Seminar on
Humanitarian Logistics
Tokyo University of Marine Science and Technology

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An Agent-based Model for Resource Allocation During Relief Distribution

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OUTLINE

1. Background:

- Disaster and logistics
- Importance of resource allocation
- Objectives

2. Model description

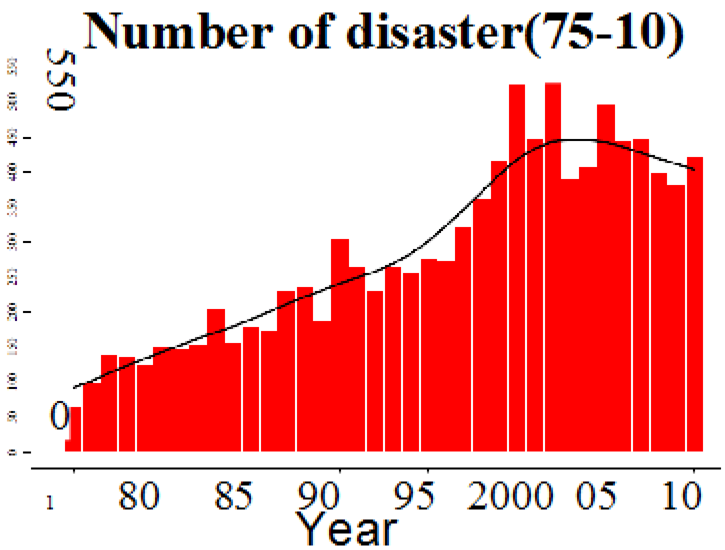
- Applicability
- Ontology of humanitarian logistics
- Agents relationship
- Simulation flow

3. Analysis

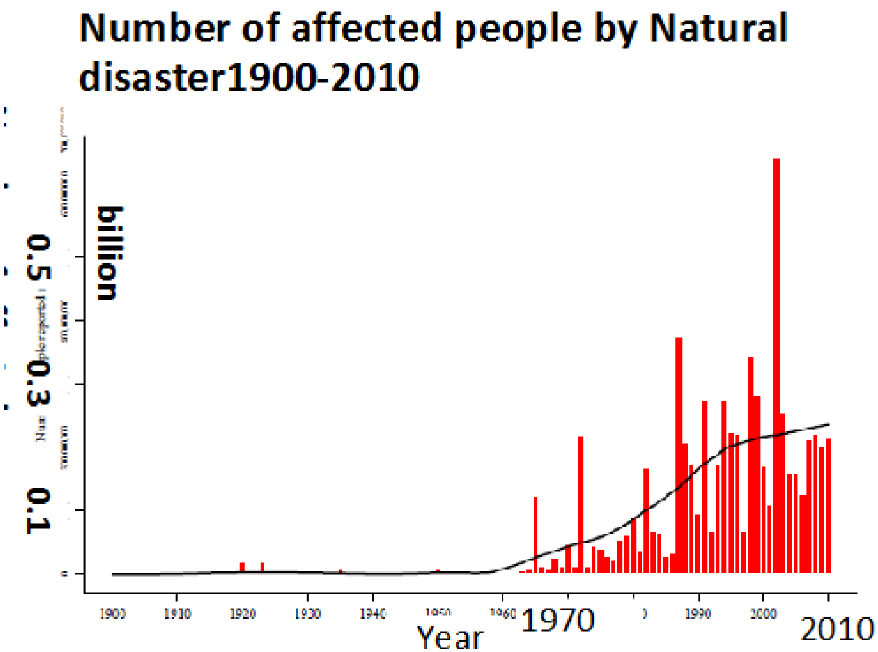
- Data
- Software
- Results

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

Source: EM-DAT database (http://www.emdat.be/)

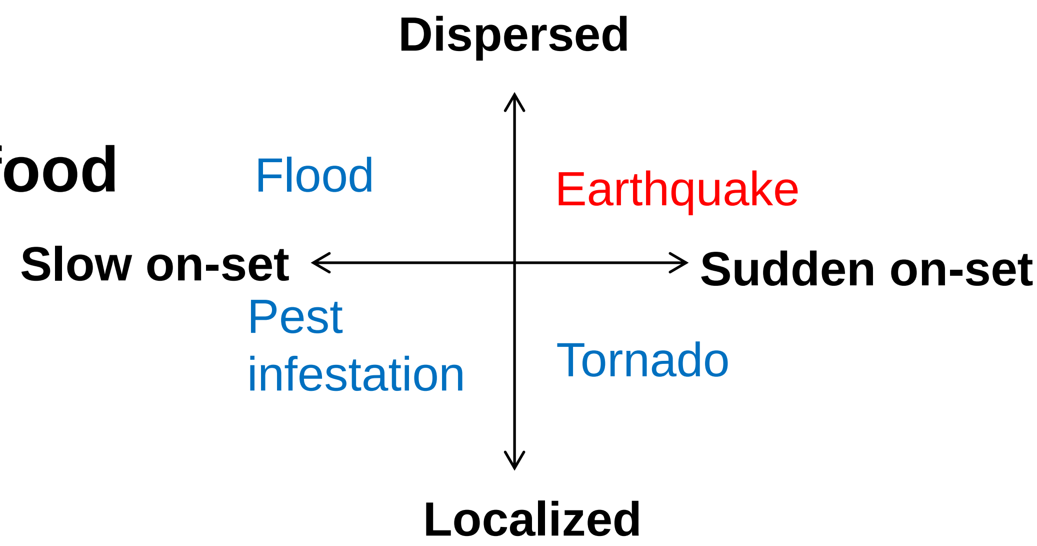
HUMANITARIAN LOGISTICS (HL)

After Earthquake

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

RELIEF

Disaster types



HL is the process of <u>planning, managing, and controlling</u> 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.

Thomas, 2003

DIFFERENCES

Business logistics

Logistics cost

Supplier ⇄ Customer

Revenue

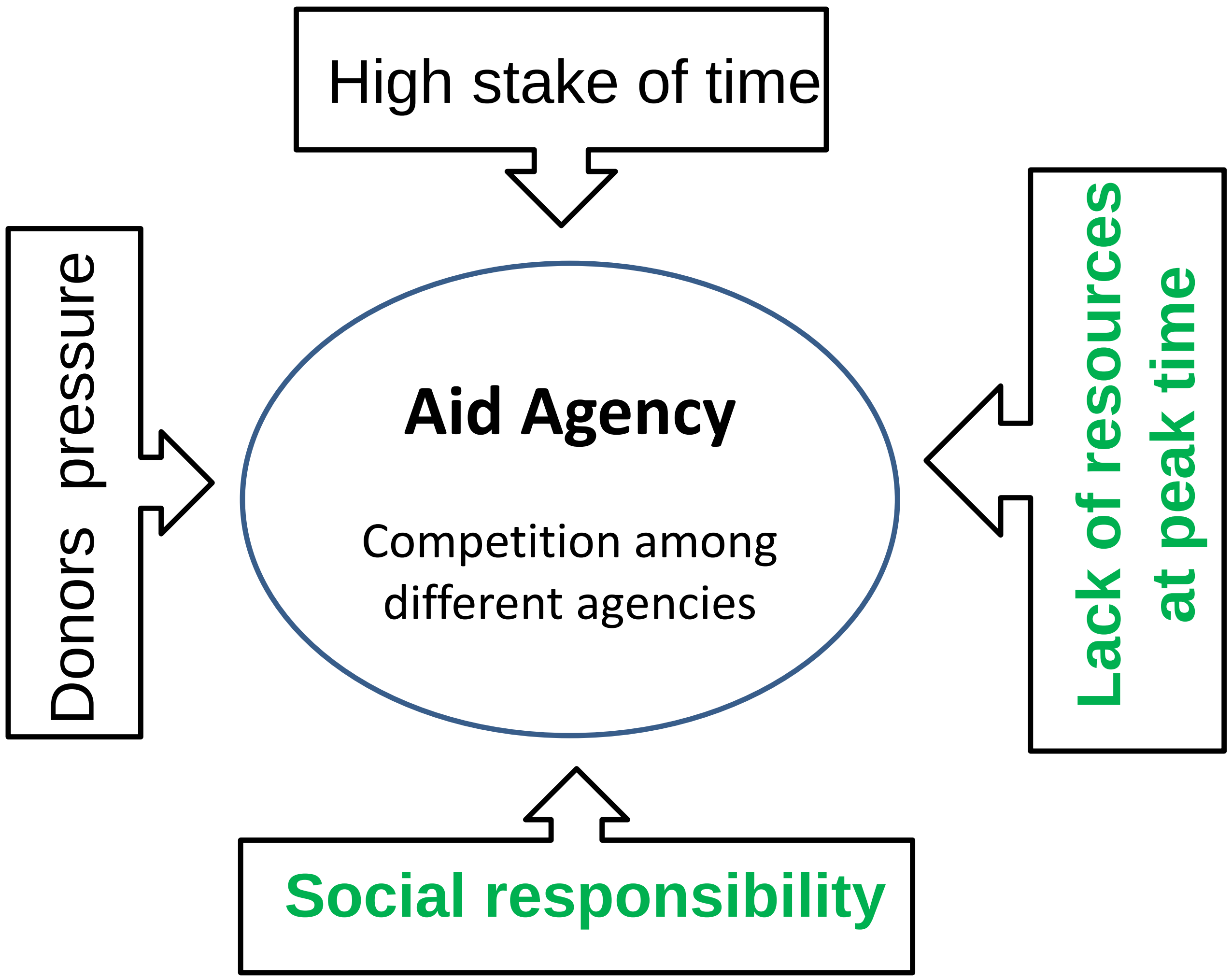
Humanitarian logistics

Logistics cost

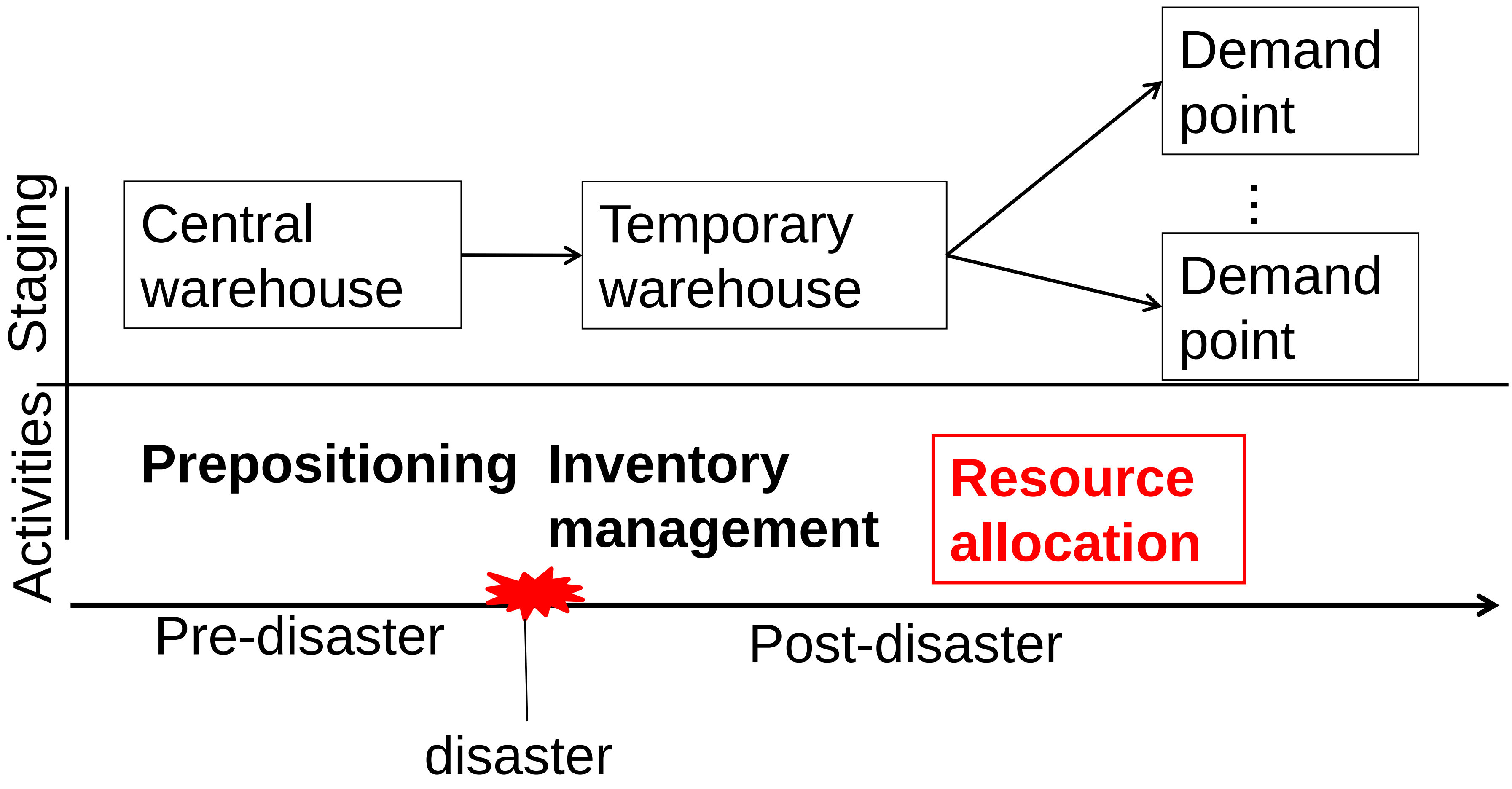
Aid organization ⇄ Victim

No monetary value

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.

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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

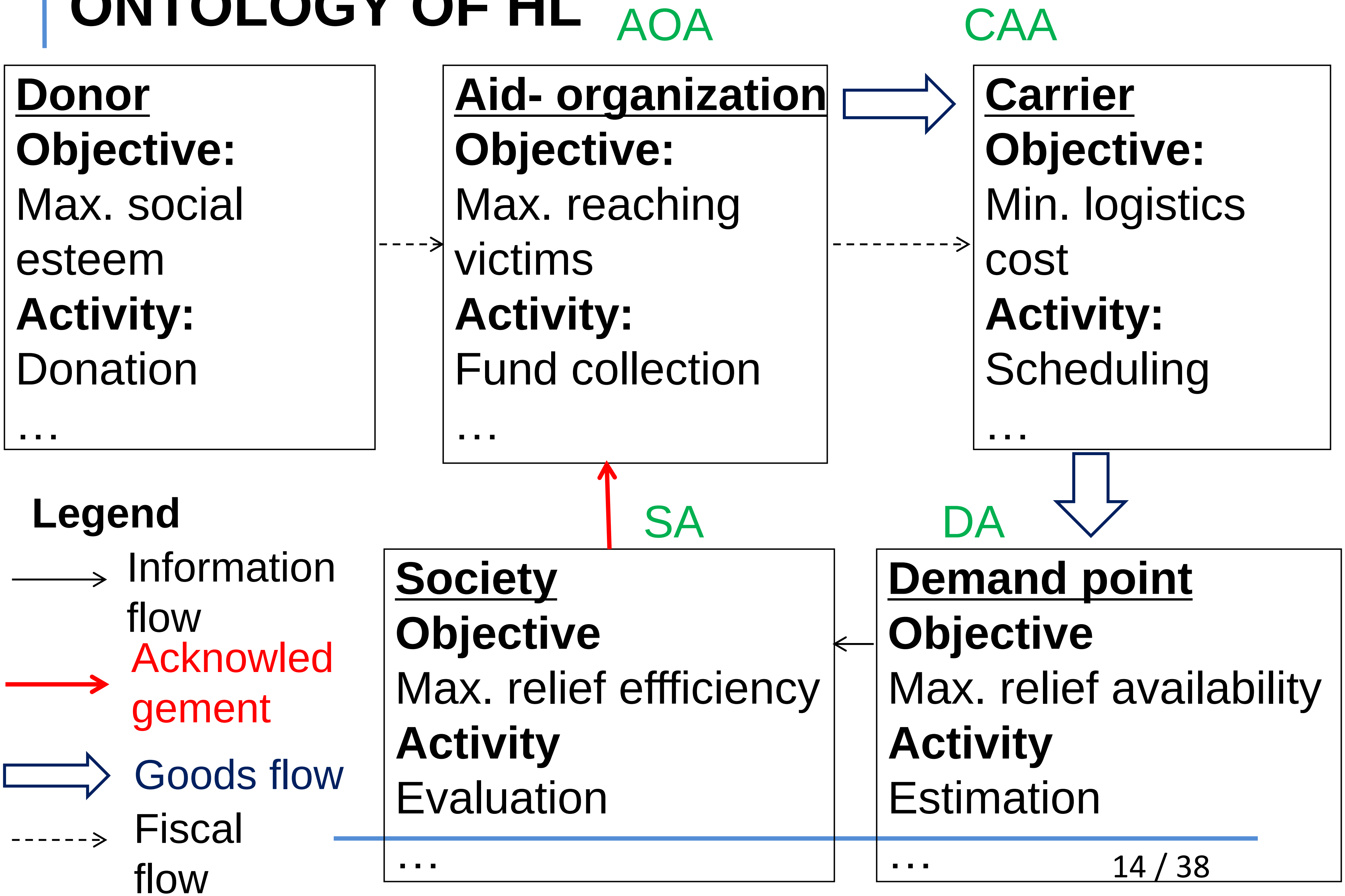
MODELS COMPARISON

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	Information sharing is easy to model.	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

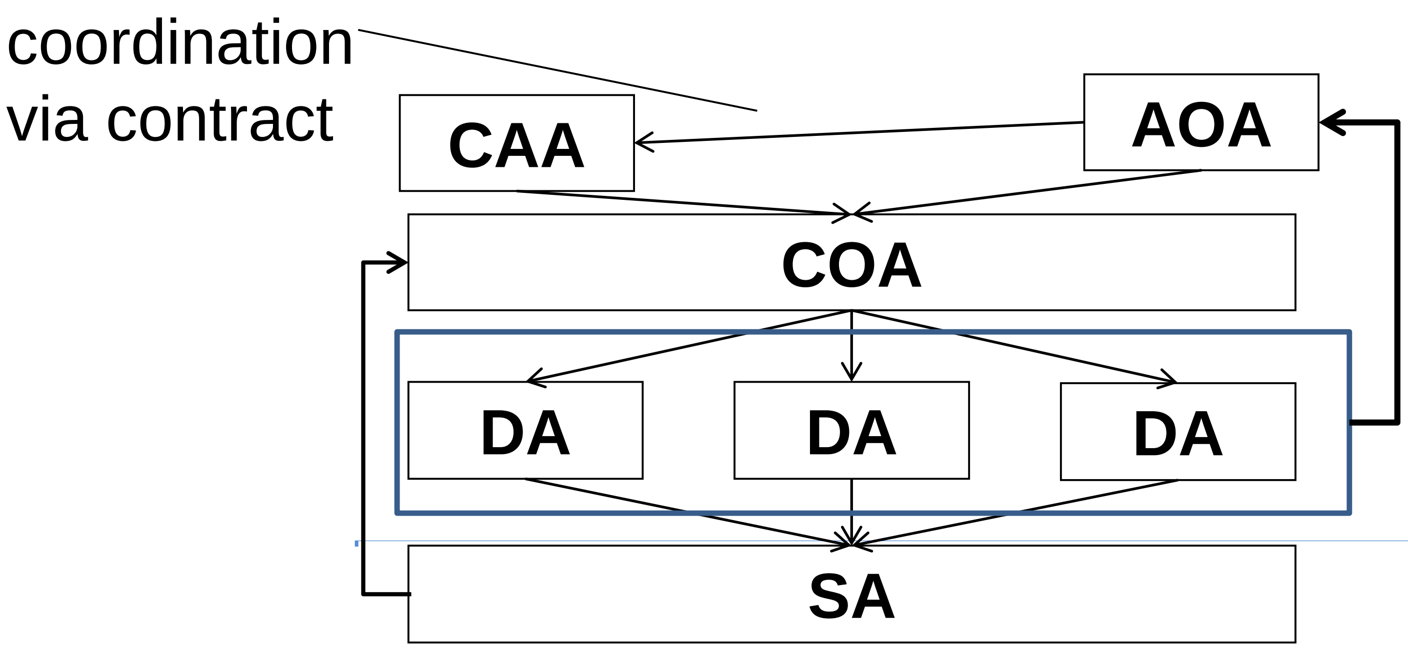
Criteria	Agent-based model	Operational research model
Time scale	if system is highly dynamic, ABM is more applicable.	Require long time to responds to changed environment.
Output	Agent does not have global view, however ABM can produce competitive result.	Can produce global solution.

ONTOLOGY OF HL

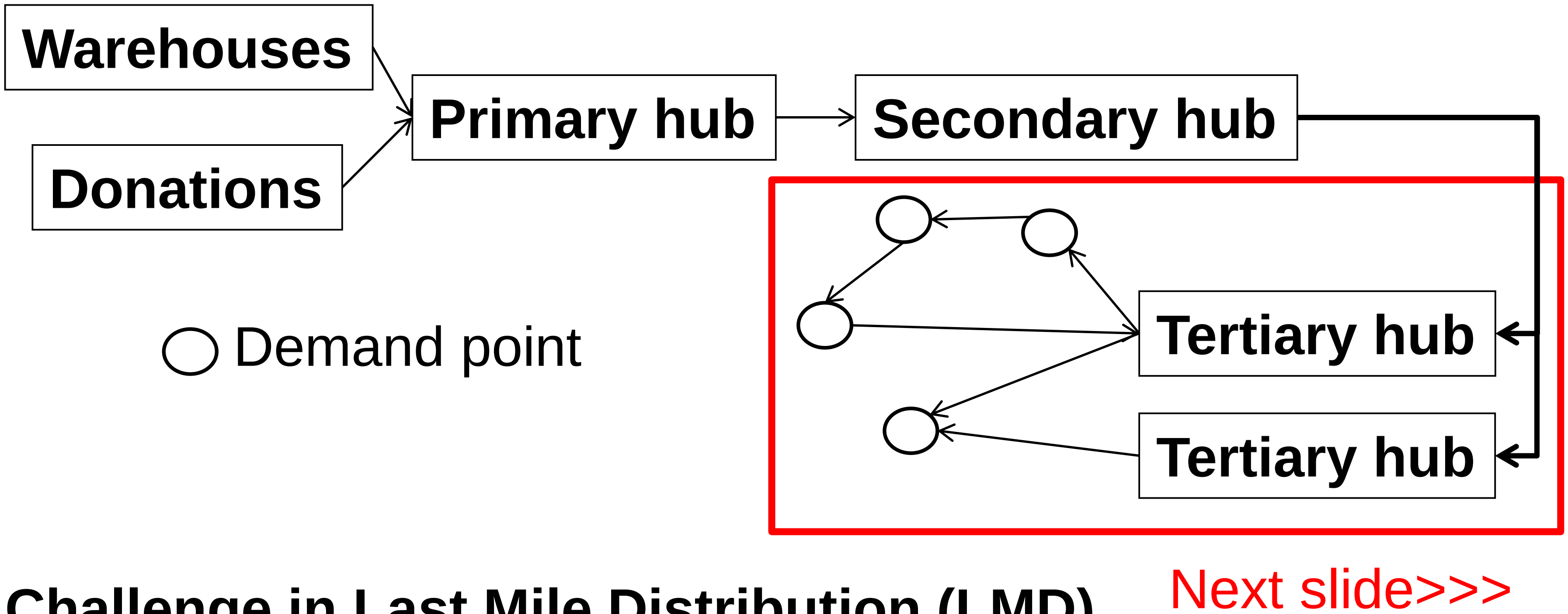


AGENTS' RELATIONSHIP

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



STAGES AND ACTION LINKS (1)

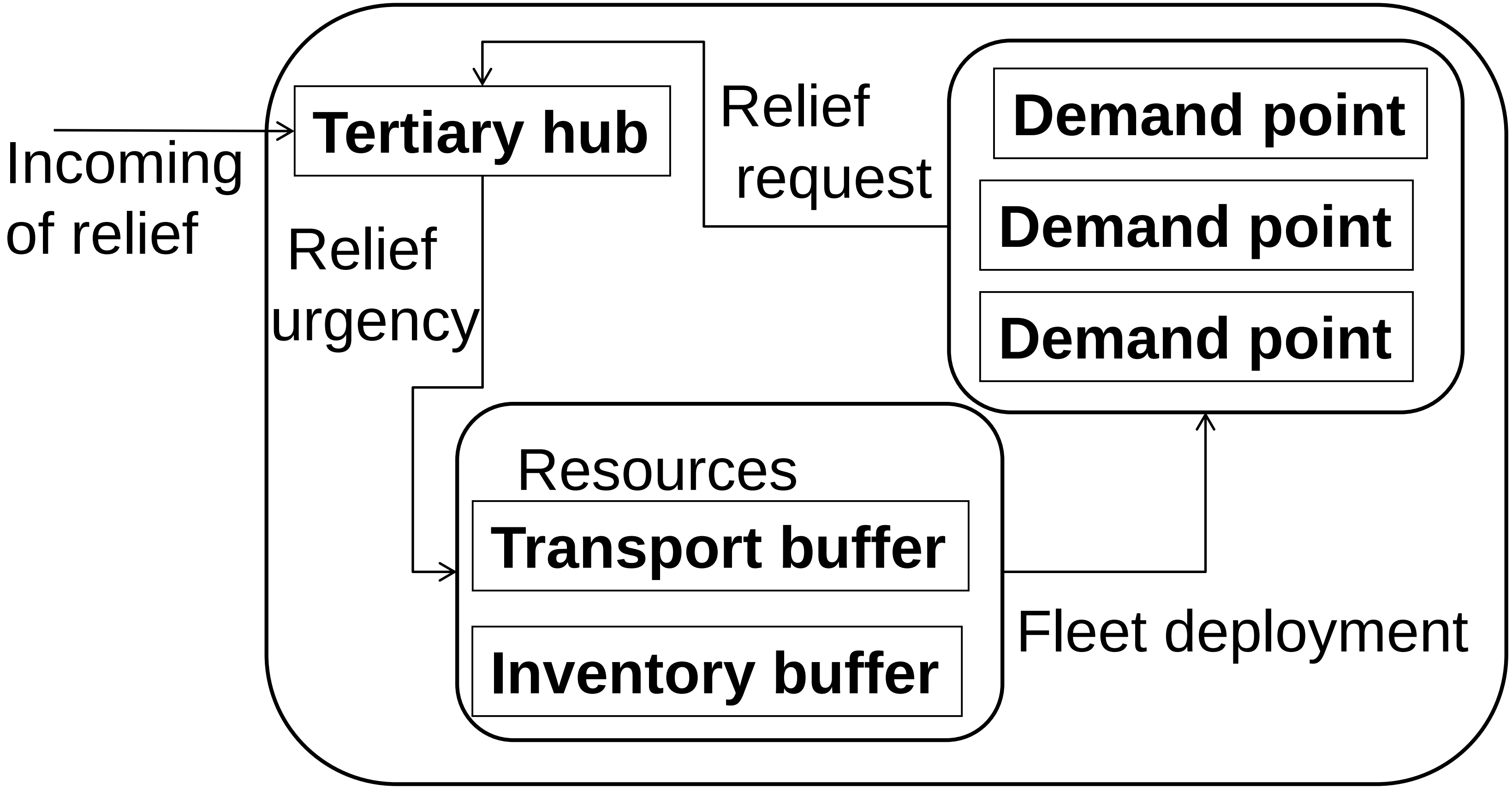


<u>Challenge in Last Mile Distribution (LMD)</u>

- Network disruption
- Information complexity
- Demand management

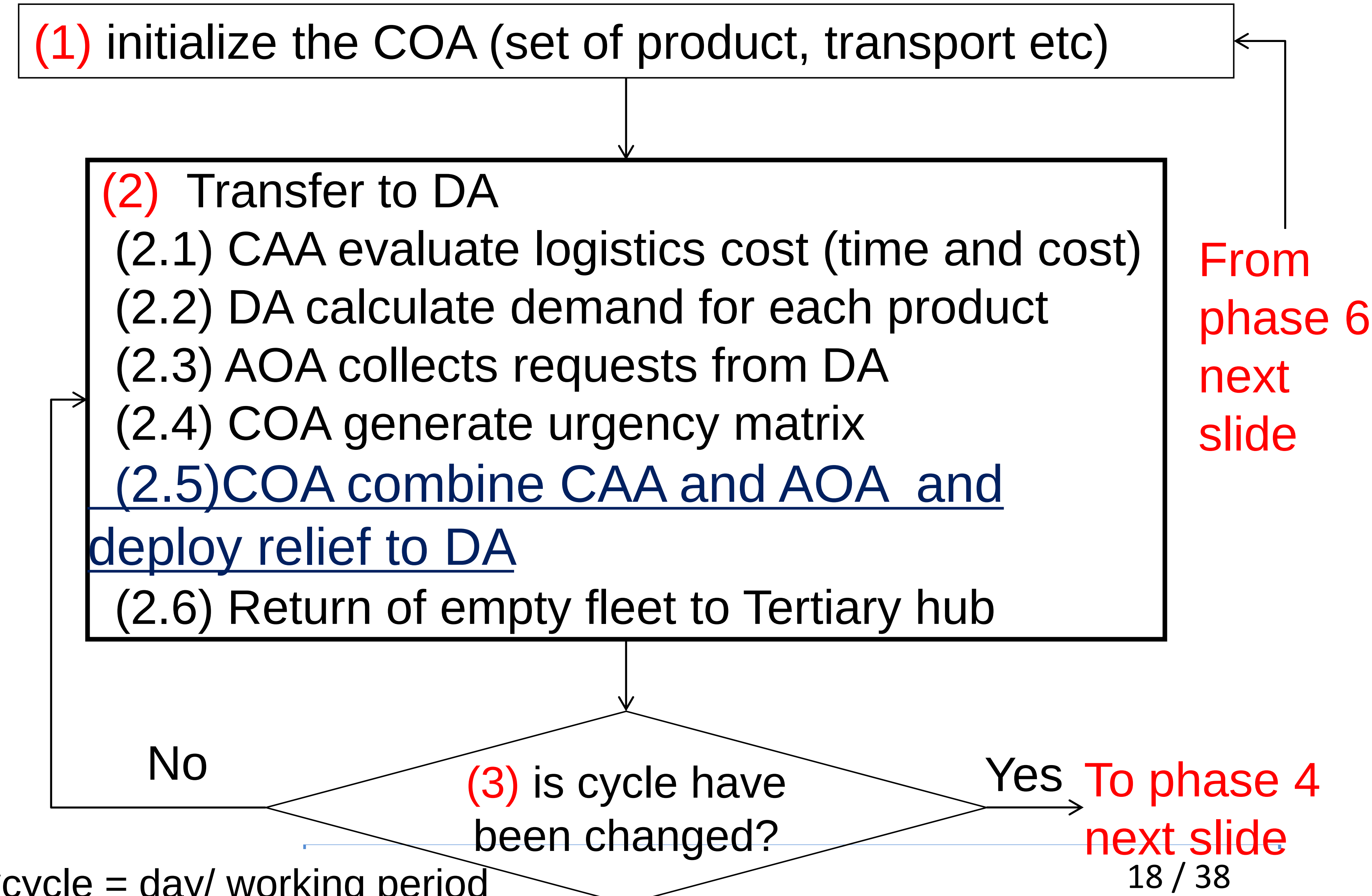
UNDP, 1995; Balcik and Beamon, 2007

STAGES AND ACTION LINKS (2)



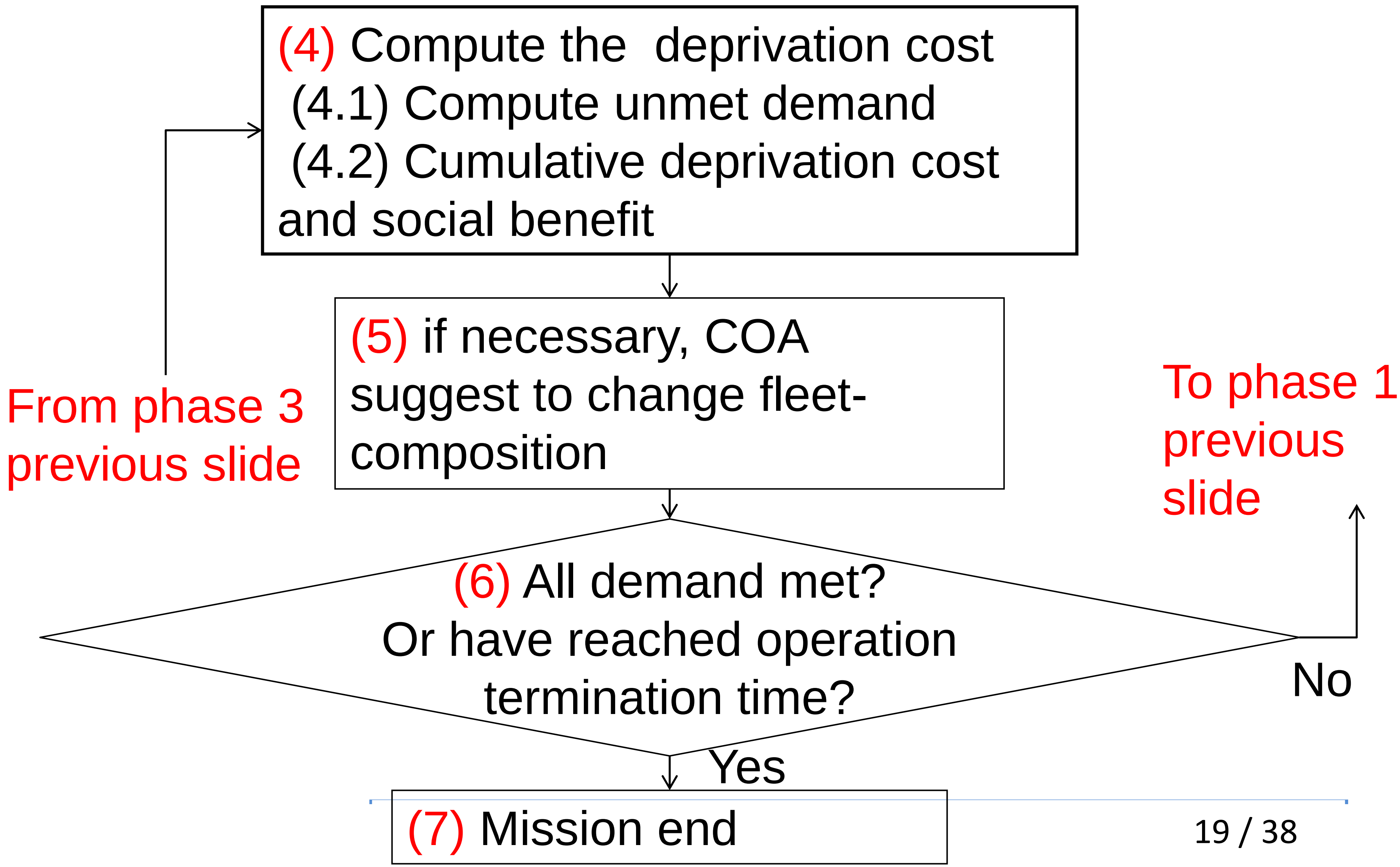
Last mile logistics (LMD) system

SIMULATION FLOW(1)



*cycle = day/ working period

SIMULATION FLOW(2)



PHASE 2

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

Step 2.2. Relief demand: Time dependent

- food

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

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*

* see appendix for details

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.

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Features in five cities of three prefectures

DATA

Vervaeck et al., 2011

Prefecture	Demand agent (city)	Victims	% Fatalities	% Frail People	Density (#/km²)
Fukushima (hub1)	A1 : Iwaki	341,983	0.10	0.065	270
	A2 : Namie-machi	18,866	0.97	0.065	99
	A3 : Minamisoma	69,171	1.00	0.065	170
	A4 : Soma	37,843	1.21	0.066	190
	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
	A8 : Ishinomaki	160,835	3.65	0.060	295
	A9 : Minami-sanriku	16,294	2.30	0.060	120
	A10 : Kesennuma	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

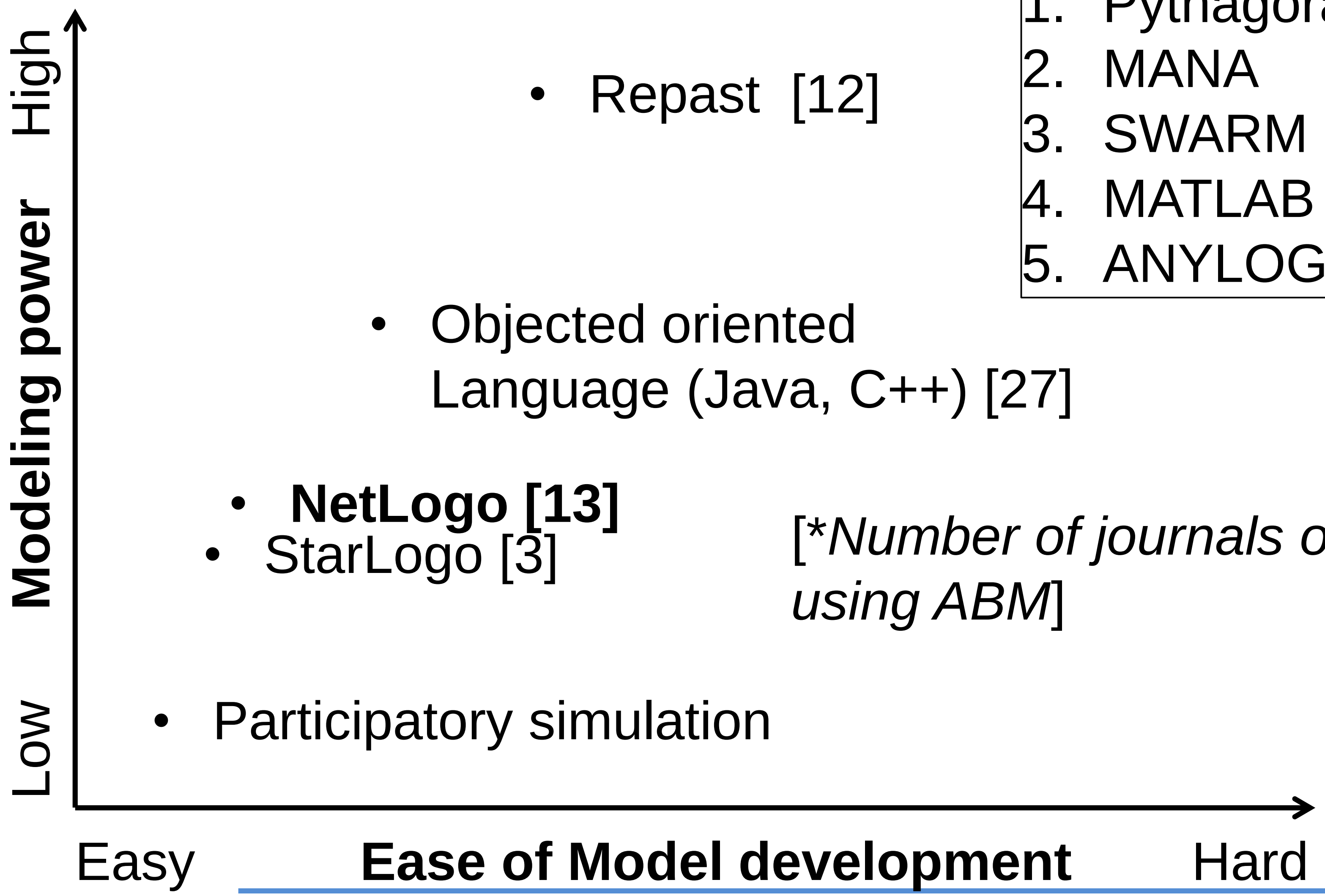
DATA

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	γ = 1.63	-> fixed cost for delay
	β= 0.00002	-> cost for per hour delay

SOFTWARE COMPARISON

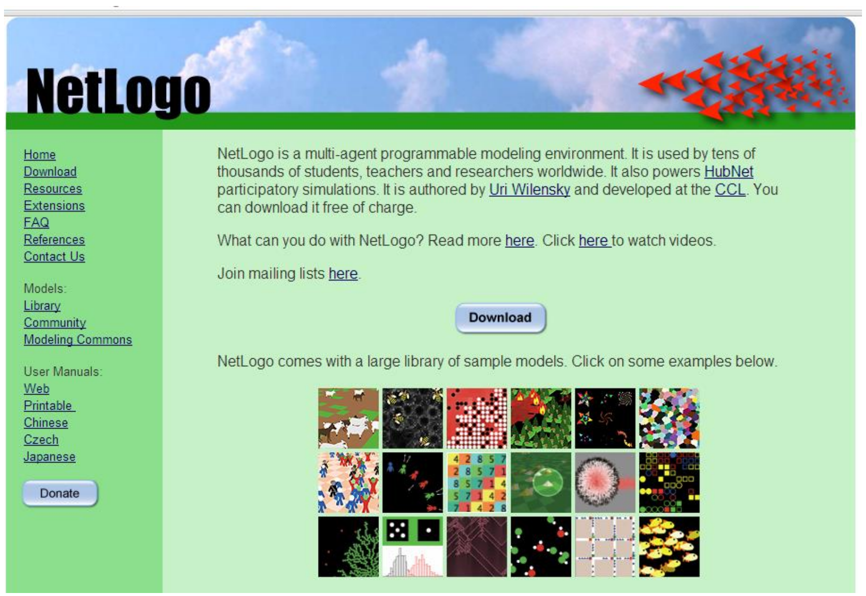
Other software

1. Pythagoras
2. MANA
3. SWARM
4. MATLAB
5. ANYLOGIC

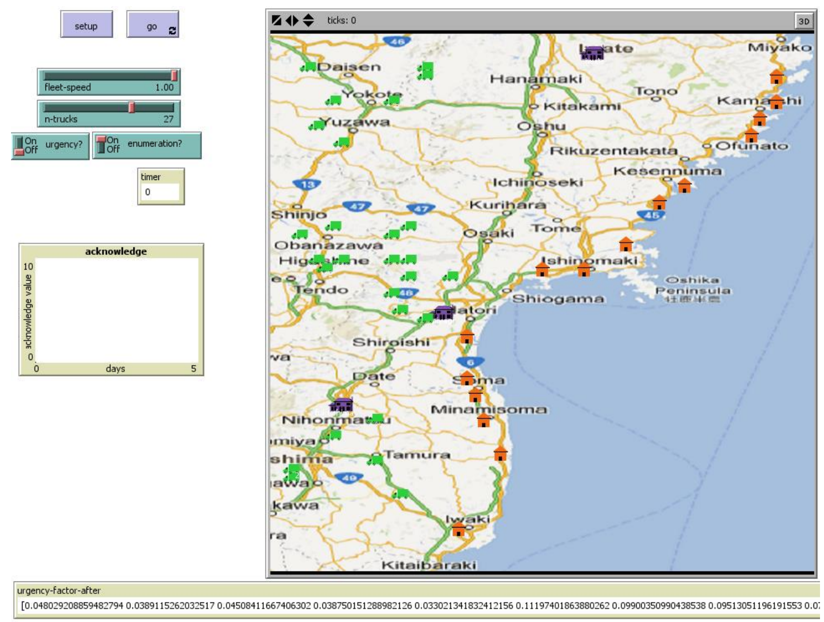


SIMULATOR

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



>>NetLogo web<<



>>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 ($X10^{-2}$)	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 (A5) Most urgent (A8)

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

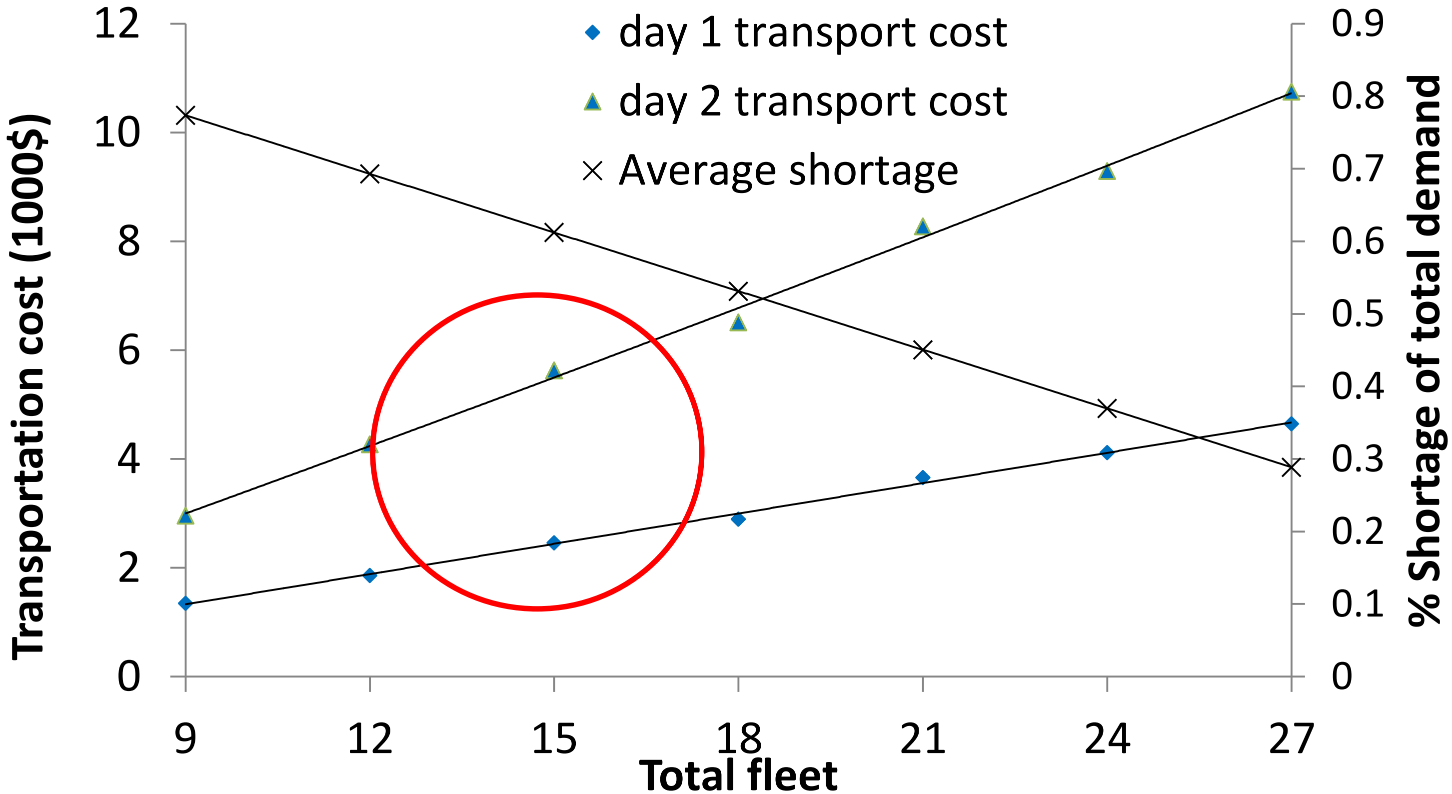
FLEET ALLOCATION

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 <<

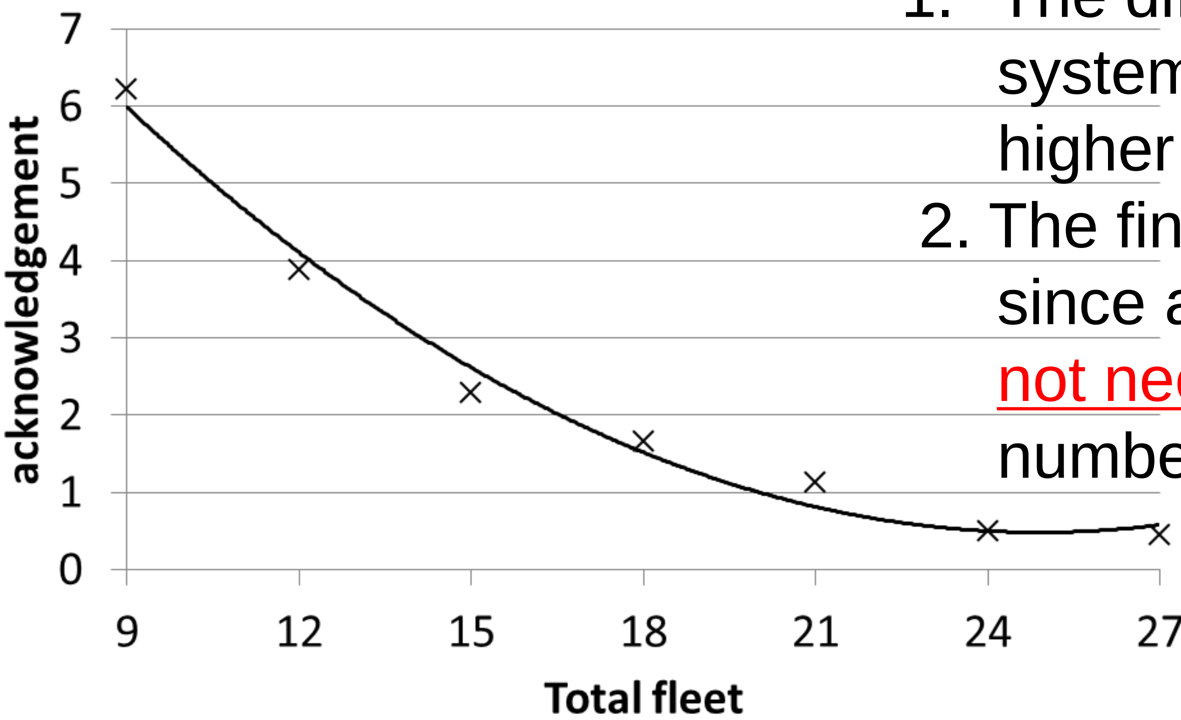


- Transport cost day 2 > Transport cost day1
- Deprivation (shortage) cost decreases with increases of total fleet

ACKNOWLEDGEMENT

dc= Deprivation cost
TC= Transport cost

$$acknowledgement = \frac{social\_benefit}{cost} = \frac{dc_{enu} - dc_{decom}}{TC_1 - TC_2}$$



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

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appendix: TOPSIS

1. Normalize the criteria

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

assessment matrix

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

2. The entropy value

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij}$$

Where, $k = \frac{1}{\ln n}$

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

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

5b. Negative ideal solution

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

6. Weighted Euclidean

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

7. Relief urgency

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