An optimization model for volunteer assignments in humanitarian organizations

(by M. Falasca and Zobel)

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Group 1

Content

1.0 Introduction

- Coordinating large numbers of volunteers
- Proper management of volunteer labor
  - Determining where to send the volunteers
  - What tasks to assign
- Assignments based not just on abilities but also according to preferences
- Sustainability

2.0 Background

- Volunteer management

  Recognizing contributions and matching volunteers to appropriate tasks

- Labor scheduling

  With incorporation of both **labor shortages** and **volunteer preferences**

  - ➢ Scheduling volunteers for an annual music festival (by Gordon and Erkut)

    Labor shortages not considered

  - ➢ Optimizing the assignment of reviewers for an academic conference (by Sampson)

    Both considered

  - ➢ Modeling to assign volunteers in bike sharing program (by Kaspari)

    Volunteer preferences considered

Considerations

✓Labor costs (expenses of volunteers) taken into account

✓Possibility of multiple possible work locations

✓Volunteers’ preferences considered

✓Supporting the assignment of groups of volunteers, such as corporate or family, rather than just individual volunteers

✓Visualizing the relative impact on volunteer satisfaction of requiring a particular minimum level of task completion, or determining the relative cost associated with satisfying a given percentage of volunteer preferences

? Supporting assignments of groups (e.g., family) rather than individuals

- Short Term:

  Quick response and well-organized structure of action-taking

  Skills of individuals known

  More motivational

- Long Term:

  Slackness

3.0 Characterization of a Humanitarian Volunteer Management Model

- Different than those of a for-profit business

  Rather than focusing on maximizing revenues, seeking to improve operations

Comparison of paid labor and volunteer labor scheduling models.

Model attribute	Paid workforce	Volunteer workforce
Key objective	Maximize profits by minimizing labor costs	Maximize task completion by minimizing shortages
Key constraint	Demand level	Volunteer labor size
Labor pool size constraint	Sufficient/unconstrained	Size of committed labor
Labor costs	Non-zero	Low yet still non-trivial
Labor preferences	Employees' shift preferences may be considered	Volunteers' time and task preferences must be considered
Shortages	Not an issue	Shortages must be balanced among time blocks, tasks and locations

- limited time availabilities
- number of undesired assignments
- number of undesired tasks

?   How to rate the required skills

Ex: Case of the 2004 tsunami

- Assumption of traditional business
- Needs vs. Volunteers
- Surveys

4.0 Proposed Model

Decision variables:

$x_{ijkl} = 1$ if volunteer or group i is assigned time block j and task k at location l, 0 otherwise.

$y_{jkl} =$ the shortage of volunteers (number of persons) for time block j of task k at location l.

Parameters:

$n_i =$ The total size of volunteer group i ($n_i = 1$ for individuals, 2 or greater for groups).

$e_{jkl} =$ The total number of volunteers (number of persons) required for time block j of activity k at location l.

$d_{jkl} =$ Task shortage cost for time block j of task k at location l.

$\bar{v}_i =$ Maximum number of time blocks assigned to volunteer or group i.

$\underline{v_i} =$ Minimum number of time blocks assigned to volunteer or group i.

$u_i =$ Maximum number of undesired time blocks assigned to volunteer or group i over scheduling period.

$w_i =$ Maximum number of undesired tasks assigned to volunteer or group i over scheduling period.

$p_{jkl} =$ Maximum shortage of volunteers (number of persons) for time block j of task k at location l.

$a_{ijl} = 1$ if volunteer or group i prefers not to be assigned time block j at location l, 0 otherwise.

$b_{ik} = 1$ if volunteer or group i prefers not to be assigned task k, 0 otherwise.

$f =$ Available budget for the scheduling period.

$c_{jkl} =$ Cost of utilizing a volunteer for time block j of task k at location l.

Model formulation:

$$\text{Min} \sum_{j\in T}\sum_{k\in K}\sum_{l\in L} d_{jkl}y_{jkl} \tag{1}$$

$$\text{Min} \sum_{i\in V}\sum_{j\in T}\sum_{k\in K}\sum_{l\in L} a_{ijl}n_i x_{ijkl} + \sum_{i\in V}\sum_{j\in T}\sum_{k\in K}\sum_{l\in L} b_{ik}n_i x_{ijkl} \tag{2}$$

st

$$\sum_{i\in V} n_i x_{ijkl} + y_{jkl} \geq e_{jkl}, \quad j\in T,\ k\in K \text{ and } l\in L \tag{3}$$

$$\sum_{i\in V}\sum_{j\in T}\sum_{k\in K}\sum_{l\in L} c_{jkl}n_i x_{ijkl} \leq f \tag{4}$$

$$\underline{v_i} \leq \sum_{j\in T}\sum_{k\in K}\sum_{l\in L} x_{ijkl} \leq \bar{v}_i, \quad i\in V \tag{5}$$

$$\sum_{j\in T}\sum_{k\in K}\sum_{l\in L} a_{ijl}x_{ijkl} \leq u_i, \quad i\in V \tag{6}$$

$$\sum_{j\in T}\sum_{k\in K}\sum_{l\in L} b_{ik}x_{ijkl} \leq w_i, \quad i\in V \tag{7}$$

$$y_{jkl} \leq p_{jkl} \quad j\in T,\ k\in K \text{ and } l\in L \tag{8}$$

$$\sum_{l\in L} x_{ijkl} \leq 1, \quad i\in V,\ k\in K \text{ and } j\in T \tag{9}$$

$$x_{ijkl} \in \{0,1\}, \quad i\in V,\ j\in T,\ k\in K \text{ and } l\in L \tag{10}$$

$$y_{jkl} \geq 0 \text{ and integer}, \quad j\in T,\ k\in K \text{ and } l\in L \tag{11}$$

$x_{ijkl} = 1$ if volunteer or group i is assigned time block j and task k at location l, 0 otherwise.

$y_{jkl} =$ the shortage of volunteers (number of persons) for time block j of task k at location l.

$n_i =$ The total size of volunteer group i ($n_i = 1$ for individuals, 2 or greater for groups).

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c_{jkl} = Cost of utilizing a volunteer for time block j of task k at location l.

$$\text{Min} \sum_{j\in T}\sum_{k\in K}\sum_{l\in L} d_{jkl}y_{jkl} \tag{1}$$

$$\text{Min} \sum_{i\in V}\sum_{j\in T}\sum_{k\in K}\sum_{l\in L} a_{ijl}n_i x_{ijkl} + \sum_{i\in V}\sum_{j\in T}\sum_{k\in K}\sum_{l\in L} b_{ik}n_i x_{ijkl} \tag{2}$$

st

$$\sum_{i\in V} n_i x_{ijkl} + y_{jkl} \geq e_{jkl}, \quad j\in T,\ k\in K \text{ and } l\in L \tag{3}$$

$$\sum_{i\in V}\sum_{j\in T}\sum_{k\in K}\sum_{l\in L} c_{jkl}n_i x_{ijkl} \leq f \tag{4}$$

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$$x_{ijkl}\in\{0,1\}, \quad i\in V,\ j\in T,\ k\in K \text{ and } l\in L \tag{10}$$

$$y_{jkl} \geq 0 \text{ and integer}, \quad j\in T,\ k\in K \text{ and } l\in L \tag{11}$$

? Number of undesired locations

a_{ij} = 1 if volunteer or group i prefers not to be assigned time block j, 0 otherwise.

s_i = Maximum number of undesired locations assigned to volunteer or group i over scheduling period

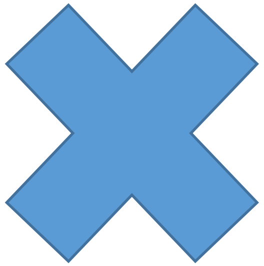
g_{il} = 1 if volunteer or group i prefers not to be assigned location l, 0 otherwise.

Min $\quad \sum_{i \in V} \sum_{j \in T} \sum_{k \in K} \sum_{l \in L} \quad (a_{ij}n_i x_{ijkl} + b_{ik}n_i x_{ijkl} + g_{il}n_i x_{ijkl})$

$\sum_{j \in T} \sum_{k \in K} \sum_{l \in L} \quad a_{ij}x_{ijkl} \le u_i$

$\sum_{j \in T} \sum_{k \in K} \sum_{l \in L} \quad b_{ik}x_{ijkl} \le w_i$

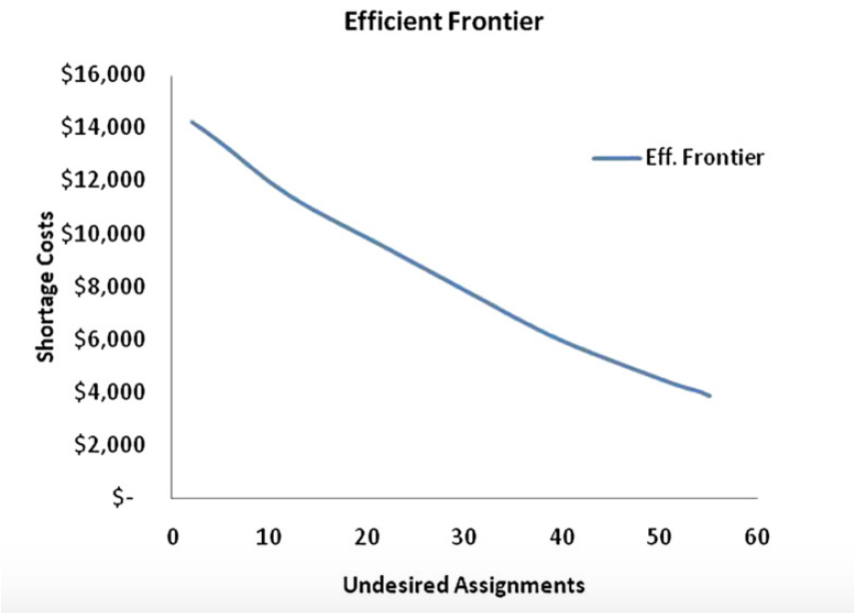
$\sum_{j \in T} \sum_{k \in K} \sum_{l \in L} \quad g_{il}x_{ijkl} \le s_i$



5.0 Solution Approaches

- Aim
  - Minimizing task shortages
  - Minimizing undesired assignments

- Method
  - The efficient frontier approach (traditional)
  - The fuzzy approach



What is Efficient Frontier?

- Highest expected return for defined level of risk

  OR

- Lowest risk for given expected level of return
- **$E(Rp) = w_1E(R_1) + w_2E(R_2)$**
- **$Var(R_p) = w^2{}_1Var(R_1) + w^2{}_2Var(R_2) + 2w_1w_2Cov(R_1, R_2)$**
- Assign values for $E(R_1)$, $E(R_2)$, $stdev(R_1)$, $stdev(R_2)$, and $\rho(R_1, R_2)$
- $w_2=1-w_1$

Plot(std(portfolio),Exp(portfolio)) in Excel :: Portfolio Frontier

Portfolio A is more attractive if $E(R_A) \geq E(R_B)$ and $\sigma_A \leq \sigma_B$

Efficiency Frontier

- Minimize objective function (1)
  - Resulting solution z^{shortage} relaxation parameter β where β =1 initially

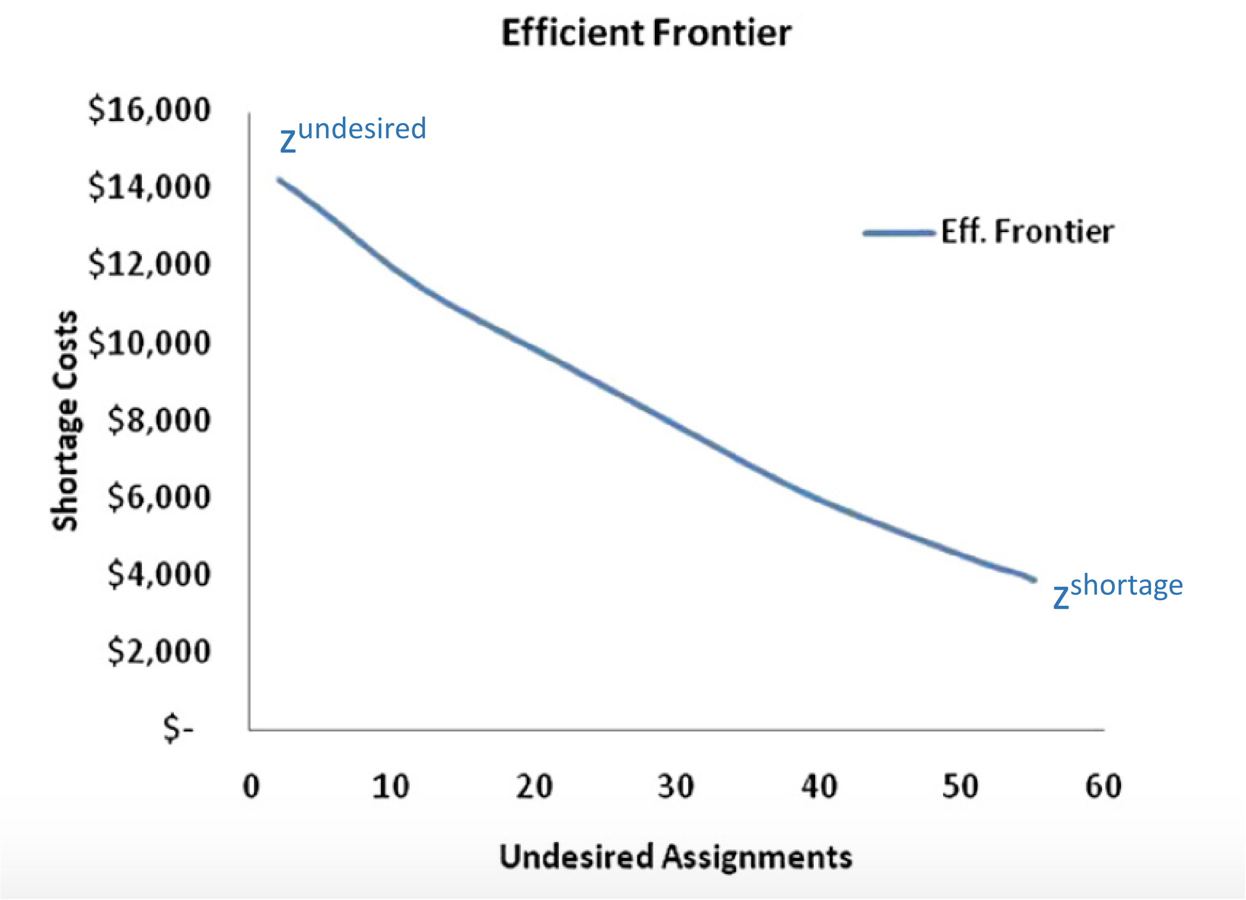
$$\sum_{j \in T} \sum_{k \in K} \sum_{l \in L} d_{jkl} y_{jkl} \leq \beta z^{\text{shortage}} \qquad (12)$$

- Repeatedly solve the problem of minimizing objective function (2) for incrementally larger values of β
  - Plot each $z_{\beta}^{undesired}$ & $z_{\beta}^{shortage}$ pair
  - Smallest possible number $z^{undesired}$

Efficiency Frontier

- Two extreme situations
  1) Objective: $z^{shortage}$
     Min shortage costs, $\beta = 1$
     Humanitarian situations
     Immediate need: Tsunami

  2) Objective: $z^{undesired}$
     Long run completion of tasks
     Post-crisis: Syrian Refugees



Balancing Conflicting Objectives

- Goal programming formulation
- Specifying relative performance
  - Weights: w_1, w_2
  - Single objective
  - Reformulating as percentage deviation

$$\text{Min } \alpha\left(\frac{\left(\sum_{j\in T}\sum_{k\in K}\sum_{l\in L} d_{jkl}y_{jkl}\right) - z^{\text{shortage}}}{z^{\text{shortage}}}\right) + (1-\alpha)\left(\frac{\left(\sum_{i\in V}\sum_{j\in T}\sum_{k\in K}\sum_{l\in L} a_{ijl}n_i x_{ijkl} + \sum_{i\in V}\sum_{j\in T}\sum_{k\in K}\sum_{l\in L} b_{ik}n_i x_{ijkl}\right) - z^{\text{undesired}}}{z^{\text{undesired}}}\right) \tag{13}$$

$$\alpha = w_1/(w_1 + w_2)$$

? What if generating vice versa

$$\sum_{i \in V} \sum_{j \in T} \sum_{k \in K} \sum_{l \in L} a_{ijl} n_i x_{ijkl} + \sum_{i \in V} \sum_{j \in T} \sum_{k \in K} \sum_{l \in L} b_{ik} n_i x_{ijkl} \leq \beta z^{undesired}$$

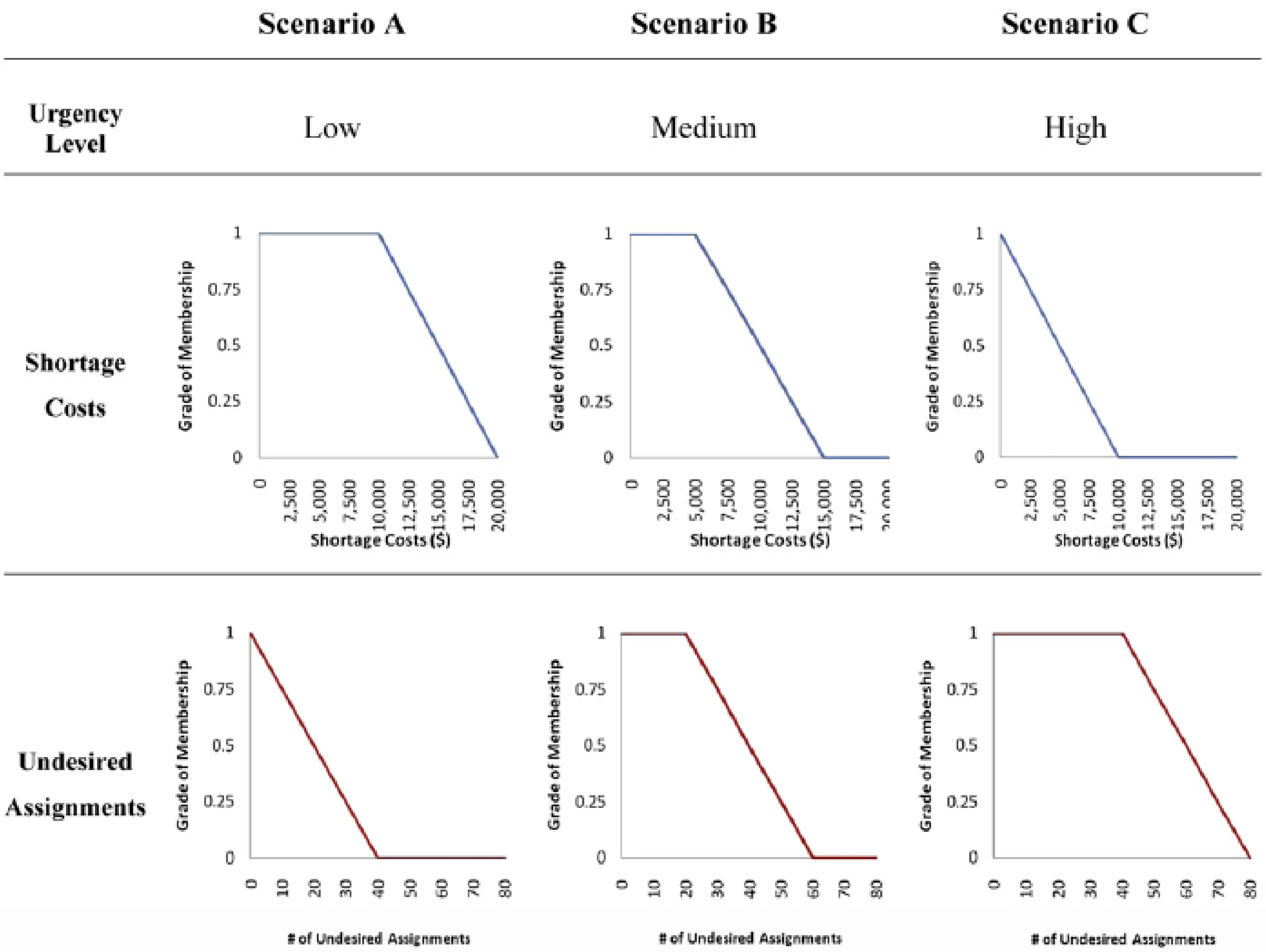
Preference on minimizing the number of undesired assignments rather than minimizing the total shortage cost

The Fuzzy Approach

- Applied
  - Traditional labor scheduling [1]
  - Allocating nurses to hospital wards [1]
  - Assigning aircrew members to rotations
- Why
  - Dealing uncertainties in target values (preferences)
    - Disaster scenarios contain imprecise information
  - Too complex to represent precise information
  - Resembles human reasoning in its use of approximate information

The Fuzzy Approach

- Fuzzy sets
  - Different objectives for potential schedules
- Membership function:
  - Each fuzzy set represented as function



? Determining the thresholds due to different scenarios

- Too relative and qualitative
- Making more quantitative through more scientific computations of global, past data

Implementation in Turkey

Human Resource Management, 2015

*Aim: To maximize employee performance along the organization's strategic objectives.

*Methodology

1. Scale Development
2. Sampling Design
3. Model Development
4. Data Collection

Mazi, Ş. (2015). The Effects of the Implementation of Human Resource Management on Volunteer Satisfaction in Nonprofit Organizations. *Akademik Araştırmalar Dergisi*. Retrieved April 29, 2019.

6.0 Conclusions and Future Research

- How a volunteer labor force is different from a traditional business model
  - Two approaches presented
  - Issues: labor costs, multiple location, group assignments
- Goal is to increase efficiency and effectiveness of volunteers
- Limitations
  - Membership functions are linear
- Future
  - Combined planning and scheduling model

Thank you for listening!

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