Locating Temporary Shelter Areas after a Large-Scale Disaster

by

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Agenda

- Humanitarian Logistics
- Disasters and Shelter Areas
- Problem Definition
- Literature Review
- Mathematical Model
- Computational Studies
- Decision Support System
- Conclusion
Humanitarian Logistics

• A subtopic of logistics that focuses on
  • providing relief goods
  • evacuating the affected people from the disaster area
  • selecting the location of temporary shelter areas
  • selecting the location of warehouses
  • optimizing the supply chain
Humanitarian Logistics

- 3 principles
  - Humanity
  - Neutrality
  - Impartiality
Disasters

- “a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community’s or society’s ability to cope using its own resources.” (IFRC)
## Disasters in Turkey

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<th>Type of Disaster</th>
<th># of households destroyed</th>
<th>Percentage (%)</th>
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**Total:** 650,654 100%

Source: Ozmen et al. (2005)
Shelter Areas

- After a disaster, homeless people stay in shelter areas.
- They are important because the community needs to be reestablished during the recovery and mitigation periods.
Sphere Project

- Started in 1997 by several humanitarian organizations and International Red Crescent and Red Cross Movement
- Defines standards and some quality measurements for humanitarian operations.
- Two principles:
  - Everyone has the right to live in dignity and receive necessary aid
  - Whenever there is human suffering, necessary relief actions should be taken
Sphere Project

- For temporary settlements,
  - Must plan settlement areas, access to those areas and routes to public facilities. These areas should be far from threat zones.
  - Must provide enough supply of tents, shelter kits, construction kits and cash.
  - Must provide adequate space to everyone to live
  - Must provide necessary utilities to achieve best thermal conditions.
Turkish Red Crescent

- In Turkey, TRC is the main authority for identifying the shelter area locations.
- First they identify the candidate locations.
- Each candidate location has a weight w.r.t. some criteria.
- Sort w.r.t. these weights and open facilities one by one until there is enough space for all the population.
Turkish Red Crescent

• Criteria:
  • Transportation of relief items
  • Procurement of relief items
  • Healthcare institutions
  • Structure and type of the terrain
  • Slope of the terrain
  • Flora of the terrain
  • Electrical infrastructure
  • Sewage infrastructure
  • Permission to use
Turkish Red Crescent

- No population – shelter area assignment
- No consideration of shelter area utilization
- Distances between population and shelter area ignored
Problem Definition

• Develop a methodology that decides on
  • the locations of the shelter areas
  • assignment of population points to shelter areas
  • considers utilization of shelter areas
  • considers distances between shelter areas and the affected population.
Literature Review

- Pan (2010)
  - Two Maximal Covering Set formulations: capacitated vs. uncapacitated
  - Test the model on random data

- Li and Jin (2010)
  - Two stage approach:
    1) select shelter locations, 2) assign populations
  - Introduce randomness by generating different scenarios
Literature Review

• Dalal et. al (2007)
  • Cluster the villages, open a shelter area for each cluster
  • Uses a heuristic approach to solve the problem

• Liu et al. (2010)
  • Define criteria for shelter area selection
  • No mathematical model
  • Findings can be used to determine candidate locations
Literature Review

- There is no study that
  - Selects the location of shelter areas from a candidate set
  - Considers their capacity and “weight”
  - Assigns districts to them
  - Considers their utilization
Mathematical Model

- Maximize the minimum weight of operating areas.
- Minimize total distance from the shelter areas to nearest main roads and health facilities.
- Maximize the total utilization of open shelter areas.
- Minimize the maximum pairwise utilization difference of open shelter areas.
- Minimize the total distance

Subject to;
- Assign all districts to an area
- Respect capacity of shelter areas
- Calculate utilization
Weight Function

- Structure of the terrain
- Type of terrain
- Slope of the terrain
- Flora of the terrain
- Electrical infrastructure
- Sewage infrastructure
- Using permission of the landscape
Mathematical Model

Sets

- I: set of candidate locations
- J: set of districts

Parameters

- \( w_i \): weight of candidate location \( i \), between 0 and 1.
- \( d_i^{\text{health}} \): distance b/w candidate location \( i \) and nearest health bldg.
- \( d_i^{\text{road}} \): distance between candidate location \( i \) and nearest main road
- \( \text{demand}_j \): total demand of the area \( j \) (in m\(^2\))
- \( \text{cap}_i \): capacity of candidate location \( i \) (in m\(^2\))
- \( \text{dist}_{ij} \): distance between candidate location \( i \) and demand point \( j \)
- \( \text{utilSpace} \): assigned space for utilities per shelter area
Mathematical Model

The population needs to be converted into “demand”

\[ \text{demand}_j = \text{population}_j \times \text{percentAffected} \times \text{livingSpace} \]

- \textit{percentAffected}: percentage of population that is assumed to live in the shelter areas
- \textit{livingSpace}: assigned living space per person
- \textit{population}_j: the number of people living in district \( j \)
Mathematical Model

**Decision Variables:**

- $x_i$: 1 if candidate location $i$ is chosen, 0 otherwise.
- $y_{ij}$: 1 if district $j$ is assigned to location $i$, 0 otherwise.
- $u_i$: utilization of candidate location $i$
Objective Function

Maximize the minimum weight of operating shelter areas:

$$\max \left( \min \left( w_i x_i + (1 - x_i) : i \text{ in I} \right) \right)$$
Constraints

- Every district (demand) is assigned to an open shelter area.
- Demand assigned to a shelter area cannot exceed its capacity.
- Calculate utilization of each shelter area by relating assigned demand to capacity.
- **OBJECTIVE 2:** $d_i^{\text{health}} \leq \text{DistHealth}$
- **OBJECTIVE 3:** $d_i^{\text{road}} \leq \text{DistRoad}$
- **OBJECTIVE 4:** $u_i \geq \beta$
- **OBJECTIVE 5:** $|u_i - u_j| x_i x_j \leq \alpha$
- **OBJECTIVE 6:** assign every district to nearest open shelter area
Constraints

where:

- $\text{DistHealth}$: max. allowable shelter area – health facility distance
- $\text{DistRoad}$: max. allowable shelter area – main road distance
- $\beta$: threshold value for minimum utilization of open shelter areas
- $\alpha$: threshold value for pairwise utilization difference of open shelter areas
Computational Study

- Model is tested on a sample data on Kartal, Istanbul.
- 25 potential shelter areas
- 20 districts
Computational Study
Results

- Generated 3000 instances by varying $DistHealth$, $DistRoad$, $\beta$, and $\alpha$.
- Solved using Gurobi integrated with DSS.
- The objective value decreases as $\beta$ is increased and $\alpha$, $DistHealth$ and $DistRoad$ are decreased.
- This is expected as these changes tighten the feasible set.
### Computational Study

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The objective value when DistHealth = DistRoad = 5
Computational Study

- As $\beta$ increases and $\alpha$ decreases, the average of average utilization tends to increase.

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Computational Study

- As $\beta$ increases and $\alpha$ decreases, the maximum number of open shelter areas decreases.

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Computational Study

- As $\beta$ increases and $\alpha$ decreases, the number of infeasible cases increases.

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Computational Study

- The model is also tested with a sample data based on Asian side of Istanbul.
- 270 districts
- 361 candidate shelter sites
Computational Study

The districts in the Asian side of Istanbul
Computational Study

Location of candidate shelter areas in the Asian side of Istanbul
Computational Study

- Optimal solution found in 11 hours when utilization constraints are relaxed.
- No integer incumbent when the utilization constraints are included in the model.
- Changed the objective to «minimizing the number of open shelter areas»
- After 24 hours, an upper bound of 20 is found.
- Model is modified
  - Minimize the total distance between districts and shelter areas
  - Relax the «nearest assignment» constraints
  - Relax the utilization constraints
  - Open «p» shelter areas
Computational Study

The Objective Value

The graph shows the objective value decreasing as the number increases from 20 to 40.
Computational Study

Average Utilization

![Average Utilization Graph]
Computational Study

Number of "Not Closest"
Decision Support System

- An ArcGIS extension that utilizes Gurobi and developed in C#
- The user
  - Can solve the mathematical model
  - Edit the solution
  - Save the current solution
  - Compare up to 4 solutions
  - Visualize the current solution
  - Graph the shelter area utilizations
  - See the lists of assignments
Decision Support System

- 5 layers needed:
  - Location of districts with population data in its data table
  - Location of candidate shelter areas with has weight and capacity data in its data table
  - A layer that contains the hospitals
  - A layer that contains the main road junctions
  - A “Network Dataset” that contains the road network
Decision Support System
Decision Support System

- Minimum Utilization: 0.6
  - The utilization of each open location must be greater than this value. Enter 0 if you want this constraint to be omitted.

- Maximum Pairwise Utilization: 0.2
  - The pairwise utilization difference of all open shelter areas must be less than this value. Enter 1 if you want this constraint to be omitted.

- Threshold Health Distance: 5
  - There has to be a health institution within this distance of a shelter area. Enter this value in kilometres.

- Threshold Main Road Distance: 5
  - There has to be a main road within this distance of a shelter area. Enter this value in kilometers.

- Living Space per Person: 3.5
  - Assigned living space per resident in a shelter area. Enter this value in square meters.

- Space for Utilities: 45
  - Assigned space for sanitary and dining utilities per shelter area. Enter this value in square meters.

- Percent of Population Affected: 0.125
  - Enter the percent of population that will reside in shelter areas. Enter this value between 0 and 1.

- Number of People per Household: 3.5
  - Enter the average number of people per household in the area.

- Solve the Model
Decision Support System

![Custom Solver Interface]

- **Swap Districts**
- **Open/Close a Shelter Area**
- **Assign (M)**
- **Assign (A)**
- **Enable/Disable a Location**

**Select a Closed Shelter Area to Disable**
- B23

**Select an Disabled Shelter Area to Enable**

**You are about to disable B23**

**Drawing Section**
- Paint Midpoints
- Paint Districts
- Draw Lines
- Draw the Current Solution

**View Current Solution**
- Select an Open Area

**Graph Section**
- Utilizations of shelter areas
- AV3, B7, P4, L2

**Utilization Graph**

![Graph Chart]
Decision Support System
Decision Support System
Conclusion

- Shelter areas are important for the recovery process after a disaster
- In this study, a mathematical model is formulated
- Computational study is performed on a data based on Kartal, Istanbul and the Asian side of Istanbul
- To implement the mathematical model, a decision support system is developed.
Thank you...