On the Economic Aspects of the Design of a Relief System in a Metropolitan City

A top-down approach

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Participants of the project

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Assumptions

1. **Metropolitan city (huge population)**
2. **Large scale disaster**
3. **No poisonous gas leaking**
4. **The occurrence of the disaster is expected,**
5. **however, the time of the disaster is not known.**

Consequences:

- **Earthquake and tsunami are the main concerns.**
- **Industrial and other man-made disasters excluded.**

Post-disaster situation

1. Many houses collapsed.
2. People outside the buildings survived.
3. Most of the people under the debris died.
4. Some people survived, however they are trapped under the debris.
5. All survivors are shocked.
6. Many people lost family members and friends.
7. Some streets are covered by debris or are damaged.

Needs in the immediate post-disaster period

- Relief items for everybody. Water, bandage, banquet, pain killer and other basic medicine.
- Emergency services including transportation and operation.
- Immediate life saving actions as cleaning respiratory tracks.
- Local medical help: minor injuries, life saving medicines like insulin, medicines for heart diseases and epilepsy, etc.
- Information: missing/found persons, usable/not usable streets, etc.
- Further relief items: baby food, food, hygienic item, etc.

The project

- To design a relief organization which can meet the basic needs.
- It includes decisions on
  - technology,
  - structure,
  - capacities,
  - special solutions for various departments.
- First 48 hours versus long term solution.
  - Local relief versus long distance relief.
  - Security.
  - Debris collection, shelters, community management.

How to design a system?

- Top-down approach
- The main structure is designed first:
  - Subsystems and their connections
- The subsystems are designed in the same way.
- The design must reach the bottom with executable functions.

- Bottom-up approach
- The design starts with the executable functions.
- (Sub)systems are organized from the functions.
- The design goes up in the same way.
- The design must produce a complete system.
  - For example clear leadership is needed.

Advantages and disadvantages

- Top-down approach
- No action if the bottom is not reached.
- It is clear that which experts are needed.
- Without clear concept only ad hoc (amateur) solutions are possible.
- Very often no calculations and actions.

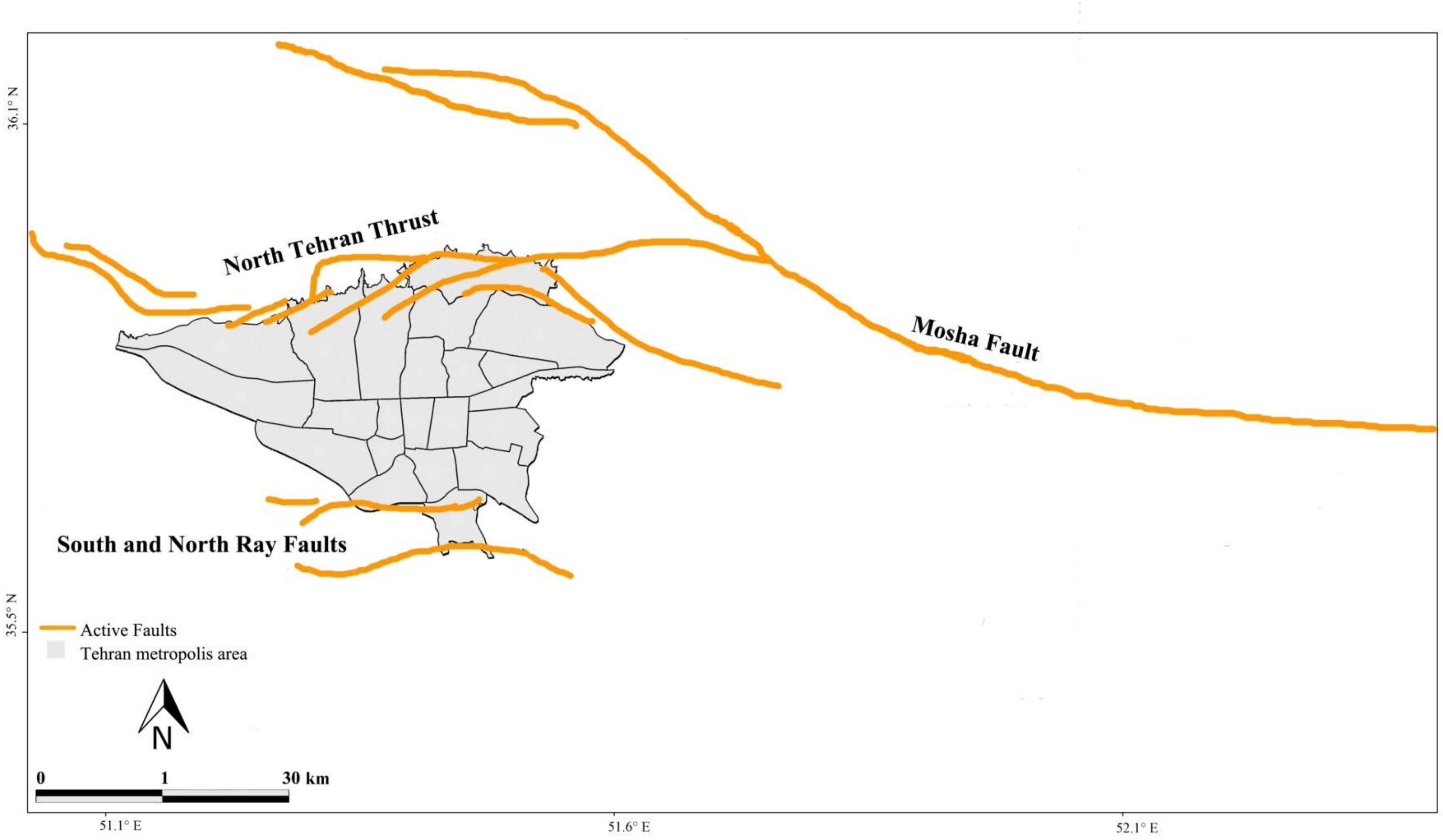
- Bottom-up approach
- Something is always done.
- Without clear concepts the elements don’t cooperate properly.
- Calculations are easier.

Level 0: Basic concepts

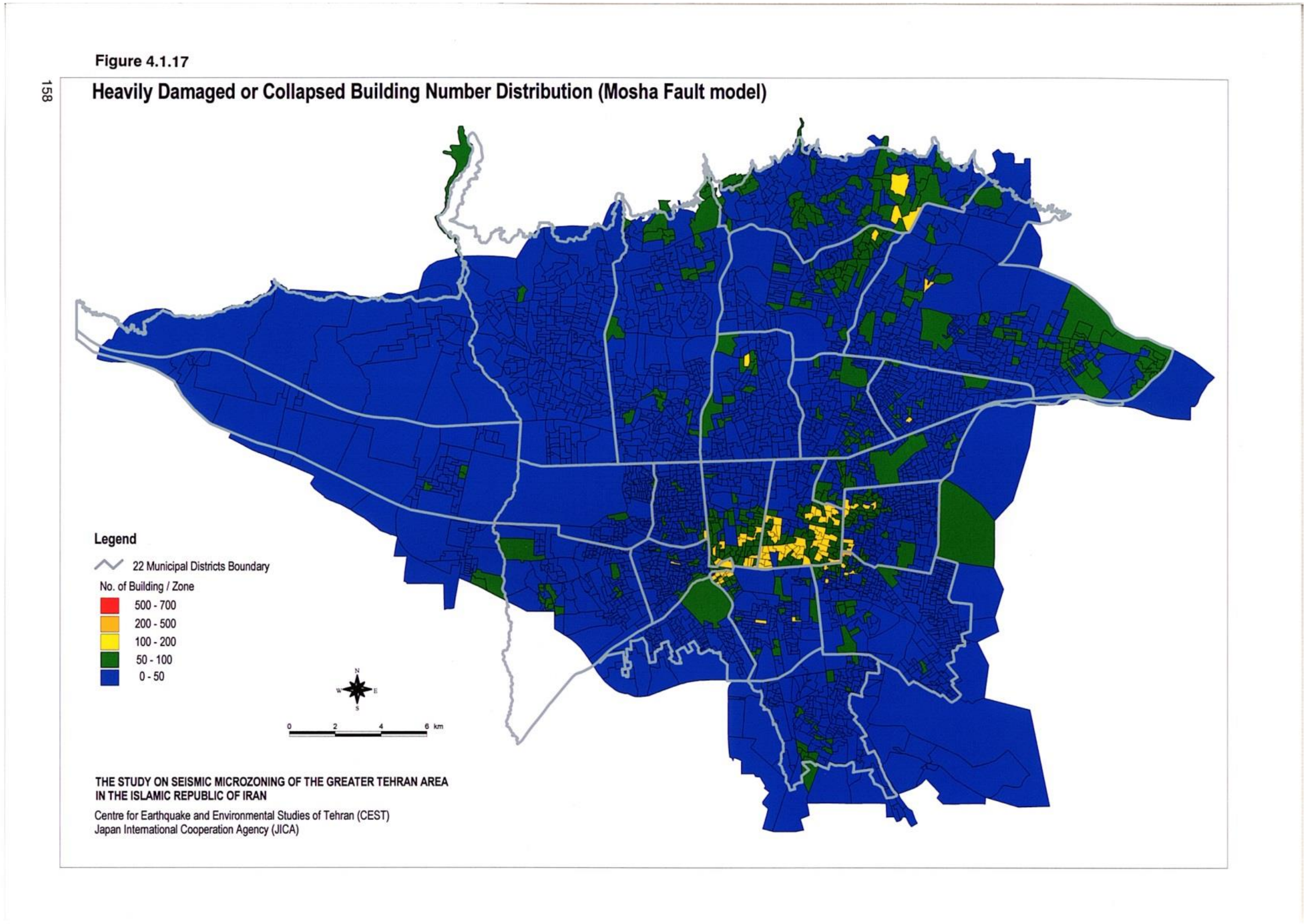
- UAV (Unmanned Aerial Vehicle) technology is used for
  - transportation of relief items,
  - reconnaissance,
  - patrolling.
- Advantages
  - No traffic jam.
  - No detour.
  - No problem with people (security).
  - Large variety of vehicles.
- Supply Points

Level 0: Basic concepts

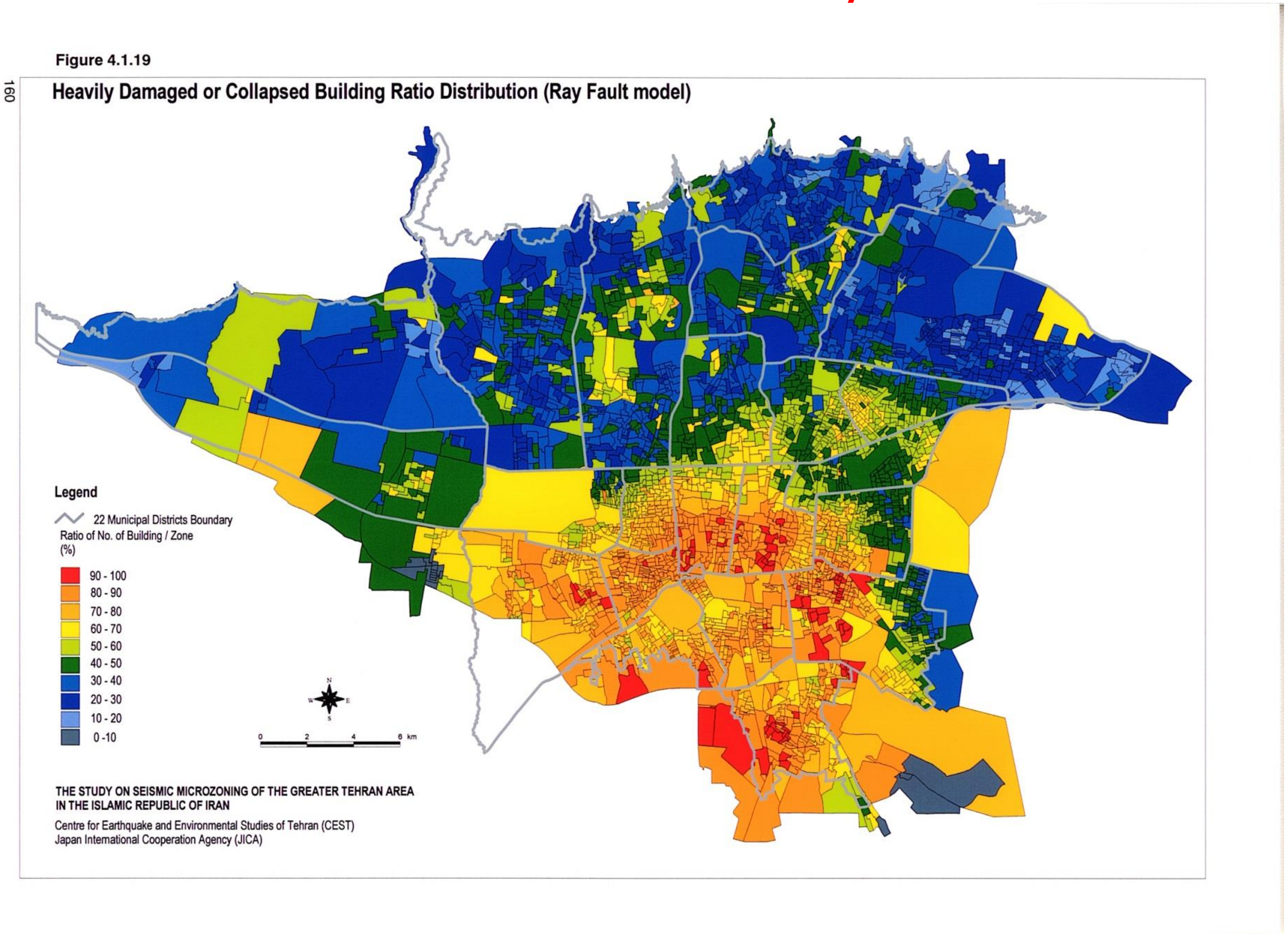
- **Example: Tehran**



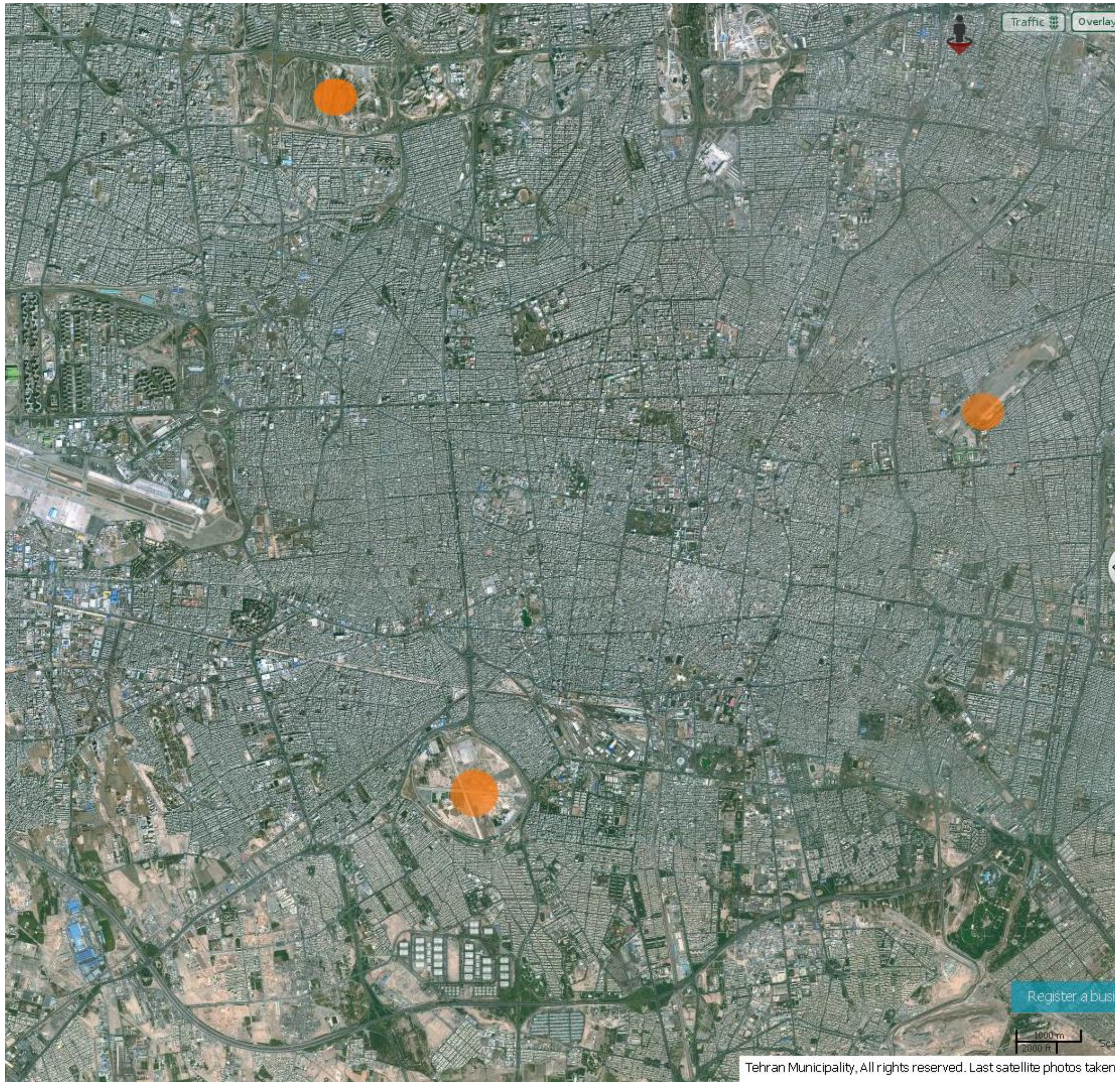
The Effect of Mosha Fault



The effect of the Ray Fault



Depots


Traffic
Overlay
Tehran Municipality, All rights reserved. Last satellite photos taken

UAVs

Kaman K-max (United States Marine Corps)

Scout B1-100 (courtesy of Aeroscout GmbH, Switzerland)

Colibri I (Universidad Politécnica de Madrid www.vision4uav.eu)

UVH-29E (Credit: UAVOS GmbH www.uavos.com)

Muli-Rotor UAV (Hexacopter)

Black Hornet Nano Helicopter (Photo: Richard Watt/MOD)

Capacity calculation

- **460 Scout B1-100 is enough for Tehran**

Important activities in the first 48 hours

Operation	Start	Finish	Place
Alert	0	1 minute	DCC
Receiving local information and emergency calls	0	Continuously	DCC
Reconnaissance flights	1 minute	2 hours	Air
First wave of relief transportation	1 minute	3 hours	Air
Installation of outdoor supply points	10 minutes	1.5 hours	Ground
Mobile medical units visit the local area of the disaster theatre	0.5 hour	Continuously	Ground
Transportation of injured people to hospitals		Continuously	Ground and air

Operation	Start	Finish	Place
Operation rooms of hospitals are adapted to emergency situation		3 hours	Hospitals
Connection of local police units to DCC is established		1 hour	Broadcast
Patrol flights	1 hour	Continuously	Air
Policemen are deployed for traffic control	1 hour	According to need	Ground
Temporary communication towers for mobile phones are installed	1 hour	3 hours in the case of the first tower	Ground
Second wave of relief transportation	2 to 3 hours	12 to 15 hours	Air
Third wave of the relief	15 hours	24 to 36 hours	Air

The System

Level 1: The structure of the relief system

- Disaster Command Center
  - Early warning
  - Control of aerial vehicles
  - Information center
    - Public information: lost/found people; working hospitals; available supply points; etc.
    - Up-dated description based on humans' and UAVs' reports.
  - Control of ground vehicles
  - Control of security forces/police

Subsystems under DCC: 1. Depots

- Storing relief items
- Storing UAVs
- Starting, receiving, and recharging UAVs
- Storing, and starting emergency communication equipment, and vehicles
- Functions in pre-disaster period:
  - change items before expiration
  - training
  - maintenance of vehicles

Subsystems under DCC: 2. Supply points

- Supply points cover the whole city.
- SPs are suitable for aerial delivery.
- People know their positions.
- Each SP keeps contact to local medical units.
- Special medicines are transported to SPs.

Subsystems under DCC: 3. Sensors

- **Local sensors**
- **Geophysical observatories**
- **Main function: to indicate occurrence of the disaster**

Subsystems under DCC: 4. Reconnaissance unit

- **At the beginning: special flights above built up areas.**
- **Later: similar patrol flights above streets.**

Subsystems under DCC: 5. Communication department

- **Communication to people**
- **Information board on the internet**
- **Communication to UAVs, both transportation and reconnaissance.**
- **Database for describing the up-date situation.**

Departments serving recovery

- Debris collection
- Shelter
- Community management
- Infrastructure rebuilding
- Relief (supply) chain

Level 2 Problems

- Communication technology
- Finding minimal paths for emergency vehicles
- Pre-disaster assignment of personnel to operating rooms
- Ground transportation
- Supply points (minimal distance = ”service level”)
- Capacity issues
- Special rules for air traffic
- Ethical issues

Financial Subsystems

- **Relief Chain Module**
- **Funds Module**

Relief Chain Module

- **Selection of suppliers**
  - **Long-term contracts**
  - **Pre-disaster and post-disaster duties**
- **Purchasing,**
- **storing, and**
- **exchanging relief items**
  - **includes selling item before the expiration of warranty**
    - **other humanitarian use**
    - **reverse logistics**

Long-term Connection to Suppliers

- **Assumptions**
  - **1. Oligopoly market.**
  - **2. Two competitors.**
  - **3. The competitors are not identical.**
  - **4. The selected competitor has an aim on the market.**
  - **5. The bargaining power of the relief system is in the range of the satisfaction of the aim.**
    - **Bargaining is *not* considered in this study as a discrete time game.**

The Bargaining Power of the Supply Chain: Microeconomic Approach

- **Notations**
- c_1, c_2 **unit costs** $c_1 < c_2$
- p_1, p_2 **unit prices** $p_1 < p_2$
- Δ_1, Δ_2 **demands on 0 prices**
- a_1, a_2 **and** b_1, b_2 **parameters of the demand functions** $(0 \leq b_1, b_2 \leq 1)$
- D_1, D_2 **demands**
- D **the demand of the relief system**
- π_1, π_2 **the profit functions**

Microeconomic Approach: Basic Equations

- **The demands:**
- $D_1 = \Delta_1 - a_1 p_1 + b_1 p_2$
- $D_2 = \Delta_2 - a_2 p_2 + b_2 p_1$
- **The profits:**
- $\pi_1 = (p_1 - c_1)\Delta_1$
- $\pi_2 = (p_2 - c_2)\Delta_2$

Case 1: The Supplier is Firm 1 (the Cheaper One)

- **The aim of Supplier 1 is to kill Supplier 2, *i.e.* go under its price.**
- **The constraint is that its profit cannot be negative.**
- **The relief system gets a special price, say p_1^{barg}.**
- **Steps:**
  - **Supplier 1 reduces the price just under c_2.**
  - **Supplier 2 reduces the price also to c_2.**

Case 1: The Supplier is the Cheaper One

- **The new profit of Supplier 1:**
- $\pi_1^{new} = (c_2 - c_1)(\Delta_1 - a_1 c_2 + b_1 c_2) + D(p_1^{barg} - c_1) \geq 0$
- **Hence,**
- $$p_1^{barg} \geq c_1 - \frac{(c_2 - c_1)(\Delta_1 - a_1 c_2 + b_1 c_2)}{D}$$

Case 2: $c_1 < c_2$ and $f_1 > f_2$

- **A natural aim is to decrease the unit cost under the unit cost of the competitor.**
- $$\frac{(D_1+D)c_1+f_1}{D_1+D} < \frac{c_2D_2+f_2}{D_2} = c_2 + \frac{f_2}{D_2}$$
- **Hence,**
- $$D > \frac{f_1D_2 - f_2D_1 + (c_1-c_2)D_1D_2}{(c_2-c_1)D_2+f_2}$$

Further Factors

- **The *Royal Warrant holder* effect: increases demand**
- **Capacity constraints**
- **Reverse logistics**
- **Budget constraint**
  - **Gradual development versus complete development, *e.g.* supply points.**
- **The price of security and preparedness**

Thank you for your attention!