A multi-objective stochastic programming model for disaster relief logistics under uncertainty

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Overview

Every year, natural disasters including earthquakes, drought and flood cause large-scale destruction. A sophisticated pre-disaster relief plan reduces costs and maximizes efficiency in saving lives. This project aims to modify the multi-objective robust stochastic programming model by Bozorgi-Amiri et al. (2013) by first re-formulating it into a linear programming problem, and then building a C program with SYMPHONY, an open source solver for linear programs. We shall apply the model to a case study and look into possibilities in multiprocessing and uncertainty quantification.

The Model

The model is a two-stage stochastic integer linear program, which involves pre-disaster and post-disaster decisions, and considers three types of parties: suppliers, relief distribution centers (RDCs), and affected areas (AAs). In all cases, four flows of commodities are allowed, and for a given case study, different scenarios, sizes of RDCs and types of commodities are assumed (Figure 1). Under each scenario, the demand, supply and cost would vary.

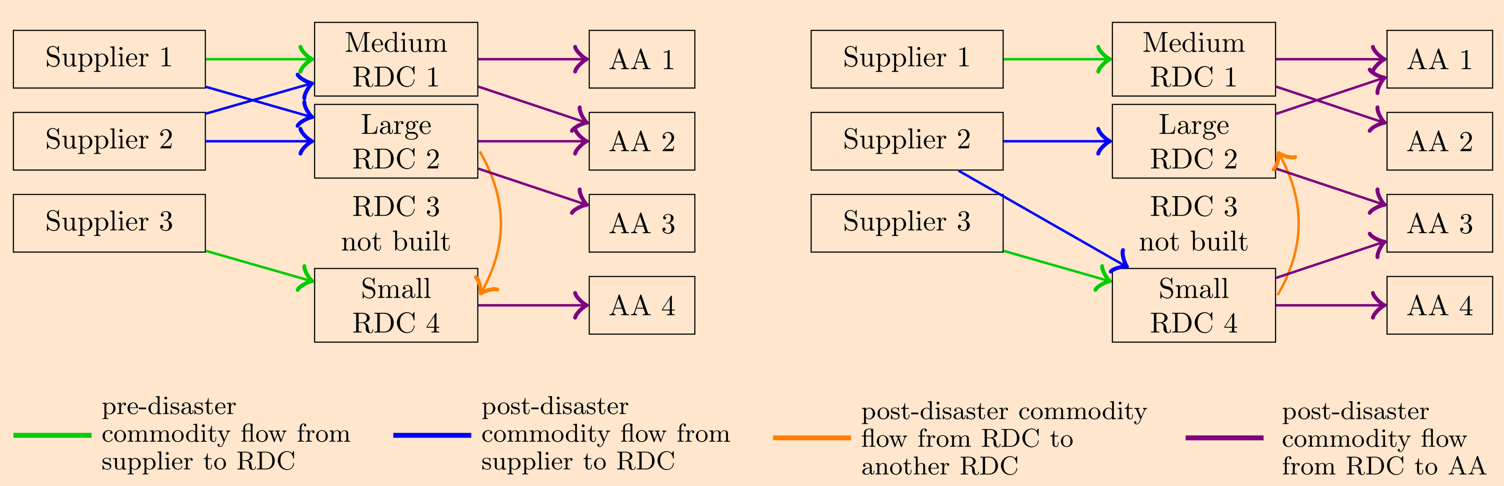


Figure 1: General schema of relief distribution chain of the model

This model has two objectives: to reduce costs, and to maximize the overall satisfaction of AAs by minimizing the sum of shortage. It suffices to seek a compromised solution balancing the two objectives.

Suppliers, RDCs and AAs were assumed to be close to each other in the model suggested by Bozorgi-Amiri et al. (2013). Our modifications include allowing the independence of locations of suppliers, RDCs and AAs and the reduction non-linear to linear constraints. These changes make the model more flexible and less complex in nature.

Mathematical Formulation

Objective 1 corresponds to the expected total cost and Objective 2 corresponds to the expected maximum total shortage of AAs. Like the model by Bozorgi-Amiri et al. (2013), an absolution deviation term is included for variability calculation:

Min. Objective 1

$$= \text{PRE} + \sum_{s\in S} p_s(\text{POST}_s) \quad \text{(expected cost)}$$

$$+\lambda_1 \sum_{s\in S} p_s \left[\left(\text{POST}_s - \sum_{s'\in S} p_{s'}(\text{POST}_{s'}) \right) + 2\theta_{1s} \right] \quad \text{(cost variance)}$$

Min. Objective 2

$$= \sum_{s\in S} p_s \left(\sum_{c\in C} \max_{k\in K}\{b_{kcs}\} \right) \quad \text{(expected sum of maximum shortage)}$$

$$+\lambda_2 \sum_{s\in S} p_s \left[\left(\sum_{c\in C} \max_{k\in K}\{b_{kcs}\} - \sum_{s'\in S} p_{s'} \sum_{c\in C} \max_{k\in K}\{b_{kcs'}\} \right) + 2\theta_{2s} \right] \quad \text{(maximum shortage variance)}$$

Case Study

The model is implemented to a case study in Iran of 5 suppliers, 15 candidate RDCs and 15 AAs, also previously done by Bozorgi-Amiri et. al (2013):

Four scenarios, three types of commodities: water, food and shelter, and three sizes of RDCs: large, medium and small are assumed. Together with these parameters, other factors including demands at each AA, procuring costs of each commodity, transportation costs, capacity of each size of RDCs and amount of supplies available at each supplier are passed to the solver for the optimal solution.

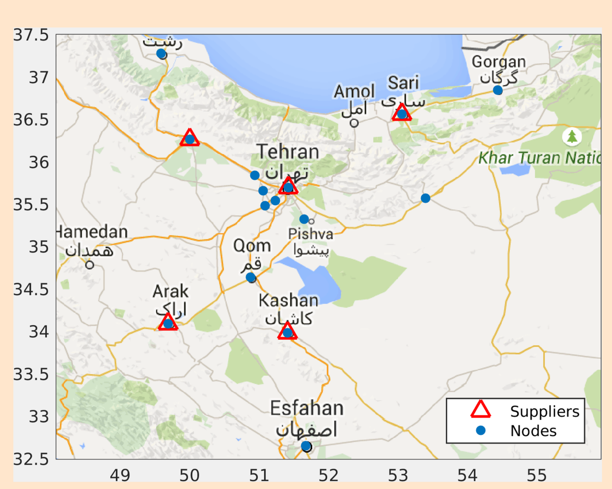
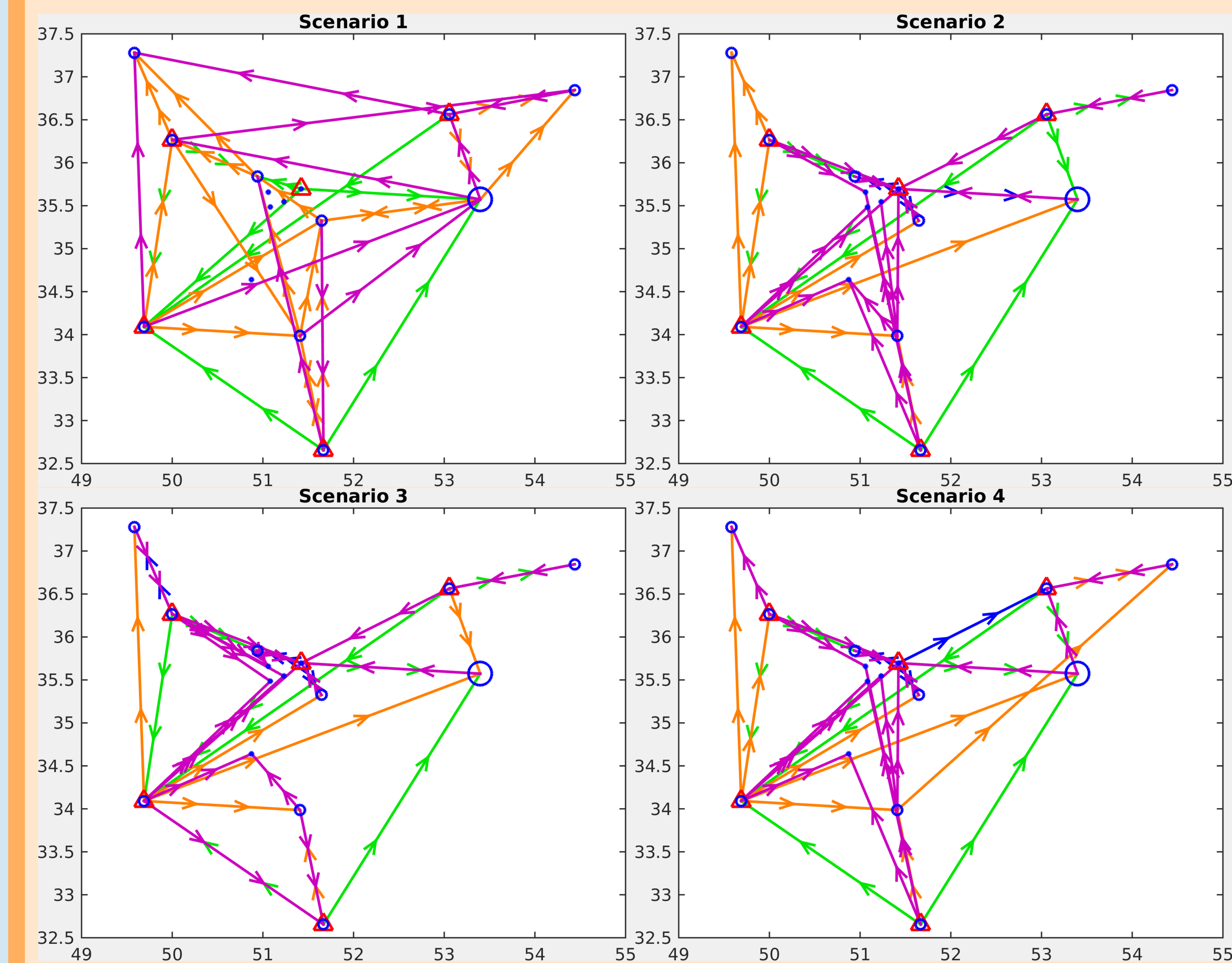


Figure 2: Map of case study

Results have shown that total of 10 RDCs (1 large and 9 small) should be built. The expected total cost is about 45.582 million. The pre-disaster cost is about 27.236 million and the expected post-disaster cost is about 18.346 million.

Charts showing different types of flows of commodities and sizes of RDCs are in the “visualization” section.

Visualization



Future Work

We plan to implement parallelization and PSUADE (Problem Solving environment for Uncertainty Analysis and Design Exploration) for uncertainty quantification. Parallelization allows the program to run multiple scenarios at a time, hence speeds up the solving process. Uncertainty quantification helps further determine the best pre-disaster relief plan through simulation and reduced uncertainties.

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References

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