DECISION AID MODELS FOR DISASTER MANAGEMENT

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Mathematical Models in Humanitarian Logistics
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UCM Research Group: Mathematical Models for Humanitarian Logistics

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1. Disaster Management

- **Hazard**: threatening event or probability of occurrence of a potentially damaging phenomenon within a given time period and area

  - **Natural**: naturally occurring physical phenomena caused either by rapid or slow onset events which can be geophysical, hydrological, climatological, meteorological or biological
    - earthquakes, landslides, tsunamis, volcanic activity, avalanches, floods, extreme temperatures, drought, wildfires, cyclones, storms/wave surges, disease epidemics, insect/animal plagues

  - **Technological or Man-made**: events caused by humans and occur in or close to human settlements
    - complex emergencies/conflicts, famine, displaced populations, industrial accidents (toxic dumps, radioactive escapes...) and catastrophic transport accidents
1. Disaster Management

• Emergencies, Disasters and Catastrophes:

- **Emergency**: situation that poses an immediate risk to health, life, property or environment

- **Disaster**: disruption of the normal functioning of a system or community, which causes a strong impact on people, structures and environment, and goes beyond local capacity of response.

- **Catastrophe**: extremely large-scale disaster

Sometimes, political decision.

*Just as “disasters” are qualitatively different from everyday community emergencies, so are “catastrophes” a qualitative jump over “disasters”*

Quarantelli (2006). Catastrophes are Different from Disasters: Some Implications for Crisis Planning and Managing Drawn from Katrina.

http://understandingkatrina.ssrc.org/Quarantelli/
1. Disaster Management

1. Disaster Management

1. Disaster Management

Number of people reported affected by natural disasters 1900 - 2010

Natural disasters caused during 2008 almost 220,000 casualties and loses estimated in more than 142,000 millions of Euros...
The number of casualties is more related to the country vulnerability than to the magnitude of the disaster or the number of disasters.
1. Disaster Management

- **Disaster response:**
  - Complex process that involves:
    - severe time pressure
    - high uncertainty
    - many stakeholders
  - High level of novelty to deal with the unexpected under uncertainty and time pressure
  - ICT used can greatly vary from one response situation to another.
  - Several autonomous agencies to collaboratively mitigate, prepare, respond, and recover from heterogeneous and dynamic sets of hazards to society.
1. Disaster Management

- Agents involved different depending on

  - the type of disaster:
    - technological disaster usually civil protection and locally security agencies
    - natural disasters usually involve also others like NGOs and international agencies

  - the disaster consequences and the place where it strikes
    - vulnerability
    - developing countries usually needs international relief operations because quickly their local capacity to respond is exceeded
1. Disaster Management

• RELIEF OPERATIONS AGENTS INVOLVED
  – Local level:
    • Local civil society organisations
    • Local agencies and civil protection
  – National level:
    • National civil protection and national army
    • Other national governmental organisations
    • National NGOs
  – International level:
    • Foreign governments and Inter-governmental organisations:
      European Union: ECHO, USA: USAID
    • International NGOs for disaster response:
      – Red Cross/Red Crescent
      – World Vision, MSF, ACF, Oxfam…
    • UNITED NATIONS: OCHA. Coordination
      – Agencies: WFP, UNICEF, UNPD, UNHCR… and local offices
    • IASC (Inter-Agency Standing Committee): primary mechanism for inter-agency coordination. Key UN/non-UN humanitarian partners
1. Disaster Management

Phases of Disaster Management

- MITIGATION and PREPAREDNESS
- RESPONSE
- RECOVERY
- EVALUATION
1. Disasters Management

- **Pre-event tasks: Mitigation & Preparedness**
  - **Mitigation**: measures to prevent or reduce the impacts
  - **Preparedness**: activities that prepare the community

- **Post-event tasks: Response & Recovery**
  - **Response**: employment of resources and emergency procedures to preserve life, property, the environment, and the social, economic, and political structure of the community *(Humanitarian logistics: Humanitarian Supply Chain)*
  - **Recovery**: actions taken after the immediate impact of the disaster to stabilize the community and to restore some semblance of normalcy

- **Evaluation**: Performance evaluation
1. Disasters Management

• **Response:** Life cycle and relative resource requirements for a relief mission

• **4 phases**

  1. **assessment** – minimal resources are required to identify what is needed, based on disaster characteristics

  2. **deployment** - resource requirements ramp up to meet a need

  3. **sustainment** - operations are sustained for a period of time

  4. **reconfiguration** - operations are reduced, then terminated
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2. Humanitarian Logistics

• What is “Humanitarian Logistics”?:

“The process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials as well as related information, from the point of origin to the point of consumption for the purpose of meeting the end beneficiary’s requirements and alleviate the suffering of vulnerable people.

It encompasses a set of activities, including preparation, planning, procurement, transportation, storage, history and customs control"

(Humanitarian Logistics Conference, 2004, Fritz Institute)

Disaster management but other relief operations, health supply chains…
2. Humanitarian Logistics

Commercial versus Humanitarian Logistics

- **Business logistics and commercial supply chains:** operations based on forecast demand, inventory control and models that optimise a dynamic system.

- **Humanitarian supply chains main differences:**
  - **unpredictable demand** in terms of timing, geographic location, type of commodity, quantity of commodity;
  - **short lead time** and **suddenness of demand** for large **amounts** of a wide variety of products and services;
  - **lack of initial resources** in terms of supply, human resources, technology, capacity and funding.

(Balcik and Beamon, 2008)
## 2. Humanitarian Logistics

<table>
<thead>
<tr>
<th><strong>Commercial</strong></th>
<th><strong>Humanitarian</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Demand pattern</strong></td>
<td>Relatively stable, predictable: fixed locations in set quantities</td>
</tr>
<tr>
<td><strong>Lead Time</strong></td>
<td>Determined by supplier-manufacturer-retailer chain</td>
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<tr>
<td><strong>Distribution Network</strong></td>
<td>Well-defined methods for locating distribution centers</td>
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<tr>
<td><strong>Inventory Control</strong></td>
<td>Well-defined methods for inventory levels</td>
</tr>
<tr>
<td><strong>Information System</strong></td>
<td>Well defined, advanced technology</td>
</tr>
<tr>
<td><strong>Strategic Goals</strong></td>
<td>Maximize profitability and high customer satisfaction</td>
</tr>
<tr>
<td><strong>Performance Measurement</strong></td>
<td>Resource performance: max profit or min costs</td>
</tr>
<tr>
<td><strong>What is demand?</strong></td>
<td>Products</td>
</tr>
<tr>
<td></td>
<td>Unpredictable timing, location, type and size. Estimated after needed</td>
</tr>
<tr>
<td></td>
<td>Almost zero lead times requirements; chain</td>
</tr>
<tr>
<td></td>
<td>Challenging due to unknowns, last mile considerations</td>
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<tr>
<td></td>
<td>Challenging high variations demands, lead times…</td>
</tr>
<tr>
<td></td>
<td>Often unreliable, incomplete or non-existent</td>
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<td></td>
<td>Minimize loss of life and alleviate suffering</td>
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<td></td>
<td>Output performance: time to respond, “customer” satisf.</td>
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<td>Supplies and People</td>
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</table>
Humanitarian Supply Chain
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3. Decision Aid Models

Mitigation, Preparedness

Planning: emergency protocols, ... Risk, uncertainty

Disaster response

Initial strategic decisions:
Assessment of consequences and needs

Medium term decisions (supply chain)

Decisions on the field

Response: Emergency intervention

Recovery ▶ Cooperation for development
3. Decision Aid Models

**Mitigation, Preparedness**
- Risk/scenario analysis, optimisation and planning (stocks, routing, location…)
- Multicriteria decisions with high uncertainty

**Disaster response**
- Information… Uncertainty, unreliable, time pressure
- Optimisation and re-optimisation of previous planning
  - Time pressure, multicriteria decisions, uncertainty
- Re-optimisation, very time pressure

**Recovery**: discrete decisions, present and future impact
3. Decision Aid Models

- Data base EM-DAT [www.emdat.be](http://www.emdat.be) of CRED (Centre for Research on the Epidemiology of Disasters)
3. Decision Aid Models

Fuzzy classification using bipolar information
3. Decision Aid Models

Case study: Haiti earthquake 2010
3. Decision Aid Models

Total Cost Itinerary:

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Equitable Itinerary:

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Vehicles & Load
$(x,a,b,c)$
- $x$: transported load
- $a$: # small vehicles
- $b$: # medium vehicles
- $c$: # large vehicles

Quality of link
- Highway (max 90 km/h)
- Road (max 70 km/h)
- Track (max 40 km/h)
3. Decision Aid Models

Maximum reliability Itinerary:

- Disaster Management
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- Conclusions
3. Decision Aid Models

All criteria-weighted Itinerary:

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- Disaster management is a **very difficult task** involving a **big amount of stakeholders**
- **Pre-event tasks** are focused on **planning** and can be developed without time pressure but very high uncertainty
- **Post-event tasks** are performed under a **high time pressure** and with main objectives: efficacy and transparency
- Humanitarian logistics and supply chain have significant differences with other logistics
- **ICT** are becoming basic tools
- **Specific decision aid models** are required, but until now no much have been developed.
- **Operational research** has to became key tool