

Humanitarian Logistics

Tokyo University of Marine Science and Technology

An Agent-based Model for Resource Allocation During Relief Distribution

Rubel Das*

Shinya Hanaoka

Dept. of International Development Engineering
Tokyo Institute of Technology

OUTLINE

1. Background:

Disaster and logistics

Importance of resource allocation

Objectives

2. Model description

Applicability

Ontology of humanitarian logistics

Agents relationship

Simulation flow

3. Analysis

Data

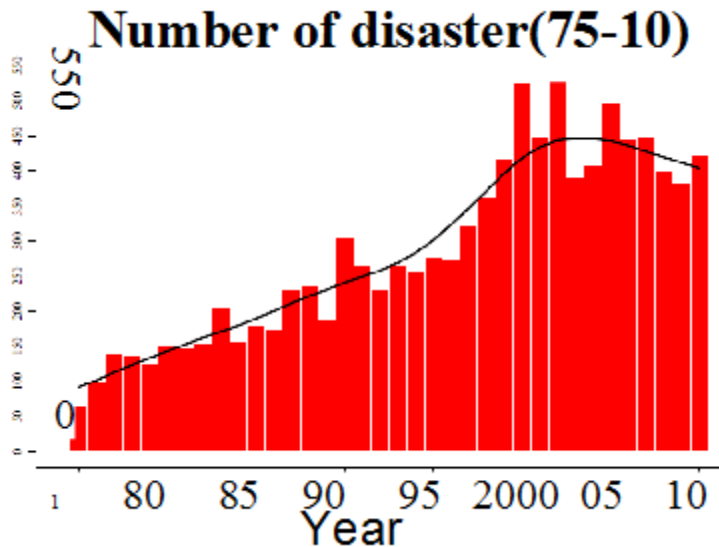
Software

Results

4. Conclusions

DISASTER PATTERN

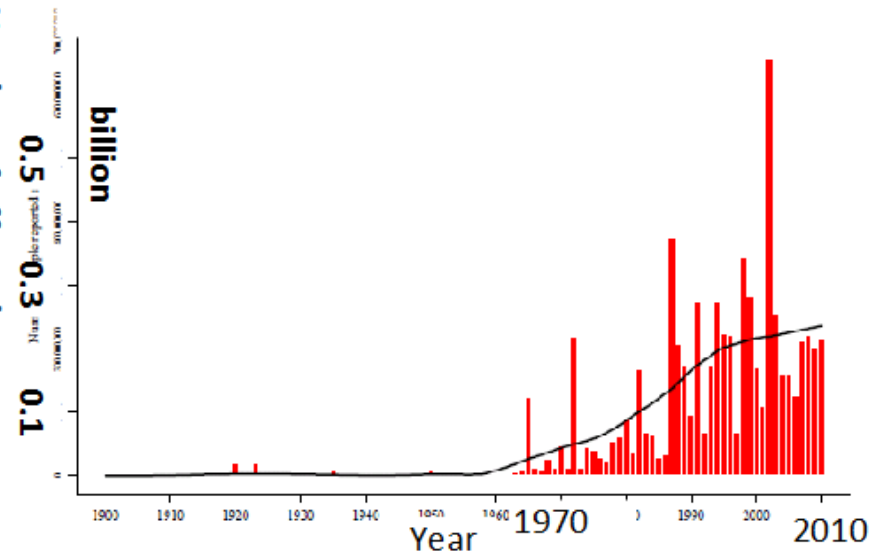
Number and impact increase **five times** in next 50 years.



Definition of Disaster

- 10 or more people killed
- 100 or more people affected
- Declaration of state of emergency
- Call for international assistance

Number of affected people by Natural disaster 1900-2010



HUMANITARIAN LOGISTICS (HL)

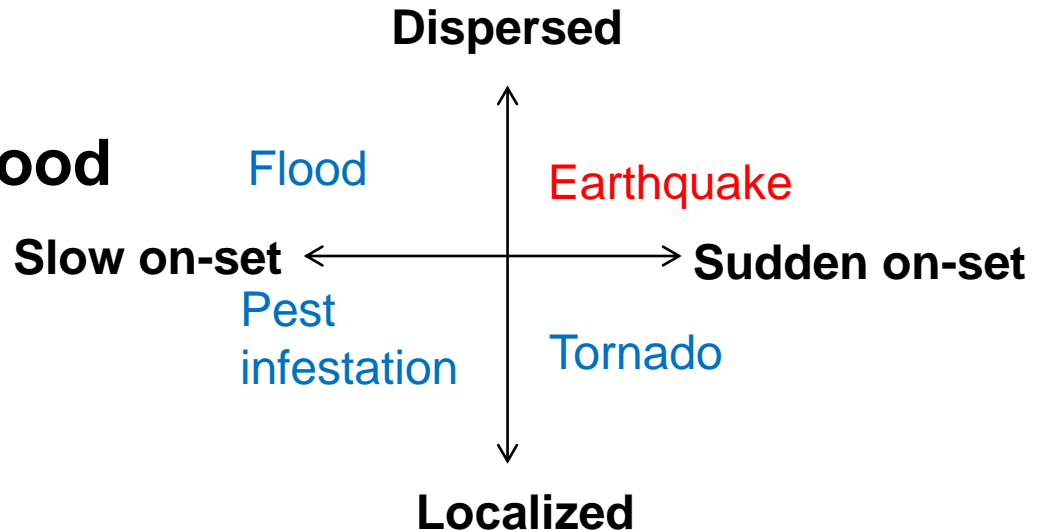
After Earthquake

- ❑ Search and Rescue
- ❑ Medical aid
- ❑ **Shelter, water and food distribution**



RELIEF

Disaster types



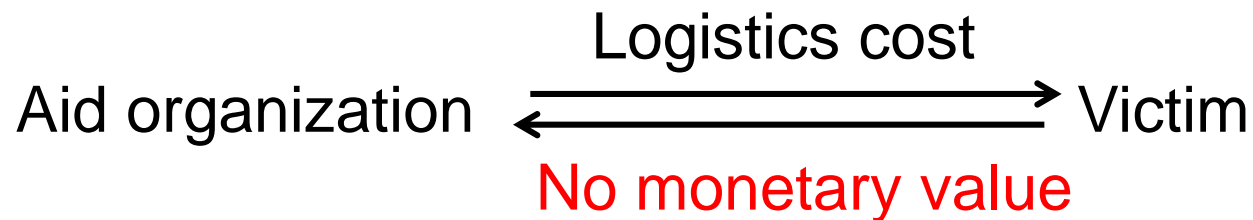
HL is the process of planning, managing, and controlling the **efficient flows of relief**, information and service from the points of origin to point of destination to meet the urgent needs of the victims under emergency situation.

DIFFERENCES

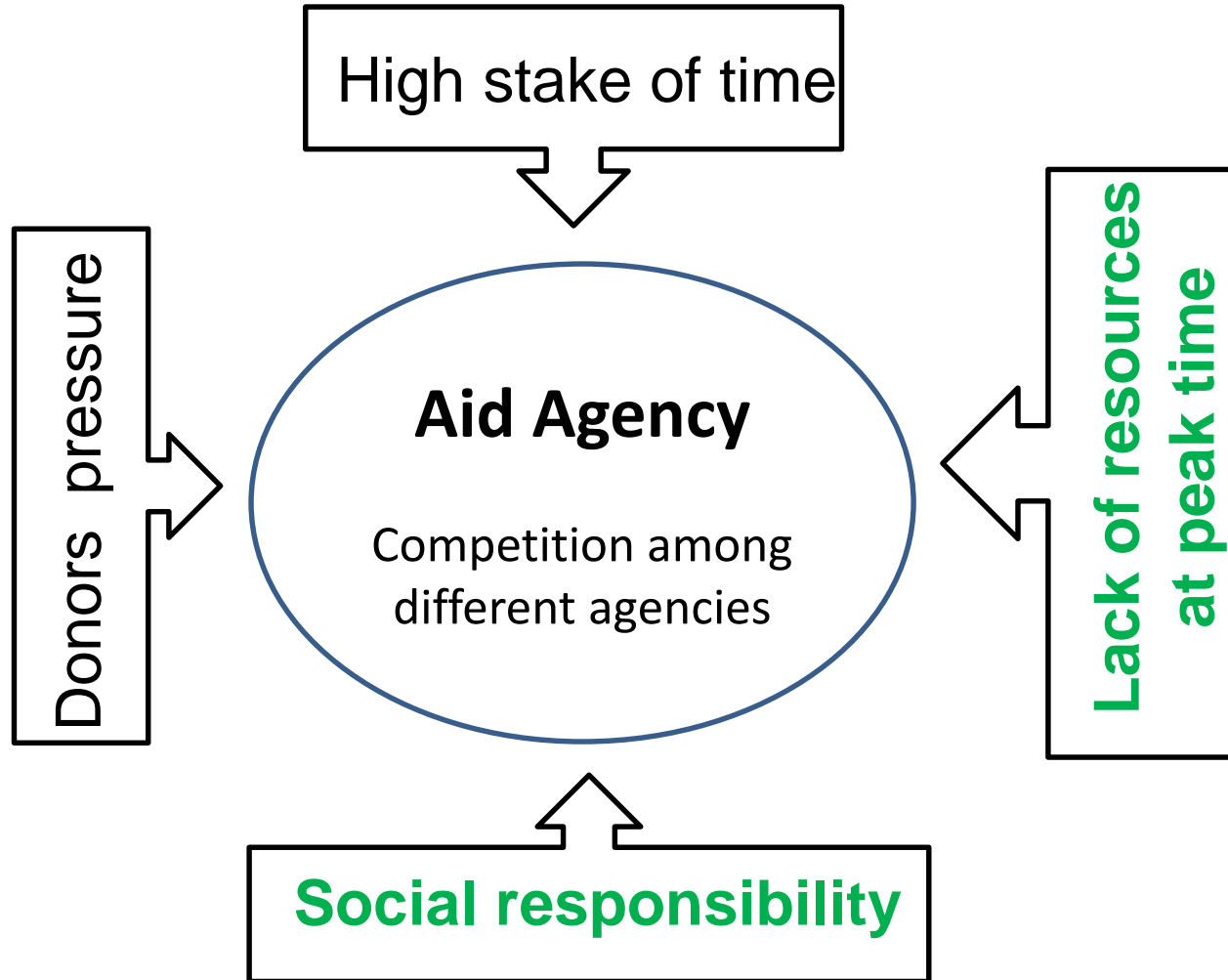
Business logistics



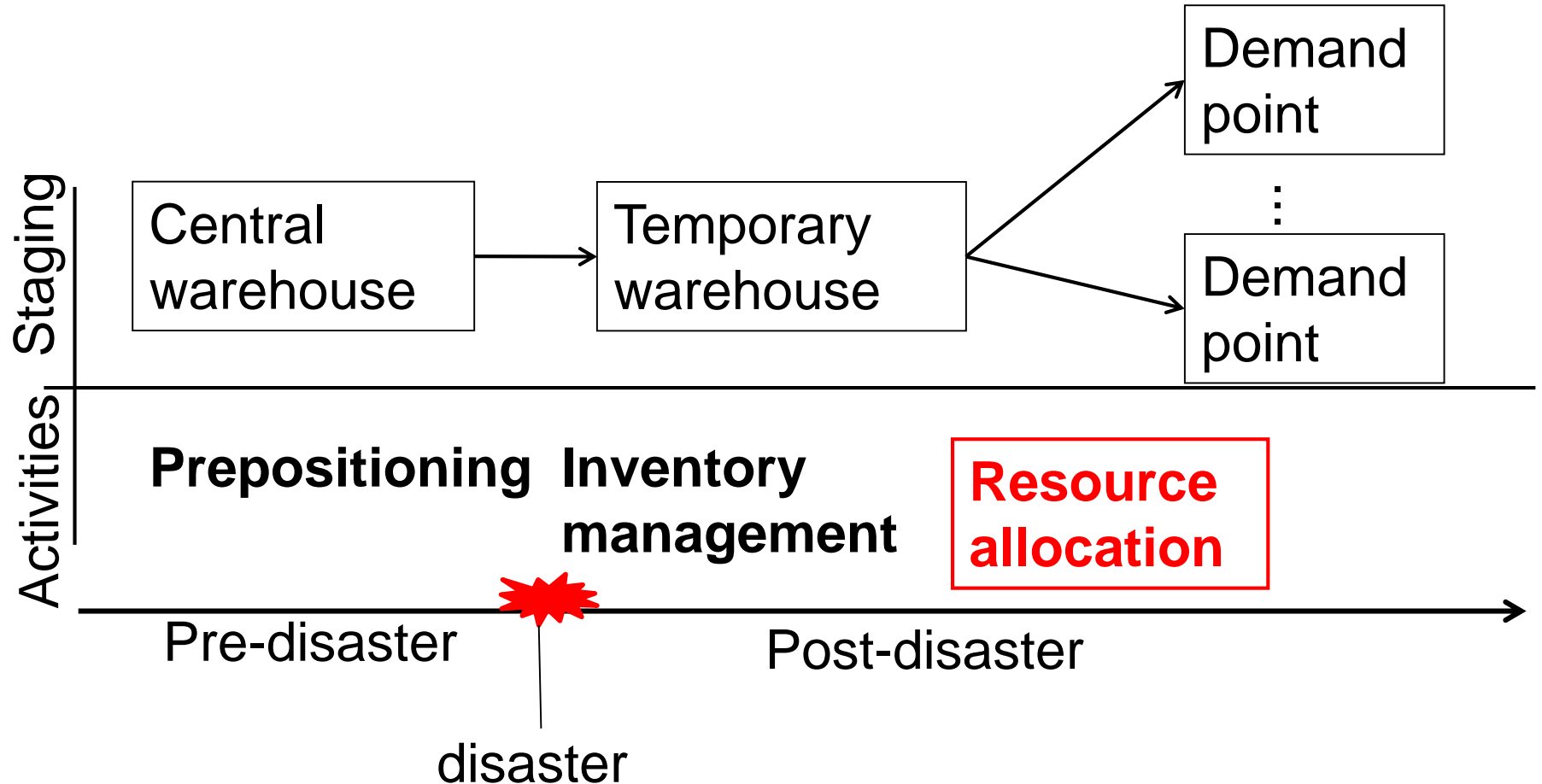
Humanitarian logistics



IMPORTANCE OF HL



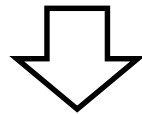
ACTIVITIES IN HL



IMPORTANCE OF RESOURCE ALLOCATION

Why Resource Allocation?

1. Large relief demand
2. Shortage of relief supply
3. **Different degree of relief urgency in different zones**



Results due to Poor Resource Allocation

1. Social **dissatisfaction** (Haiti victims fight due to relief, 2010)
2. **Conflict** between authorities (Pakistan govt. and UN conflict, 2010)

OBJECTIVES

1. To introduce an agent-based model for allocating **fleet** in the network of humanitarian logistics.
2. To analyze the effect of the number of fleet in relief distribution.

OUTLINE

1. Background:

Disaster and logistics

Importance of resource allocation

Objectives

2. Model description

Applicability

Ontology of humanitarian logistics

Agents relationship

Simulation flow

3. Analysis

Data

Software

Results

4. Conclusions

INTRODUCTION OF AGENT-BASED MODEL

- An agent-based model (ABM) consists of
 - a set of agents
 - a set of agents relationship
 - a framework for simulating agent behaviors and interactions

MODELS COMPARISON

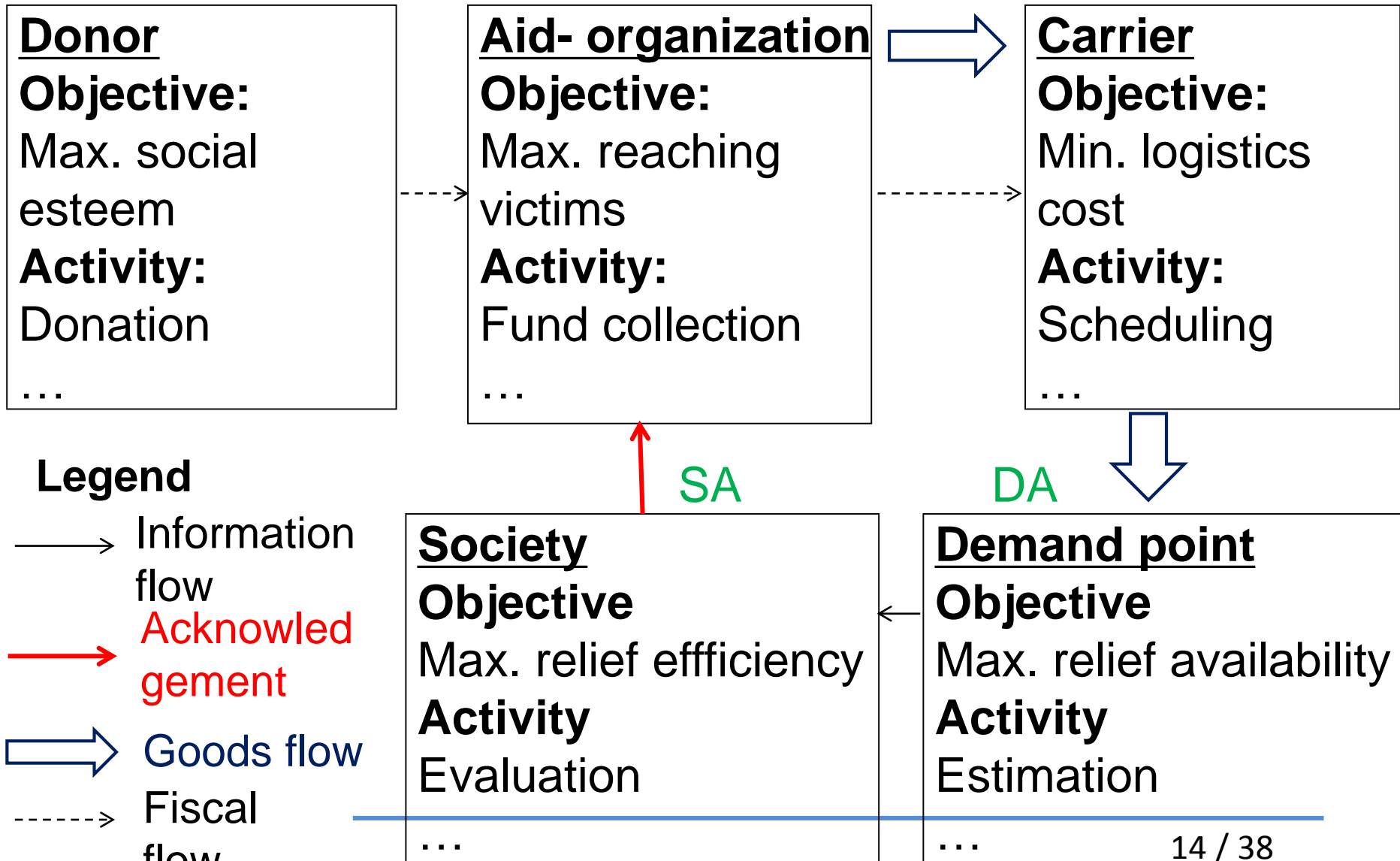
Criteria	Agent-based model	Operational research model
Flexibility	Each agent can be modeled with different properties (for example size, capacity).	Difficult to provide properties to each agent.
Information sharing	<u>Information sharing is easy to model.</u>	Difficult to share information to particular agent.
Size (variables, constraint)	Large size problem can be handled by modularity (sub-problem).	Size is constraint, though heuristics method can be applied.

MODELS COMPARISON

Criteria	Agent-based model	Operational research model
Time scale	<u>if system is highly dynamic, ABM is more applicable.</u>	Require long time to responds to changed environment.
Output	Agent does not have global view, however ABM can produce competitive result.	<u>Can produce global solution.</u>

ONTOLOGY OF HL AOA

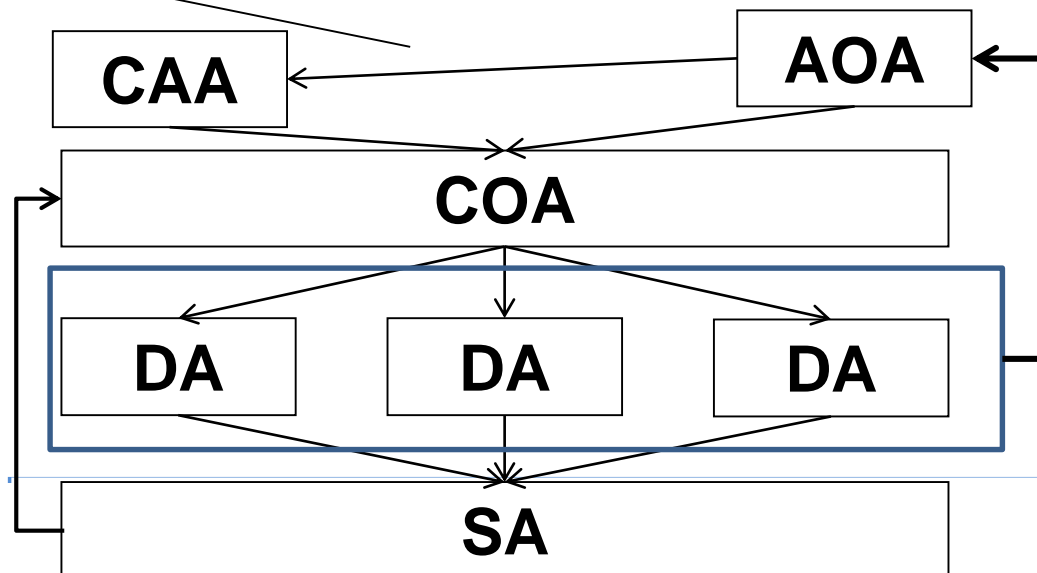
CAA



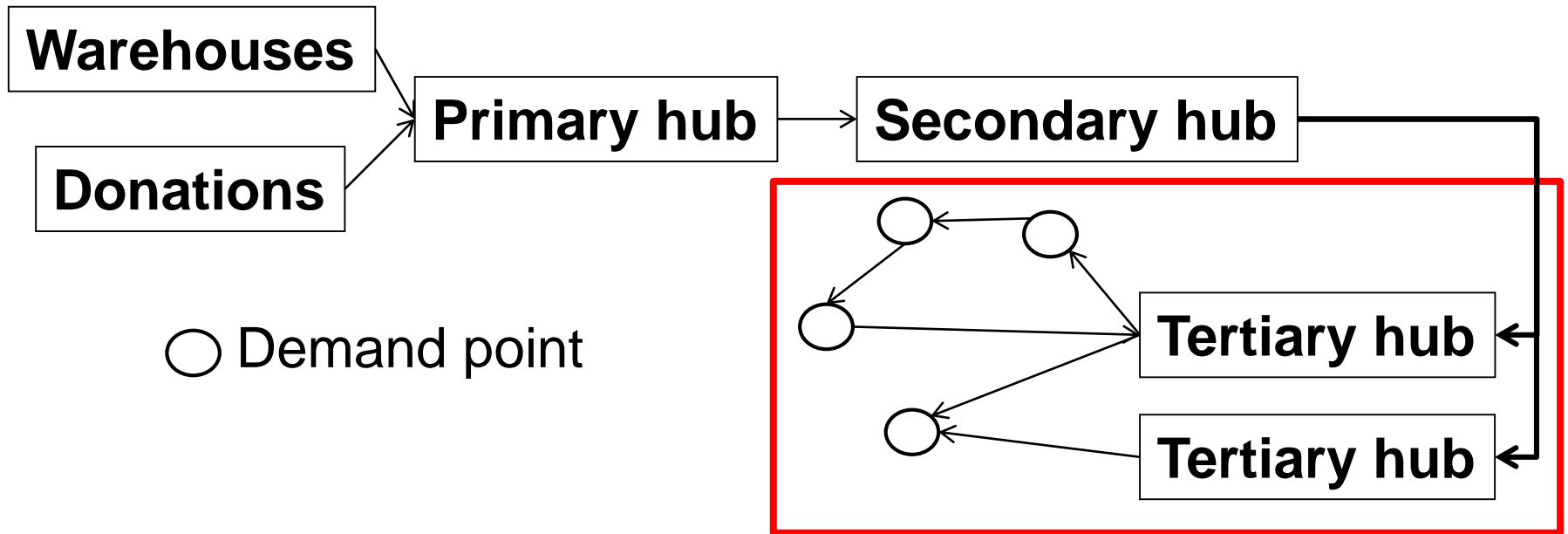
AGENTS' RELATIONSHIP

Agents	Objectives
Aid organization (AOA)	to reach more victims
Carrier (CAA)	to reduce logistics cost
Demand (DA)	to get more relief
Society (SA)	max relief efficiency
Coordinator(COA)	Serve severe victims first

coordination
via contract



STAGES AND ACTION LINKS (1)

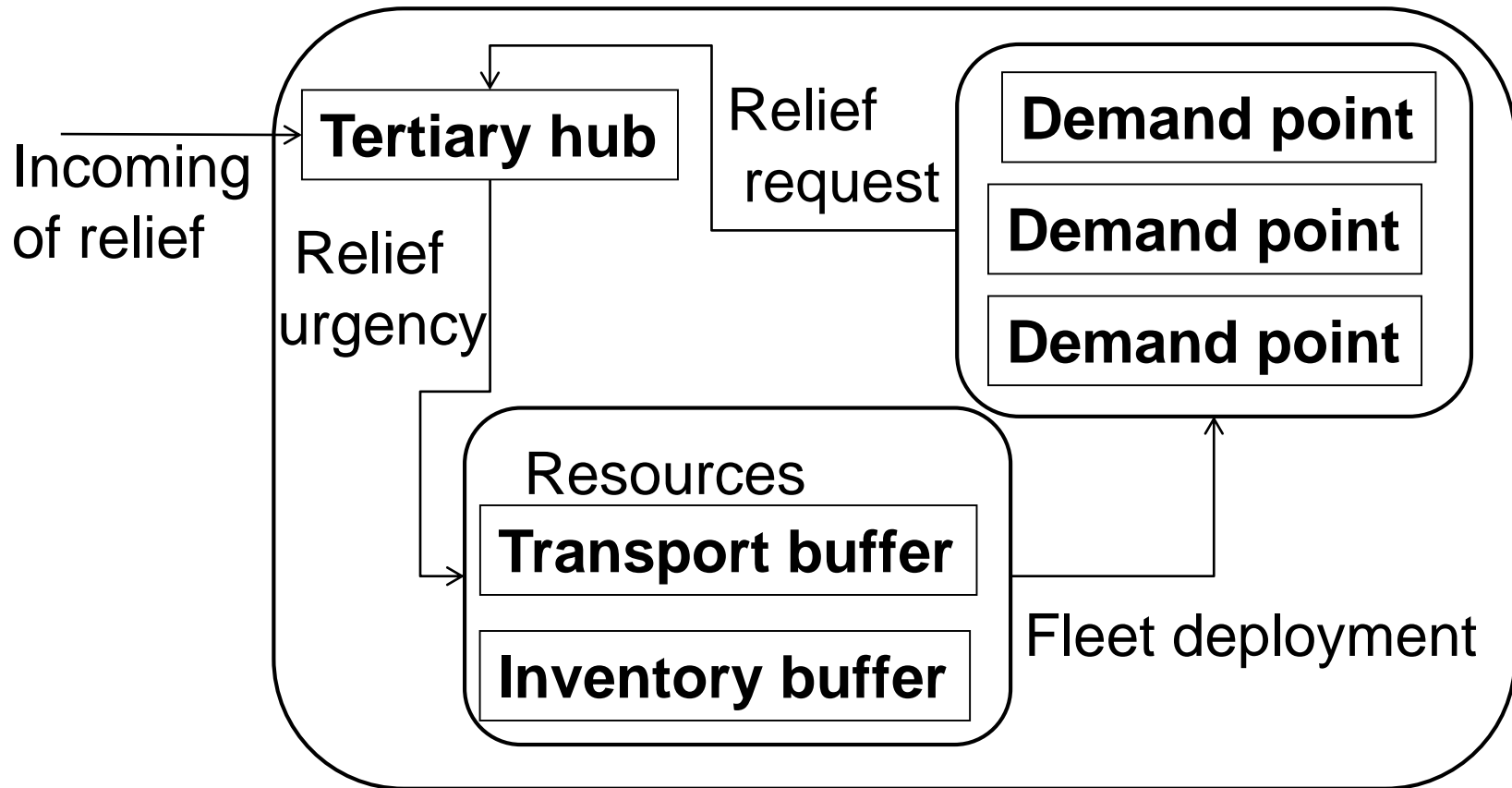


Challenge in Last Mile Distribution (LMD)

Next slide>>>

- Network disruption
- Information complexity
- Demand management

STAGES AND ACTION LINKS (2)



Last mile logistics (LMD) system

SIMULATION FLOW(1)

(1) initialize the COA (set of product, transport etc)

(2) Transfer to DA

(2.1) CAA evaluate logistics cost (time and cost)

(2.2) DA calculate demand for each product

(2.3) AOA collects requests from DA

(2.4) COA generate urgency matrix

(2.5) COA combine CAA and AOA and
deploy relief to DA

(2.6) Return of empty fleet to Tertiary hub

No

(3) is cycle have
been changed?

Yes

To phase 4
next slide

*cycle = day/ working period

From
phase 6
next
slide

SIMULATION FLOW(2)

(4) Compute the deprivation cost
(4.1) Compute unmet demand
(4.2) Cumulative deprivation cost and social benefit

(5) if necessary, COA suggest to change fleet-composition

(6) All demand met?
Or have reached operation termination time?

Yes

(7) Mission end

No

From phase 3 previous slide

To phase 1 previous slide

PHASE 2

Step 2.1. Logistics cost: $= f(\textit{distance}, \textit{time})$

Step 2.2. Relief demand: Time dependent

- food

Step 2.3. Satisfaction rate: $S_i = \frac{\textit{Delivered relief}}{\textit{Required relief}}$

Step 2.4: URGENCY MATRIX

TOPSIS = Technique for Order of Preference by Similarity to Ideal Solution

- Ranking of Demand agents (DA)

Criteria:

- 1) time varying demand for product1.
- 2) the population density associate with a given affected area.
- 3) the ratio of frail population, e.g. children and older.
- 4) the time difference of last delivery**
- 5) the restoration progress. This value lies within 1 to 10.

Step 2.4: URGENCY MATRIX

assessment matrix
(given criteria)

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ p_{n1} & p_{n2} & \cdots & p_{nm} \end{bmatrix}$$

m = number of criteria (5)
n = demand agent



By TOPSIS method

Relief urgency

$$\mu_i = \frac{d_i^-}{d_i^+ + d_i^-}$$

where, i is Demand Agent (DA)

d_i^+ = distance from positive ideal solution

d_i^- = distance from negative ideal solution

PHASE 4: DEPRIVATION COST AND SOCIAL BENEFIT

Deprivation cost

$$f_i(\Delta t) = \mu_i D_i(t) e^{\gamma + \beta \Delta t}$$

(modified from Holguin-Veras et al, 2010)

Interpretation

1. Deprivation cost (Shortage cost) due to relief “shortage” increase **exponentially with time.**
2. The urgency index (μ) create differences of deprivation cost among demand points.

PHASE 4: DEPRIVATION COST AND SOCIAL BENEFIT

$$acknowledgement = \frac{social_benefit}{cost}$$

Interpretation

- Social benefit is not easy to compute. We have used proxy for it.
- Aid organization's effort is not evaluated properly in the real world.

OUTLINE

1. Background:

Disaster and logistics

Importance of resource allocation

Objectives

2. Model description

Applicability

Ontology of humanitarian logistics

Agents relationship

Simulation flow

3. Analysis

Data

Software

Results

4. Conclusions

Features in five cities of three prefectures

DATA

Vervaeck et al., 2011

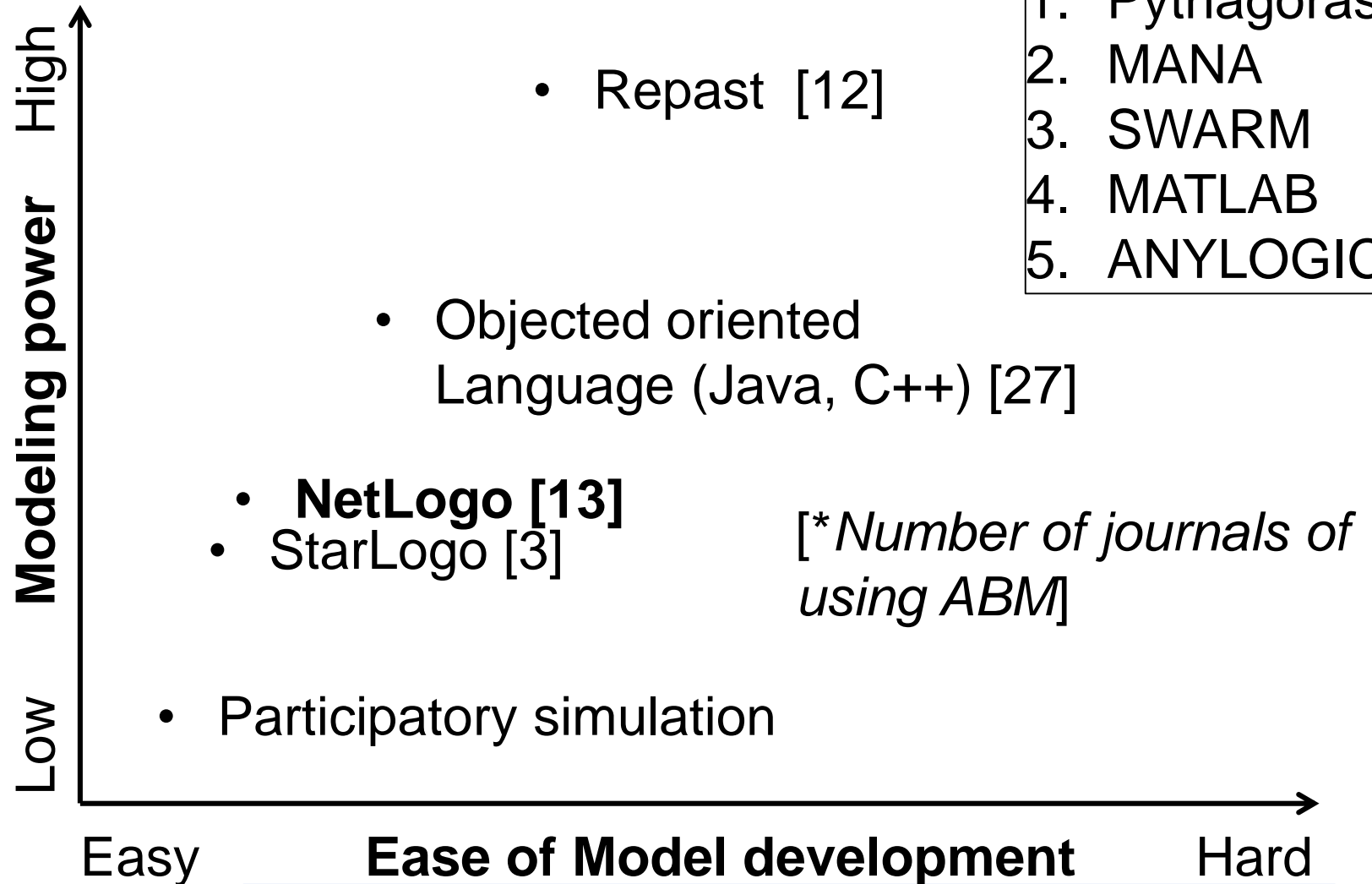
Prefecture	Demand agent (city)	Victims	% Fatalities	% Frail People	Density (#/km ²)
Fukushima (hub1)	<u>A1 : Iwaki</u>	<u>341,983</u>	<u>0.10</u>	<u>0.065</u>	<u>270</u>
	A2 : Namie-machi	18,866	0.97	0.065	99
	A3 : Minamisoma	69,171	1.00	0.065	170
	<u>A4 : Soma</u>	<u>37,843</u>	<u>1.21</u>	<u>0.066</u>	<u>190</u>
	A5 : Shinchi-machi	7,141	1.58	0.066	191
Miyagi (hub 2)	A6 : Natori	69,311	1.47	0.060	727
	A7 : Higashimatsushima	35,522	3.32	0.060	420
	<u>A8 : Ishinomaki</u>	<u>160,835</u>	<u>3.65</u>	<u>0.060</u>	<u>295</u>
	A9 : Minami-sanriku	16,294	2.30	0.060	120
	A10 : Kesenuma	63,841	7.40	0.060	220
Iwate (hub3)	A11 : Rikuzentakata	21,262	10.03	0.067	100
	A12 : Kamaichi	41,360	3.03	0.067	93
	A13 : Otsuchi	13,811	11.63	0.067	83
	A14 : Yamada-machi	16,959	4.98	0.067	77
	A15 : Miyako	57,406	1.34	0.067	46

DATA

Summary of parameters

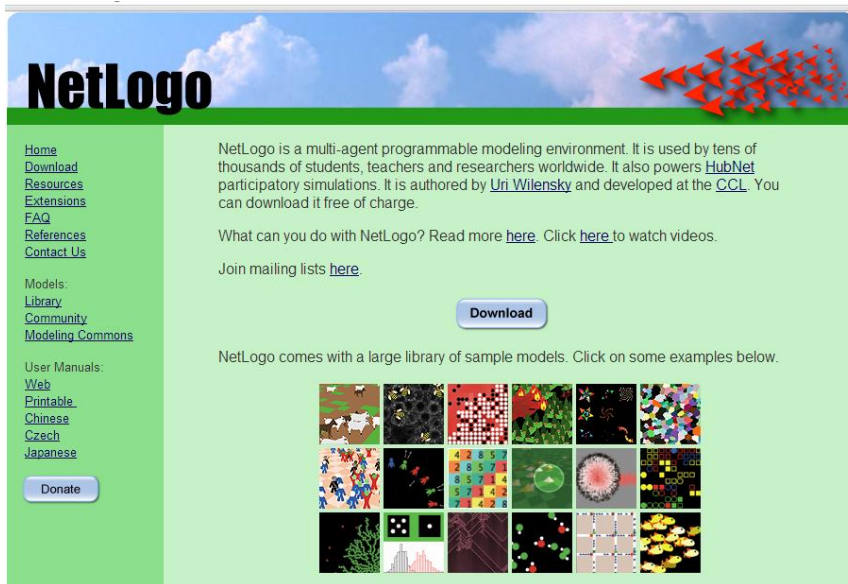
Parameter	Value
Vehicle capacity	1600 unit
planning periods	2 days
working hours	10 hours
fleet operation cost	0.79 \$ / km -> USA standard
penalty cost	$\gamma = 1.63$ -> fixed cost for delay
	$\beta = 0.00002$ -> cost for per hour delay

SOFTWARE COMPARISON



SIMULATOR

- **NetLogo** (version 5.0.3)
- Open source. link:<http://ccl.northwestern.edu/netlogo/>



NetLogo

Home
 Download
 Resources
 Extensions
 FAQ
 References
 Contact Us

Models:
 Library
 Community
 Modeling Commons

User Manuals:
 Web
 Printable
 Chinese
 Czech
 Japanese

Donate

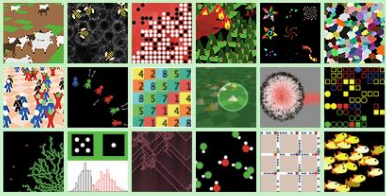
NetLogo is a multi-agent programmable modeling environment. It is used by tens of thousands of students, teachers and researchers worldwide. It also powers [HubNet](#) participatory simulations. It is authored by [Uri Wilensky](#) and developed at the [CCL](#). You can download it free of charge.

What can you do with NetLogo? Read more [here](#). Click [here](#) to watch videos.

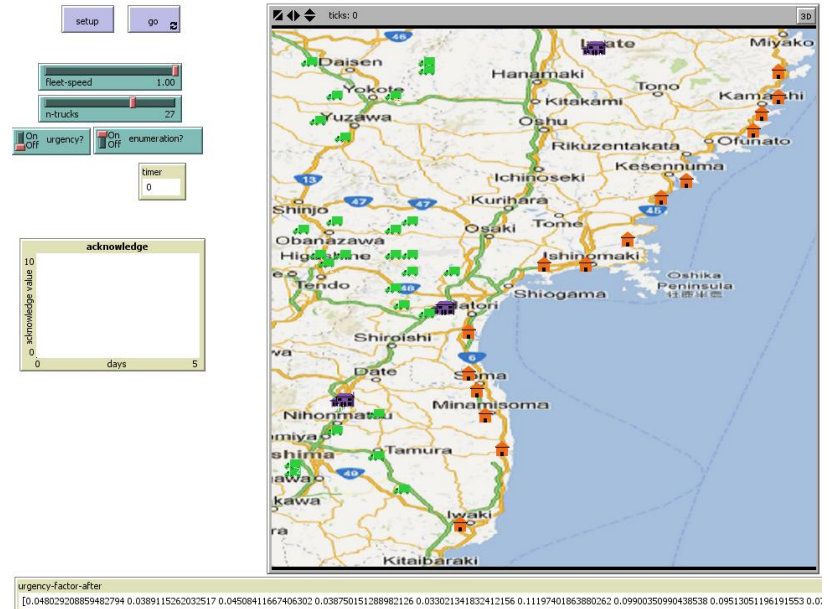
Join mailing lists [here](#).

Download

NetLogo comes with a large library of sample models. Click on some examples below.



>>NetLogo web<<



setup go

Fleet-speed 1.00

n-trucks 27

urgency? On Off enumeration? On Off

timer 0

acknowledge

10
0 acknowledge value

0 5 days

ticks: 0

urgency-factor-after
 [0.048029208859482794 0.0389115262032517 0.045068411667406302 0.038750151288982126 0.032021341832412156 0.11197401863880262 0.09900350990438538 0.09513051196191553 0.0...

>>Interface of NetLogo<<

RESULTS OF TOPSIS

Relief urgency index (μ) for demand points at Day 0

id	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
μ ($\times 10^{-2}$)	4.5	9.5	4.0	3.7	2.8	9.1	8.1	12.5	6.1	10.0	10.1	4.4	7.9	4.4	3.1

Least urgent Most urgent

id= demand agent (city) See slide 26

μ = urgency index

TWO DISTRIBUTION STRATEGY

Method 1: Enumeration approach

1. Minimization of $\min \sum_r \sum_k c_{rk} y_{rkt}$ == Transportation cost
2. Relief urgency not included

Method 2 : Decomposition approach {decompose the problem in smaller problem}

1. minimization of

$$\min Z = \sum_i w_1(1-s_i) f(1-\mu_i) + w_2 \sum_r \sum_k c_{rk} y_{rkt} \quad \forall i \in DA$$

== Suffering cost + Transportation cost

2. Relief urgency included

FLEET ALLOCATION

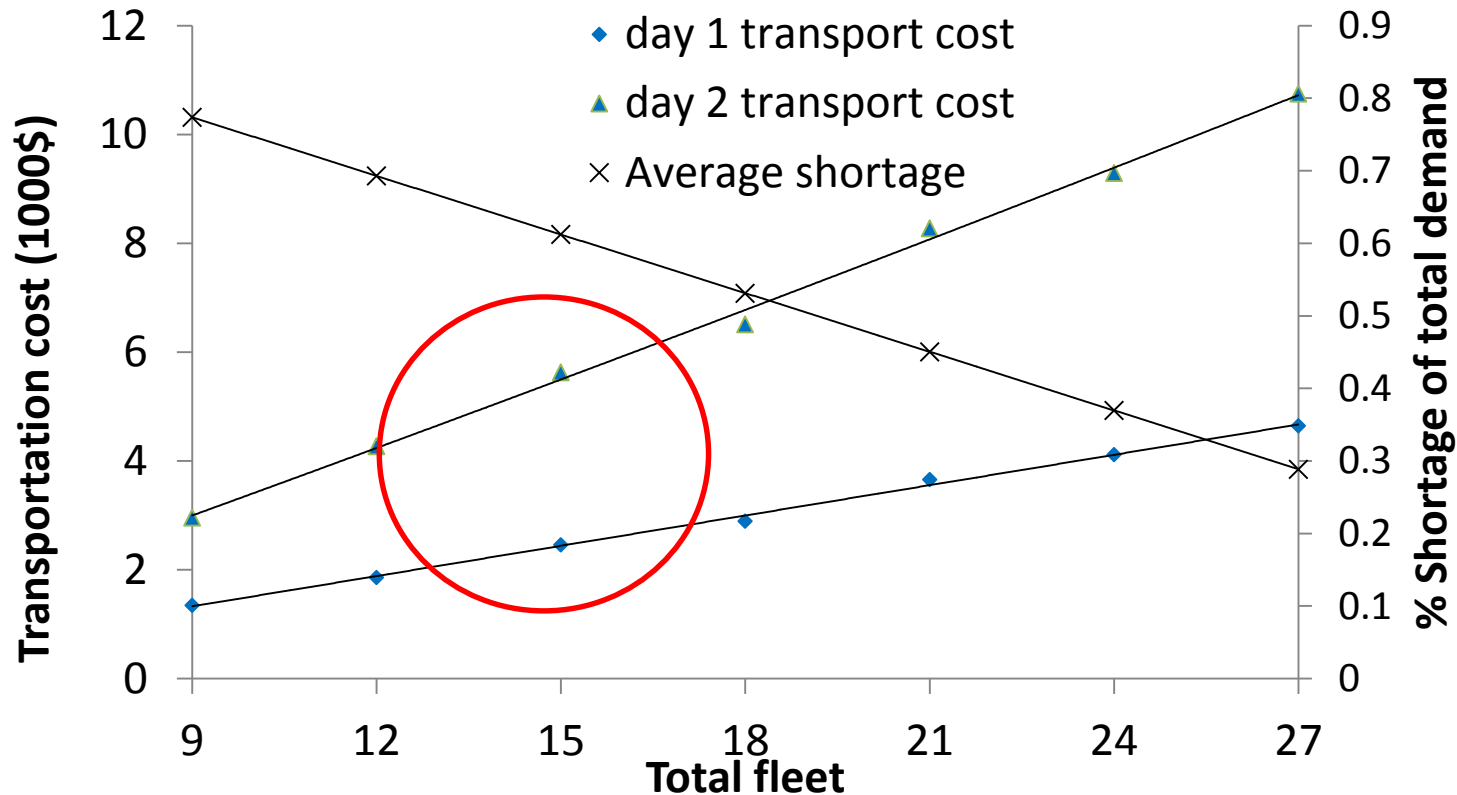
Fleet allocation for various hubs to minimize the deprivation cost

Total fleet number	Allocation of fleet			Avg. deprivation cost (\$)	
	Hub 1	Hub 2	Hub 3	Enumeration approach	Decomposition approach
9	3	4	2	5127.73	36.37
	2	5	2	5127.73	72.74
12	3	5	4	4766.33	24.22
	3	4	5	4766.33	25.36
15	4	7	4	3694.11	15.58
	5	6	4	3694.11	26.95

*** ** ** ** ** **

DECOMPOSITION APPROACH (Method 2)

>> Change of transportation cost and shortage <<

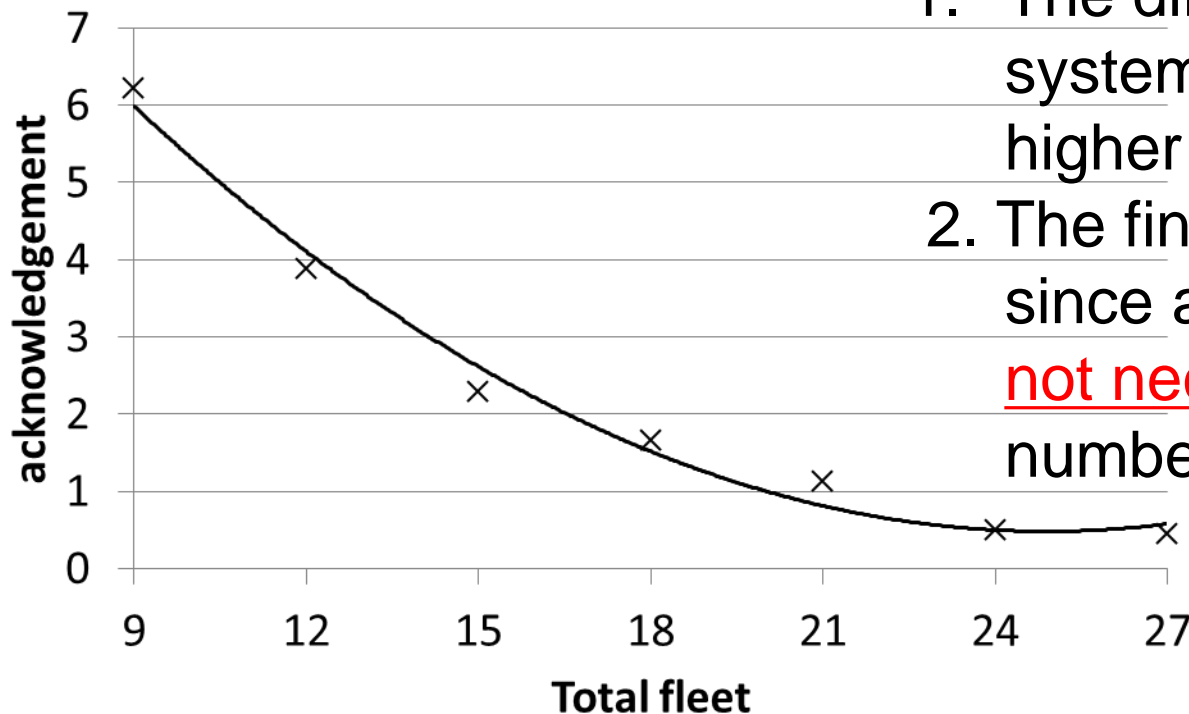


- Transport cost day 2 > Transport cost day 1
- Deprivation (shortage) cost decreases with increases of total fleet

ACKNOWLEDGEMENT

dc= Deprivation cost
TC= Transport cost

$$\text{acknowledgement} = \frac{\text{social_benefit}}{\text{cost}} = \frac{dc_{enu} - dc_{decom}}{TC_1 - TC_2}$$



1. The differences in two systems become lower for higher number of fleet
2. The finding is pragmatic since allocation model is not necessary for higher number of fleet

>> Change of acknowledgement <<

CONCLUSIONS

- We graphed the ontology of humanitarian logistics.
 - Although agents have overall goal of helping victims, they have also own targets.
- The ranking of **demand points** are made. This ranking is valuable for deciding next delivery point and time.
- Trade-off between transport cost and deprivation cost.
 - Transport cost increases to gain more social satisfaction.
 - Deprivation (shortage) cost decreases with increase of resources.
- Proxy of performance of aid-organizations is evaluated by acknowledgement value.
 - The 'acknowledgement' can be a measure for resource planning.

Submit: **An agent-based model for resource allocation during relief distribution** (Under review at Journal of Humanitarian Logistics and Supply Chain Management)

Thank you
for
your kind attention

Contact:

hanaoka@ide.titech.ac.jp
rubeldas@tp.ide.titech.ac.jp

appendix: TOPSIS

1. Normalize the criteria

$$p_{ij} = \frac{P'_{ij}}{\sum_{i=1}^n P'_{ij}}, \quad i = 1, \dots, n$$



assessment matrix

$$P = \begin{bmatrix} p_{11} & p_{12} & \dots & p_{1m} \\ p_{21} & p_{22} & \dots & p_{2m} \\ \dots & \dots & \dots & \dots \\ p_{n1} & p_{n2} & \dots & p_{nm} \end{bmatrix}$$

2. The entropy value

$$e_j = -k \sum_{i=1}^n p_{ij} \ln p_{ij} \quad \text{Where,} \quad k = \frac{1}{\ln n}$$

3. Degree of divergence

$$d_j = 1 - e_j$$

4. Weight of each criteria

$$w_j = \frac{d_j}{\sum_{j=1}^m d_j}$$

5a. Positive ideal solution

$$A^+ = \left(\max_i (p_{i1}), \max_i (p_{i2}), \dots, \max_i (p_{im}), \right) = p_1^+, p_2^+, \dots, p_m^+$$

5b. Negative ideal solution

$$A^- = \left(\min_i (p_{i1}), \min_i (p_{i2}), \dots, \min_i (p_{im}), \right) = p_1^-, p_2^-, \dots, p_m^-$$

6. Weighted Euclidean

$$d_i^- = \sqrt{\sum_{j=1}^m w_j (p_{ij} - p_j^-)^2} \quad d_i^+ = \sqrt{\sum_{j=1}^m w_j (p_j^+ - p_{ij})^2}$$

7. Relief urgency

$$\mu_i = \frac{d_i^-}{d_i^+ + d_i^-}$$