A Voting TOPSIS Approach for Determining the Priorities of Damaged Areas in Disasters

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Research motivation

- As the natural disasters occur around the world everywhere, disaster management has gained a global attention.
- Especially, relief distribution to the casualties has become one of the important issues of disaster management.
- When distributing the relief to multiple damaged areas, which have urgency might need quicker distribution of the relief, therefore, priority determination among those damaged areas becomes a critical.
- However, it would not be easy for the central or local governments to decide which damaged area is more urgent than others and moreover how to evaluate the urgency of the damaged areas.

Literature review

➢ Table. 1. Disaster logistics

Sheu JB, 2007	Disasters result in massive demands that often outstrip resources. The process of planning, managing, and controlling the flow of those resources to provide relief to affected people is called emergency logistics or disaster logistics.
National Governors' Association Center for Policy Research, 1979 FEMA IS-1, 2010	Disaster logistics covers a wide range of activities that occur at any one of the phases of disaster management, i.e., mitigation, preparedness, response and recovery in disasters. Mitigation and preparedness activities are performed before the disaster to enhance safety and reduce the potential impact on people and infrastructure. Response-related disaster logistics activities include the transportation of supplies and equipment for search and rescue, and of equipment and material for emergency repairs to the infrastructure.

➢ Table. 2. Priority determination of the damaged areas for disaster logistics

Sheu JB, 2007	Presented an emergency logistics distribution approach for quickly responding to the urgent relief demands of the affected areas. The methodologies mainly used include fuzzy clustering and multi-objective dynamic programming models.
Sheu JB, 2010	Presented a relief-demand management model for dynamically responding to the relief demands of affected people under emergency conditions of a large-scale disaster. A fuzzy clustering-based approach and TOPSIS was used in this study.
Lin, Y., Batta et al., 2011	Proposed a logistics model for delivery of prioritized items in disaster relief operations.
Afshar and Haghani, 2012	Proposed a mathematical model to minimize the total unsatisfied demand for disaster victims. In this model, the given parameters representing the relative urgency regarding commodity, time, and demand point. However, there is the lack of explanation on how the relative urgency is determined specifically.
Rivera-Royero et al., 2016	Developed a dynamic model to serve demand, while prioritizing the response, according to the level of urgency of demand points. However, they provided a suggestion that the priority of the disaster point should be determined by considering several aspects instead of giving specific methods.

Literature review

- Lack of existing researches
  - Even if there exist some related researches, most of them focused on the development of mathematical models for generating an optimized relief distribution plan or schedule.
  - The priority determination was either skipped by assuming the priorities or treated as a partial subject of their researches.

Case background

- On 19th June 2016, a severe flood occurred in Zhangbang Town, Huanggang City, Hubei Province, China. 8 villages were severely affected.

Fig. 2. The location of Hubei province in China and the location of Huanggang City in Huibei Province.

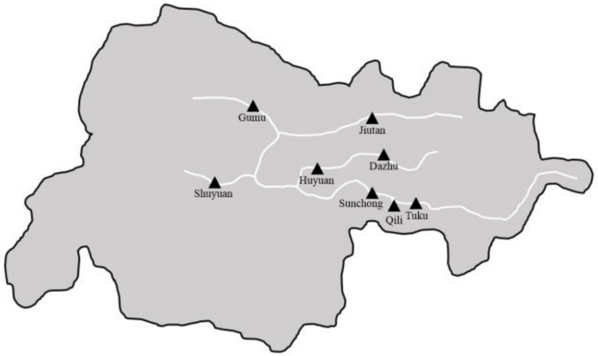

Fig. 3. The eight most severely damaged villages in the flood.

Fig. 4. Pictures of Zhangbang town 6.19 flood disaster.

- Telecommunications disruption in Tuku, Jiutan, Dazhu.
- Three sections of the only road out of Tuku village was wracked.
- At Jiutan, 4 sections of the road to the village and one bridge had been destroyed, debris flow and land collapse appeared within the scope of the village.
- No electricity or water in the whole Dazhu Village.

Research purposes

- Develop the voting TOPSIS, to consider multiple judgments of the practitioners (i.e. local officers) by adopting a voting system.
- Using a real world case: the flood case of Zhangbang Town, Huanggang City, Hubei Province of China in 2016:
  - Propose the factors which might affect relief priority.
  - Apply the voting TOPSIS to determine the relative priority among the damaged areas.

Methodology

- Voting TOPSIS
  - Step 1) Define criteria and alternatives for the given MCDM problem
  - Step 2) Apply pair-wise comparison (from AHP) to determine the relative weights of criteria
  - Step 3) DMs' vote for alternatives and generate a decision matrix which aggregates the votes using the DEA based model
  - Step 4) Apply a TOPSIS to the decision matrix to calculate final relative weights of the alternatives

Methodology

- Step 1. Define criteria and alternatives for the given MCDM problem
  - Alternatives: The damaged villages in the flood
  - Criteria:

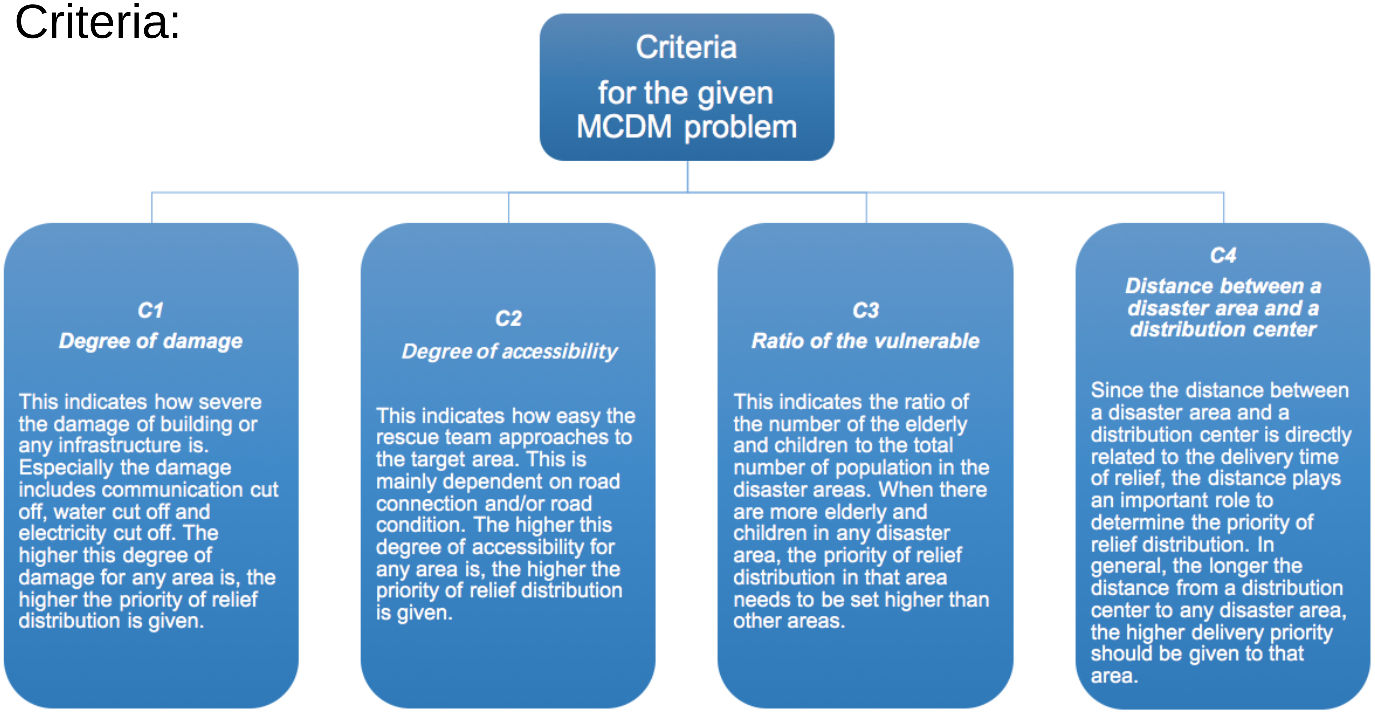

Fig. 1. Criteria for the given MCDM problems.

Methodology

- Step 2. Apply pair-wise comparison (from AHP) to determine the relative weights of criteria

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{x-l}{m-l}, l \le x \le m, \\ \frac{u-x}{u-m}, m \le x \le u, \\ 0, otherwise. \end{cases} \quad (1)$$

$$\tilde{a}^{\alpha} = [l^{\alpha}, u^{\alpha}] = [(m-l)\alpha + l, u - (u-m)\alpha] \quad \forall \alpha \in [0,1] \quad (2)$$

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}^{\alpha}{}_{12} & \cdots & \tilde{a}^{\alpha}{}_{1N} \\ \tilde{a}^{\alpha}{}_{21} & 1 & \cdots & \tilde{a}^{\alpha}{}_{2N} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{a}^{\alpha}{}_{N1} & \tilde{a}^{\alpha}{}_{N2} & \cdots & 1 \end{bmatrix} \quad (3)$$

where $\tilde{a}^{\alpha}{}_{ab} = 1$, if $a = b$, and $\tilde{a}^{\alpha}{}_{ab} = \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}$

or $\tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1}$, if $a \ne b$.

$$C(\tilde{a}_{ij}^{\alpha}) = \mu a_{iju} + (1-\mu) a_{ijl}, \qquad \forall \mu \in [0,1] \quad (4)$$

$$g_i = \left(\prod_{j=1}^{n} C(\tilde{a}^{\alpha}{}_{ij})\right)^{1/n} \qquad i = 1, \dots, n \quad (5)$$

$$w_i = g_i / \sum_{i=1}^{n} g_i \qquad i = 1, \dots, n \quad (6)$$

$$\mathrm{CI} = \frac{|\lambda_{max} - n|}{n-1} \quad (7)$$

where λ_{max} is the largest eigenvalue of $\tilde{A}$ and n is the size of matrix.

$$\mathrm{CR} = \frac{CI}{RCI} \quad (8)$$

In general, if the CR is less than 0.1, the comparisons are acceptable.

Otherwise, it is not acceptable.

Methodology

- Step 3. DMs' vote for alternatives and generate a decision matrix which aggregates the votes using the DEA based model
  - We set the following five evaluation grades (k=1,…,5) for evaluating the alternatives for each of four criteria of Figure 1. Evaluation grades = {very high (k=1), high (k=2), normal (k=3), low (k=4), very bad (k=5)}

Notations

i: the index of criteria ($i = 1, \ldots, N$)

j: the index of alternatives ($j = 1, \ldots, M$)

k: the index of evaluation grade ($k = 1, \ldots, K$)

x_k: the relative importance weight attached to the kth grade

v_{jk}: the numbers (i.e. vote) of the DMs who evaluate alternative j to the kth grade

z_{ij}: the total score of the alternative j for criterion i

Model (for any given criterion i)

Maximize β (9)

subject to $z_{ij} = \sum_{k=1}^{K} v_{jk} x_k$ for $j = 1, \ldots, M$ (10)

$x_1 \geq 2x_2 \geq \cdots \geq K x_K \geq 0$ (11)

$\sum_{k=1}^{K} x_k = 1$ (12)

Methodology

- Step 4. Apply a TOPSIS to the decision matrix to calculate final relative weights of the alternatives

Given the decision matrix $Z = \{z_{ij} | i = 1, \dots, N; j = 1, \dots, M\}$

1) Normalize the decision matrix as follows:

$$y_{ij} = \frac{z_{ij}}{\sqrt{\sum_{i=1}^{N} z_{ij}^2}} \quad \text{for } i = 1, \dots, N; j = 1, \dots, M \tag{13}$$

2) The weighted normalized value t_{ij} is calculated as follows:

$$t_{ij} = w_i y_{ij} \text{ for } i = 1, \dots, N; j = 1, \dots, M \tag{14}$$

3) The PIS (A^+) and the NIS (A^-) can be defined as follows:

$$A^+ = (t_1^+, \dots, t_N^+) \tag{15}$$

$$A^- = (t_1^-, \dots, t_N^-) \tag{16}$$

where $t_i^+ = \max_j(t_{ij})$ if criterion i is to be maximized,

and $t_i^- = \min_j(t_{ij})$ if criterion i is to be minimized

4) The separation of an alternative j from the PIS is given as

$$D_j^+ = \sqrt{\sum_{i=1}^{N} (t_{ij} - t_i^+)^2} \quad \text{for } j = 1, \dots, M \tag{17}$$

The separation of an alternative j from the NIS is given as

$$D_j^- = \sqrt{\sum_{i=1}^{N} (t_{ij} - t_i^-)^2} \quad \text{for } j = 1, \dots, M \tag{18}$$

5) Calculate the relative closeness coefficient (RCC) of the alternative j with respect to the PIS and NIS.

$$RCC_j = \frac{D_j^-}{D_j^+ + D_j^-} \quad \text{for } j = 1, \dots, M \tag{19}$$

6) Arrange the alternatives in a descending order of the RCC to obtain the best alternative.

Data acquisition

- In this study, the research data were collected by direct contact with the government of Zhangbang Town.

  - # of households
  - # of population
  - # of trapped population (in classification by age)
  - Location of temporary shelters
  - Degree of damage
  - Degree of accessibility

	C1					C2					C3	C4
	VH	H	M	L	VL	VH	H	M	L	VL	(%)	(km)
Jiutan	1	4	0	0	0	4	1	0	0	0	33.2	9.27
Dazhu	3	2	0	0	0	0	4	1	0	0	31.5	8.99
Tuku	0	5	0	0	0	3	2	0	0	0	33.0	10.21
Qili	0	0	3	2	0	1	3	1	0	0	32.2	9.23
Shuyuan	0	0	2	3	0	0	0	3	2	0	32.4	3.30
Gumu	0	0	0	4	1	1	4	0	0	0	32.9	4.96
Huyuan	0	0	3	2	0	0	0	0	3	2	32.0	6.30
Sunchong	0	1	4	0	0	0	0	0	3	2	32.8	8.43

* VH: Very High; H: High; M: Medium; L: Low; VL: Very Low

Table. 2. Voting results for C1 and C1 and the required information for C3 and C4.

Case analysis

- The weights of criteria:

C1	C2	C3	C4
0.455	0.120	0.373	0.051

- The total scores of eight villages for C1 and C2:

Village	C1 (degree of damage)	C2 (degree of accessibility)
Jiutan	1.3138	1.9708
Dazhu	1.7518	1.0218
Tuku	1.0948	1.7518
Qili	0.6569	1.2408
Shuyuan	0.6204	0.6569
Gumu	0.5255	1.3138
Huyuan	0.6569	0.5036
Sunchong	0.8029	0.5036

- The RCC of eight towns:

Village	RCC (Relative Closeness Coefficient)
Jiutan	0.7746
Dazhu	0.9896
Tuku	0.4483
Qili	0.0216
Shuyuan	0.0071
Gumu	0.0075
Huyuan	0.0137
Sunchong	0.0757

⇨

Urgency order	Village
1	Dazhu
2	Jiutan
3	Tuku
4	Sunchong
5	Qili
6	Huyuan
7	Gumu
8	Shuyuan

Conclusion and future study

- In this paper, we deal with this priority determination problem in disasters using a real world case.
- We propose the factors which might affect relief priority. And to consider multiple judgments of the practitioners (i.e. local officers) by adopting a voting system and to increase the applicability of the existing TOPSIS in the real world, a voting TOPSIS method is proposed.
- The case analysis result shows that the proposed method seems to be viable for the priority determination of the damaged areas, and more practical in the case of urgent decision making.
- This study considered only the flood situation. The feasibility of applying the proposed method to other type of disasters is also worth to research.
- Relief distribution planning with considering the relief priority of different affected areas.