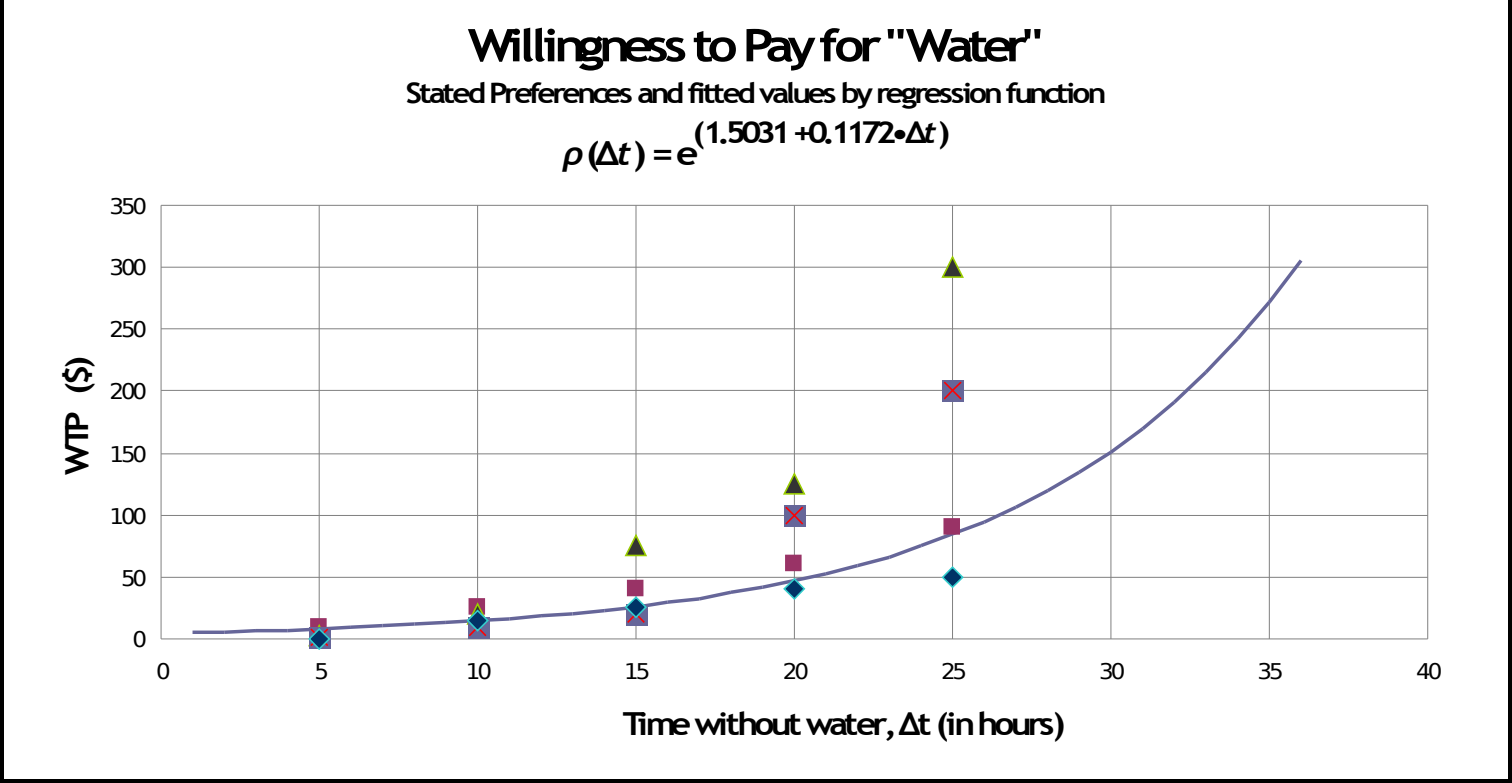
Social cost function



- Key features:
  - Highly non-linear, as a function of deprivation time $\tau\rho$
  - Non-additive demands:
    - A person that have not eaten in five days and get food in the 5th day, will not eat five days worth of food

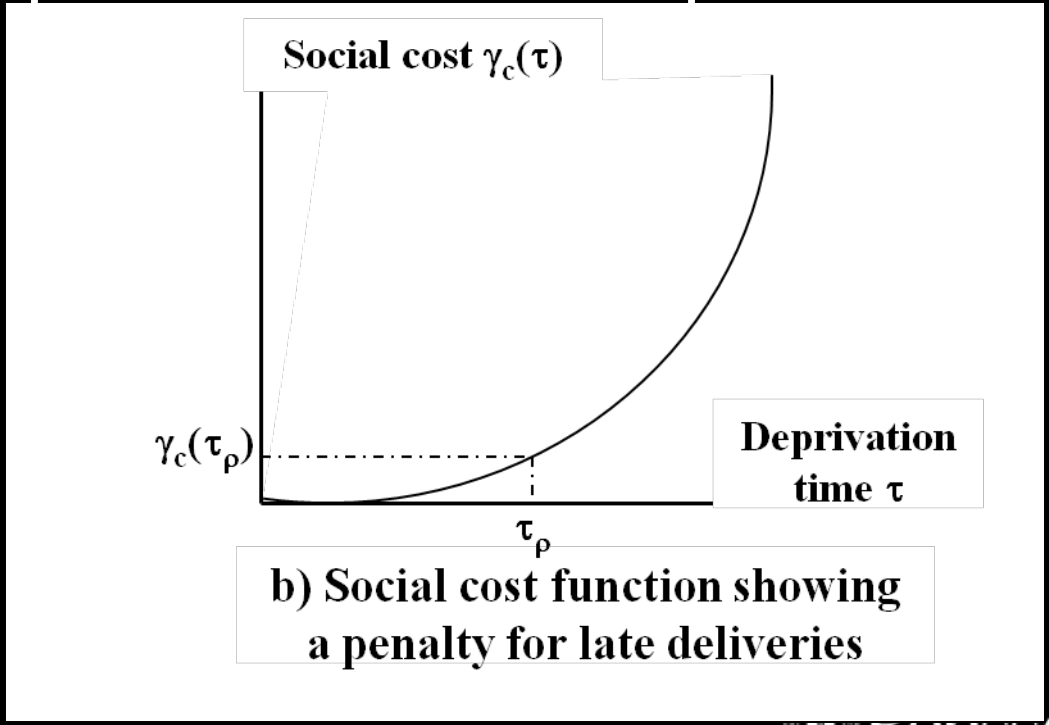
Example of a social cost function

- Using a small sample, a social cost function of not having access to water was estimated



Current approaches: Penalty based formulations

- An amount ρ is charged when a population reaches a deprivation time $\tau\rho$, with the intent of capping suffering at $\gamma_c(\tau_\rho)$
- This prompts the model to dispatch a delivery



b) Social cost function showing a penalty for late deliveries

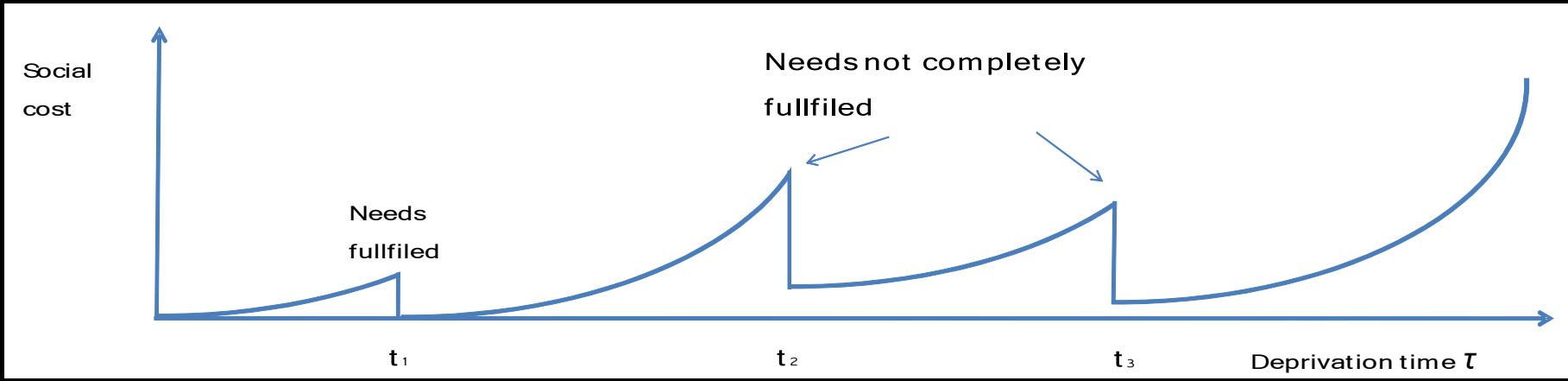
Problems with penalty based formulations

- The value of ρ does not matter, as long as it is "large" compared to delivery costs
- The threshold deprivation time τ_ρ, is far more important because it determines the permissible suffering $\gamma_c(\tau_\rho)$
- However, pre-setting τ_ρ is completely arbitrary
  - Low value → social costs are important
  - High value→ social costs are less important
  - How do you know how to set τ_ρ?

- τ_ρ is the level of service achievable given supply and demand: it cannot be pre-determined
- Paradox:
  - If the value of τ_ρ is set lower than what is achievable, no solutions will be found
  - If the value of τ_ρ is set higher than what is achievable, the population will suffer more than is actually needed
- In conclusion:
  - Penalty based formulations, setting equity constraints that mandate a delivery after a set amount of time are very problematic

The solution

- Instead of forcing the problem to fit the commercial logistics paradigm,
- Reformulate the problem as one of minimization of social costs



Analytical formulations

Considering social costs

$$\Gamma_i(t) = \sum_l \gamma(\tau_{ilt})\pi_{ilt}$$

Total social cost at node i, time t

$$X = \{(i_1, d_1, t_1), (i_2, d_2, t_2), \ldots, (i_n, d_n, t_n)\}$$

A sequence of delivery actions: node, delivery amount, and time

$$\Psi_T(X) = \Omega_T(X) + \Gamma_T(X)$$

$$\Psi_T(X) = \Omega_T(X) + \sum_i \sum_l \sum_t [\gamma(\tau_{ilt})]\pi_{ilt} x_{ilt} + \sum_i \sum_l [\gamma(\tau_{ilT})]\pi_{ilT}$$

Total cost : Delivery + Social costs

Penalty based formulation:

$$\Psi_T(X) = \Omega_T(X) + P_T(X)$$

$$\Psi_T(X) = \Omega_T(X) + \sum_i \sum_l \sum_t \rho(1 - x_{ilt})$$

Total cost : Delivery + Penalty costs

It is impossible for these formulations to reach the same solutions

Numerical examples

- Case I: One distribution center, One demand node
- Optimal policy: To deliver as much as possible

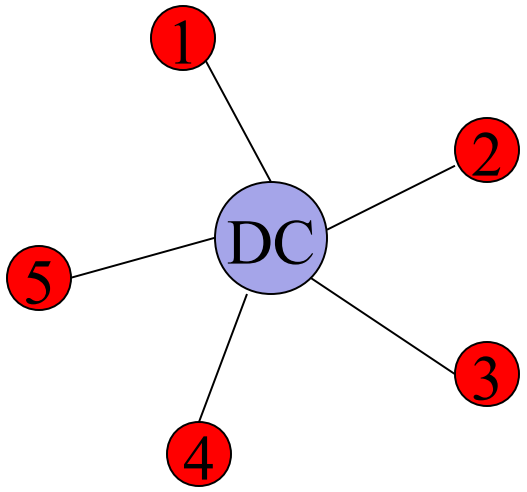
a) Social costs ($)

	Cycle Time (days)			
Truck capacity as % of demand	0.25	0.5	0.75	1
25%	348.55	2,199.97	13,982.55	131,540.51
50%	204.60	345.67	837.39	2,194.84
75%	184.88	265.09	547.48	1,265.53
100%	176.22	183.31	241.72	336.22

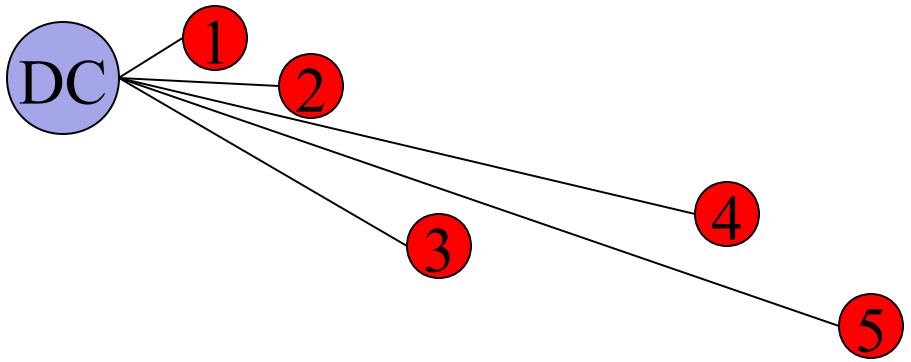
b) Average deprivation times (days)

	Cycle Time (days)			
Truck capacity as % of demand	0.25	0.5	0.75	1
25%	0.90	1.58	2.14	2.40
50%	0.48	0.90	1.29	1.60
75%	0.32	0.62	0.89	1.13
100%	0.25	0.50	0.75	1.00

Case I: One distribution center, Five demand nodes



Scenario A:
Travel times = 6 hours



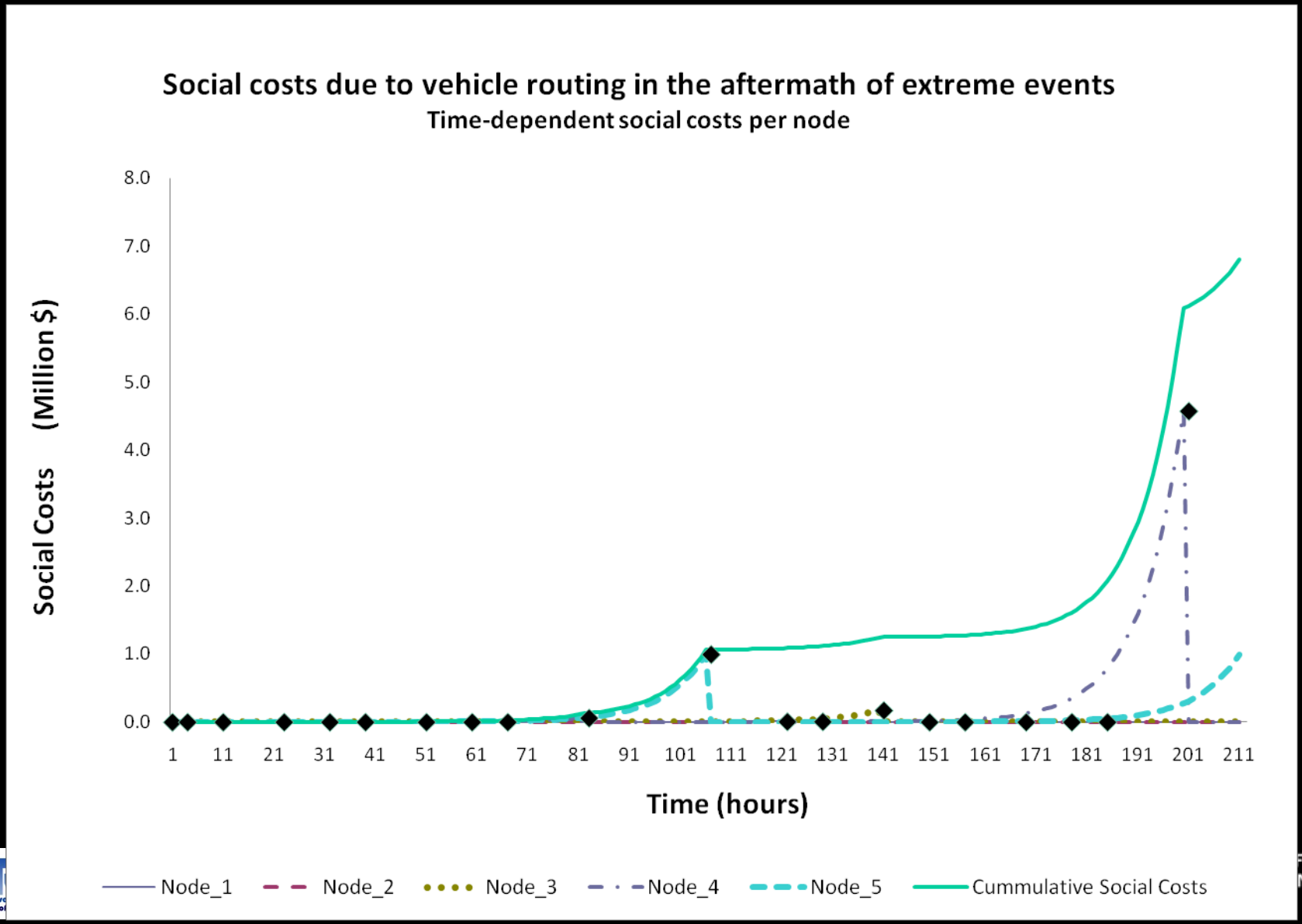
Scenario B:
Travel times = 2, 5, 7, 11, 13 hours

Solutions from heuristics

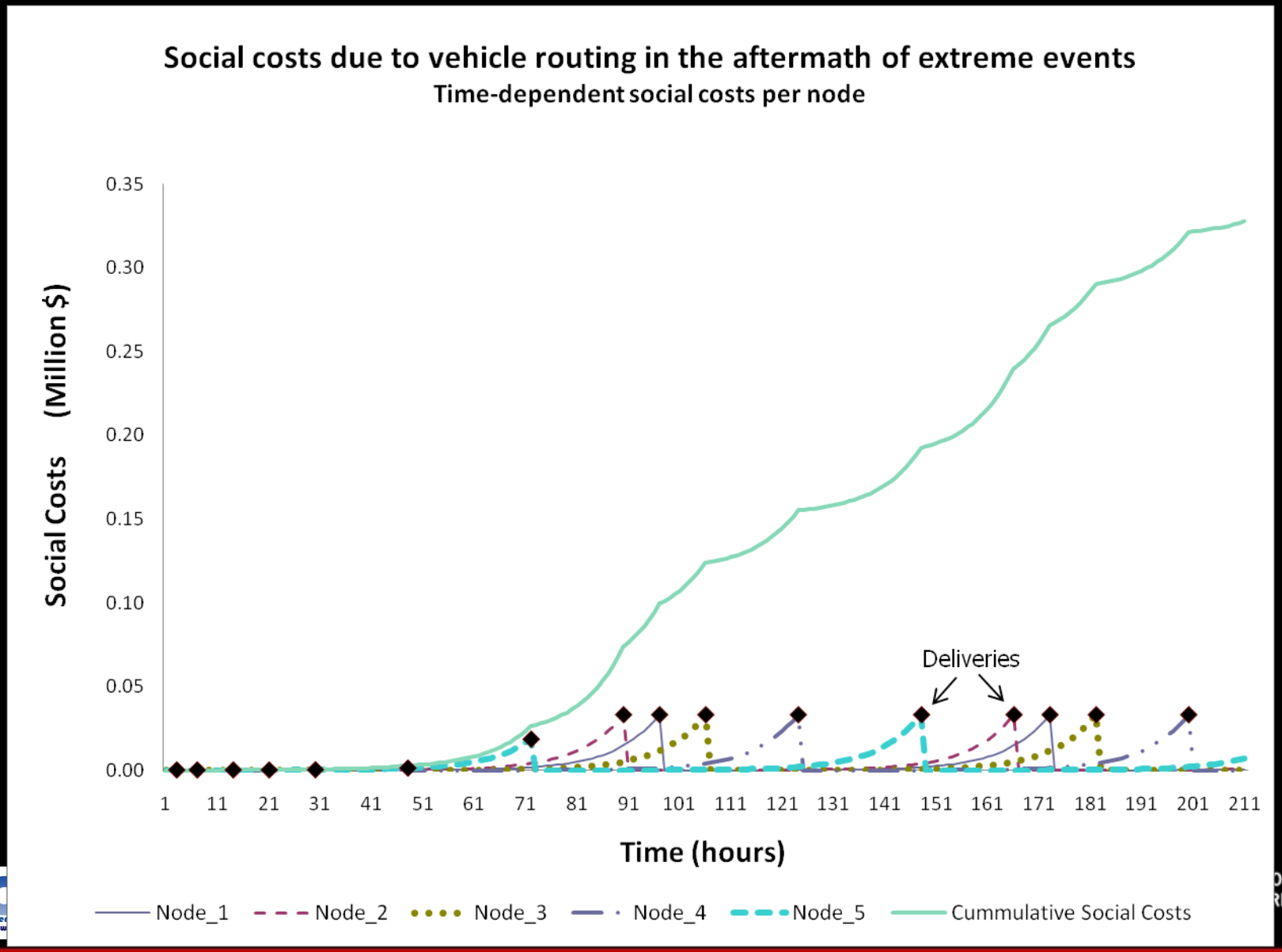
- Formulations lead to stationary delivery patterns

	Heuristic	
	Social costs	**Traditional logistics**
Strategy	Deliver next to the node with maximum: (Marginal Social Benefit / Marginal Total Cost)	Deliver at least once every 5 days Minimize: Total cost = travel costs + penalty costs
Heuristic solution (Return to depot after visiting each node)	1-1-2-1-3-4-5-2-1-3-4-5-2-1-3-4	1-2-3-1-2-3-1-2-4-5-1-2-3-1-2-3-1-2-4
Number of deliveries	16	19
Travel cost	$11,500	$11,550
Penalties for unmet	- - -	$250,000
Total social costs	$327,712	$6,807,878

Traditional (penalty based) formulation



Social cost formulation (note difference in scale)



Conclusions

- Analytical approaches to humanitarian logistics must be reformulated
- The popular penalty based formulations are very problematic
- Realism could be significantly enhanced by explicitly considering material convergence and the cost of suffering

Questions?