Fair Allocation of In-Kind Donations in Post-Disaster Phase

Zehranaz Varol

Bilkent University

National level

Regional level

National level

Individuals **NGOs** **Companies**


National level
Individuals
NGOs
Companies
DONATION
MILK


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NGOs
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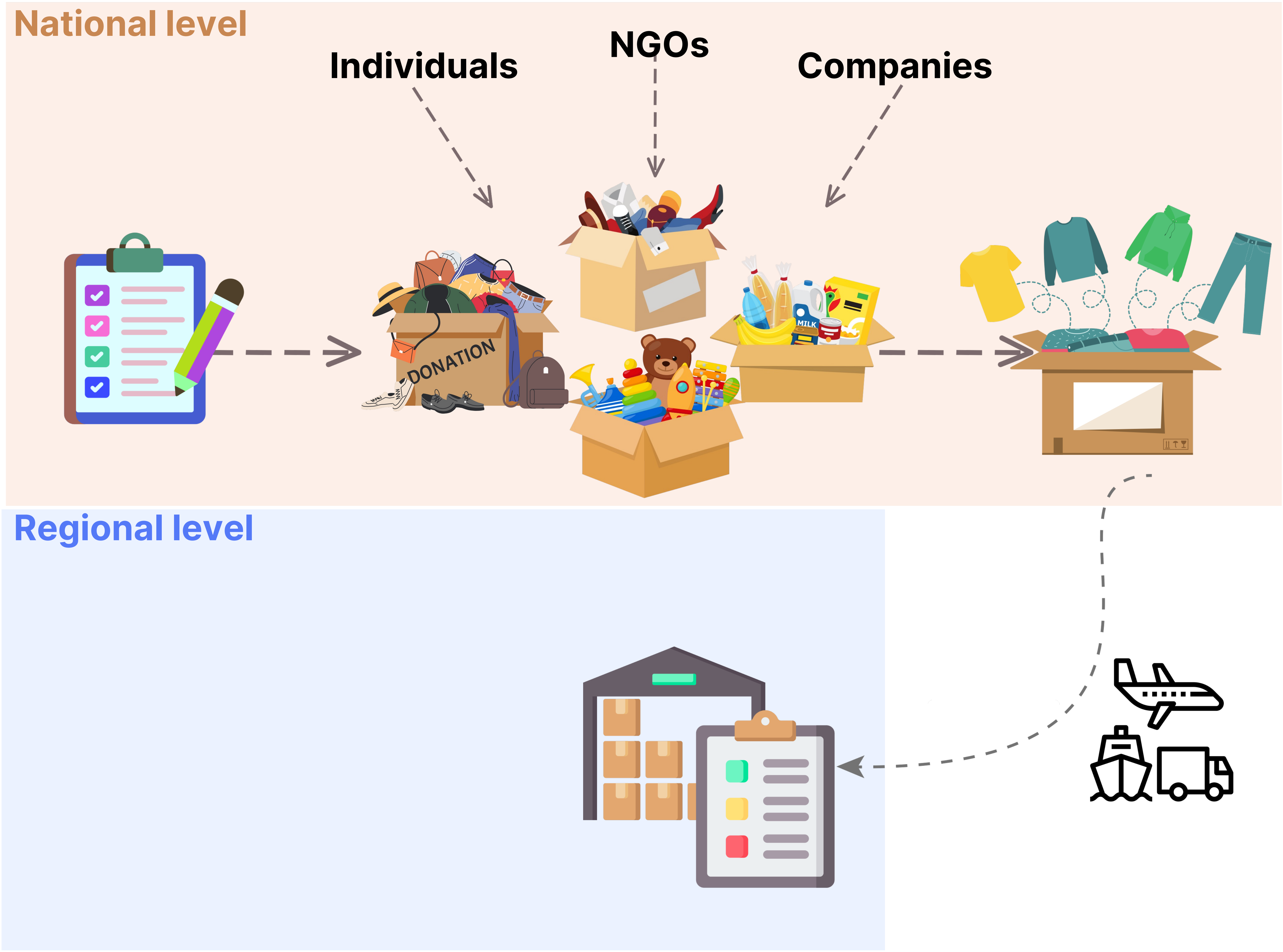
MILK



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Capacitated mobile PoDs
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Coverage radius

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- Allocation of a single durable commodity with recurring demand
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- Capacitated mobile PoDs (# is limited with a budget)
- Min-max approach
- Coverage radius
- Multi-period structure
- Inventory decisions for shelter sites

Problem assumptions

- A finite planning horizon is considered with a set of time periods
- A consumable non-perishable relief item with recurring demand is distributed
- Demand nodes are temporary settlements for disaster-victims
- Supply nodes are potential sites for mobile points of distribution (POD)
- Demand and supply are known
- Only demand nodes can store items
- Number of open depots is limited

Sets

$t \in T$: Time periods
$j \in J$: Demand nodes
$i \in I$: Possible depot locations

Parameters

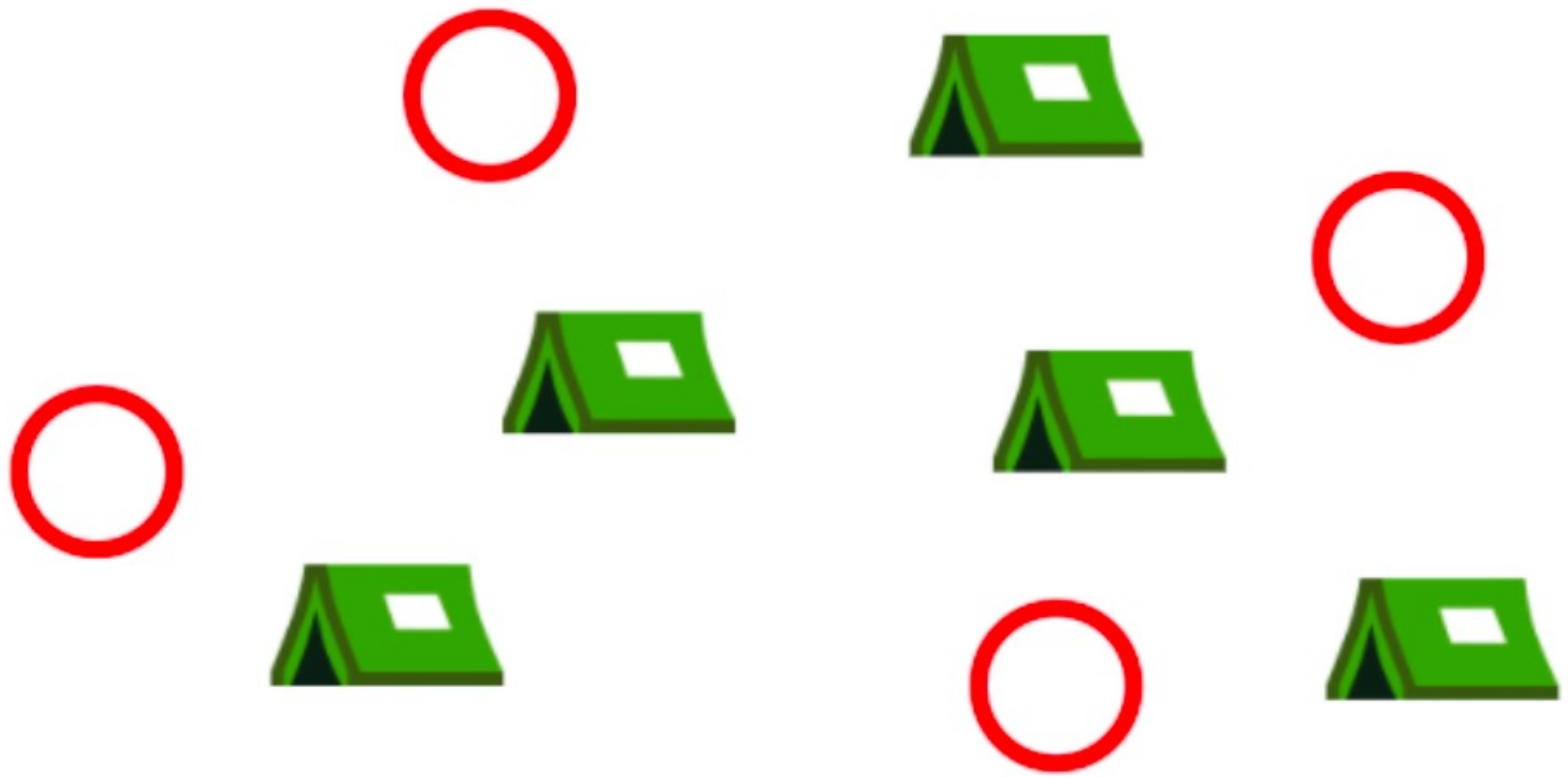
$j \in J$: Demand nodes

- d_{jt}: Demand of node j in period t
- α_j: Weight associated with demand node j

Parameters

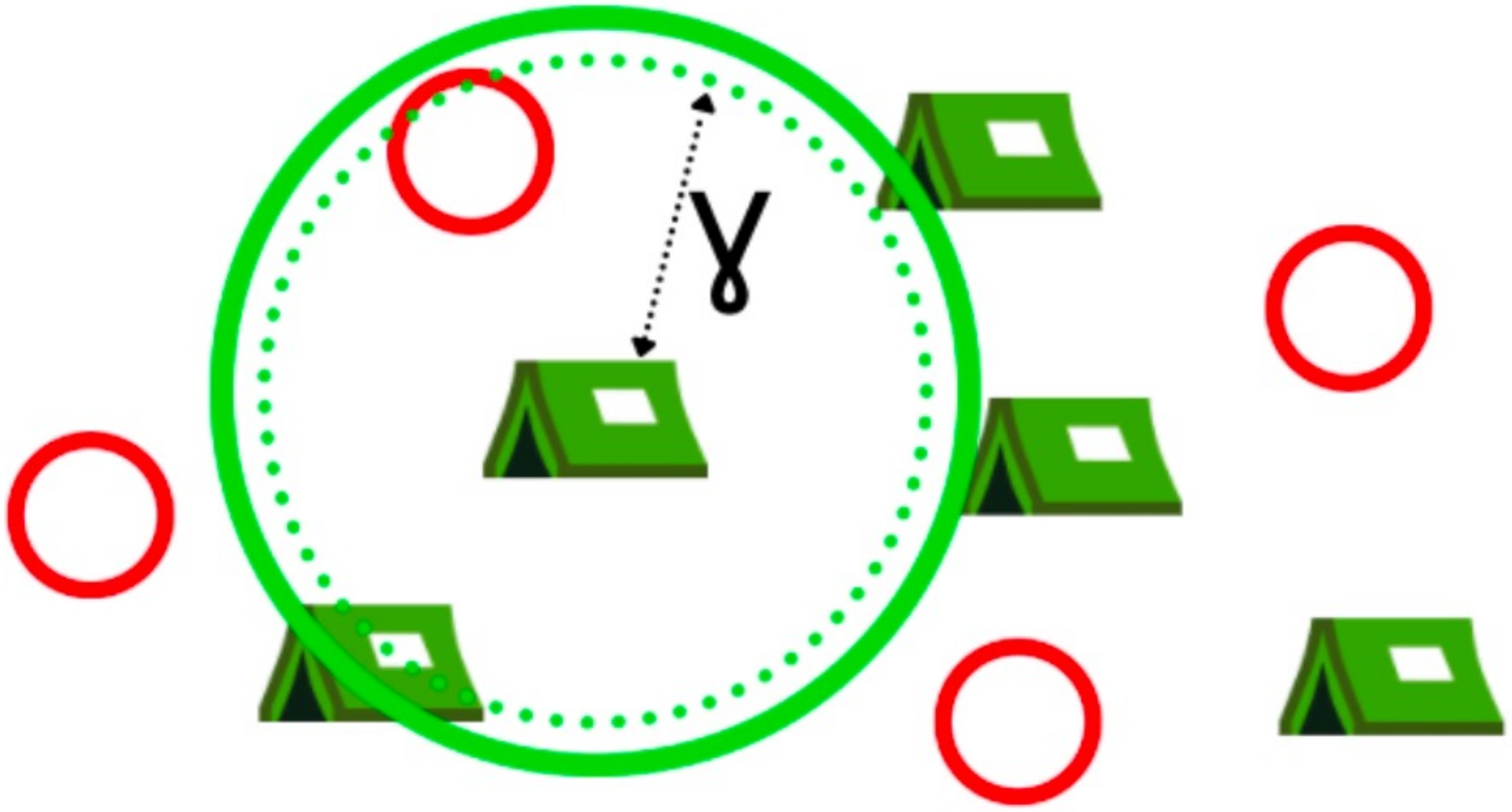
$i \in I$: Possible depot locations

- s_t: Supply amount in period t
- c_i: Capacity of depot i
- p_t: Maximum number of depots that can be opened in period t



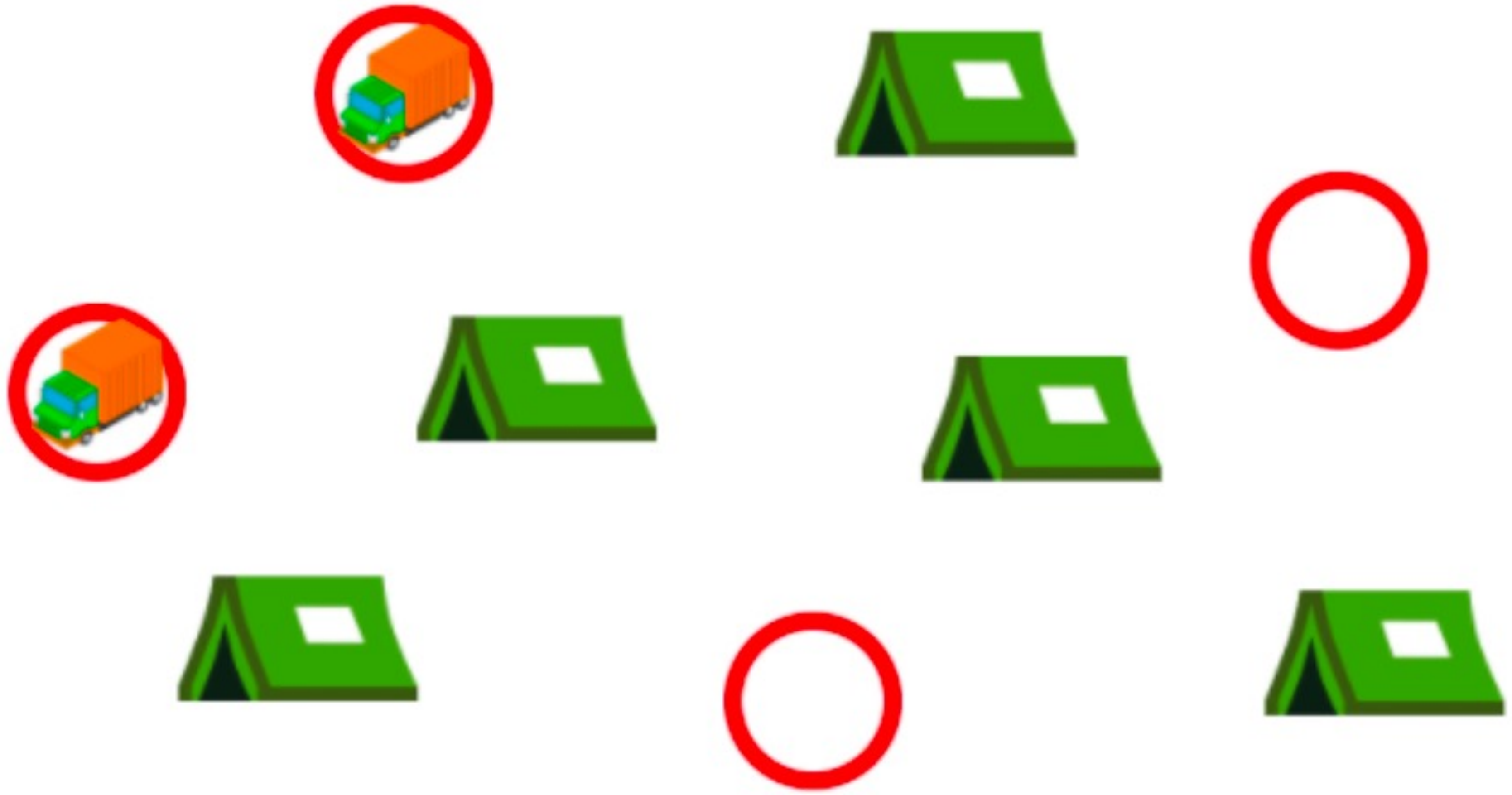
Parameters

- ℓ_{ij}: Distance between of demand node j and possible depot location i
- γ: Coverage radius for demand nodes
- $a_{ij} = \begin{cases} 1, & \text{If } \ell_{ij} \leq \gamma \\ 0, & \text{Otherwise} \end{cases}$



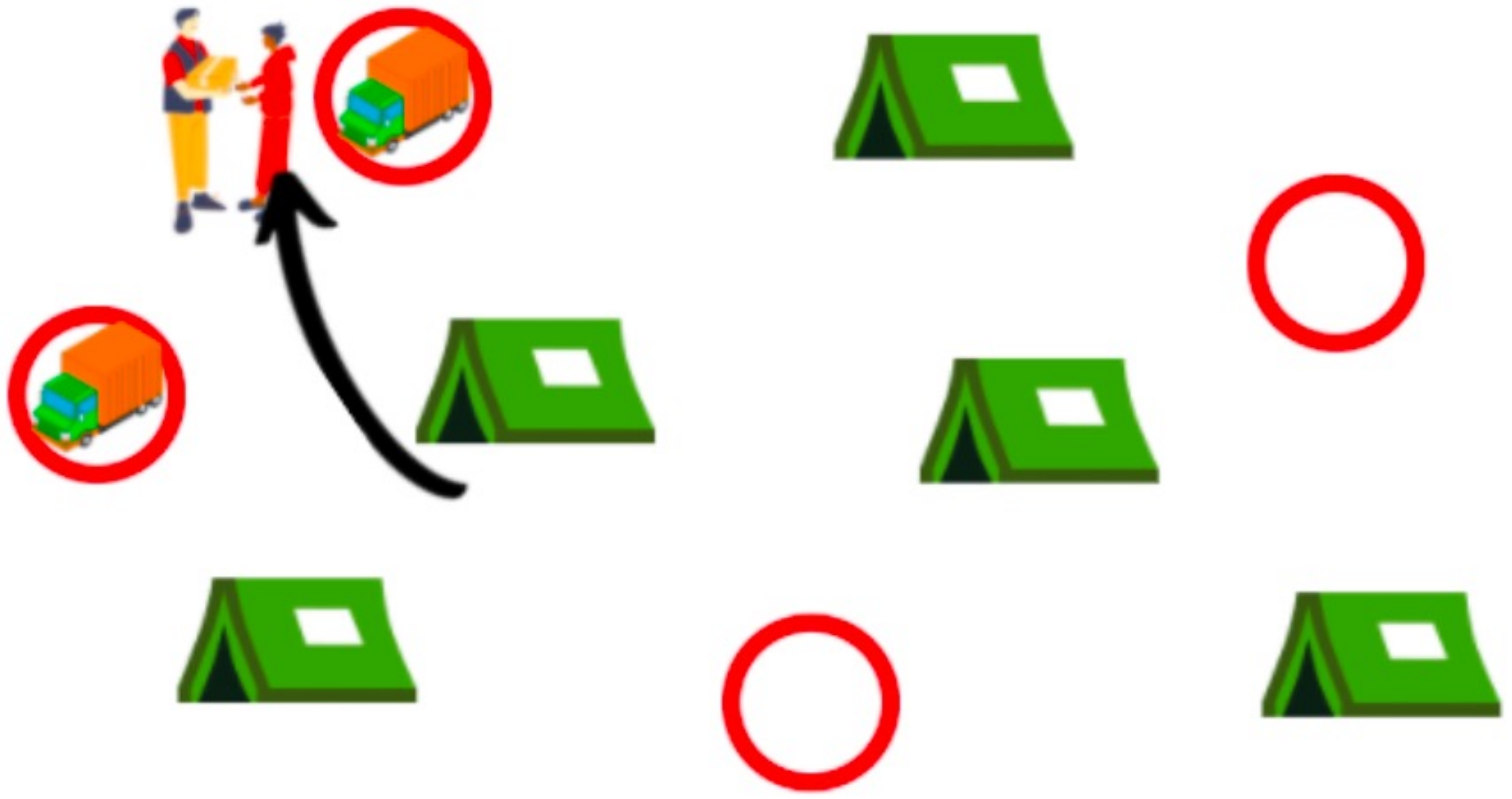
Decision Variables

- $y_{it} = \begin{cases} 1, & \text{If depot } i \text{ is opened in period } t \\ 0, & \text{Otherwise} \end{cases}$



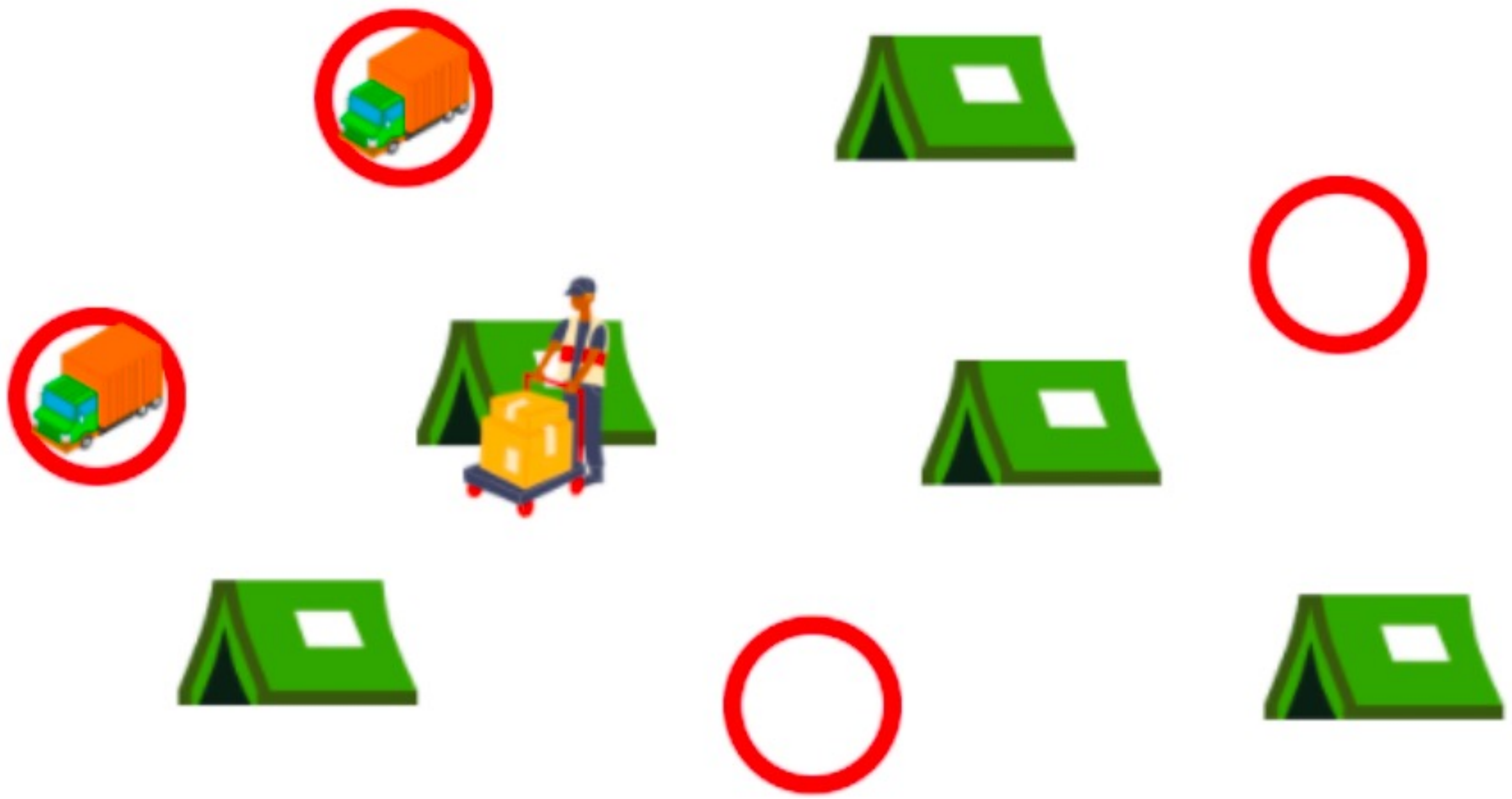
Decision Variables

- x_{ijt} = Amount assigned to demand node j from depot i in period t



Decision Variables

- v_{jt} = Inventory at demand node j at the end of period t
- u_{jt} = Shortage at demand node j at the end of period t



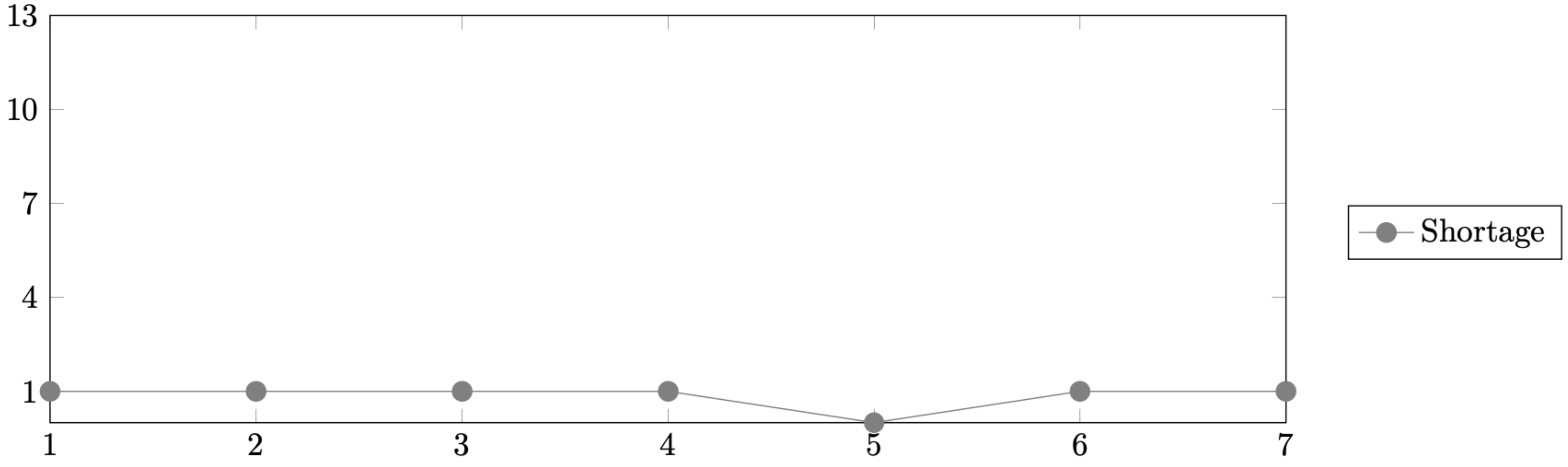
Deprivation cost

Aims to increase equity among a set of entities

- A method to quantify human suffering
- Deprived amounts and deprivation times
- The deprivation cost at a demand node is equal to the aggregation of individual costs

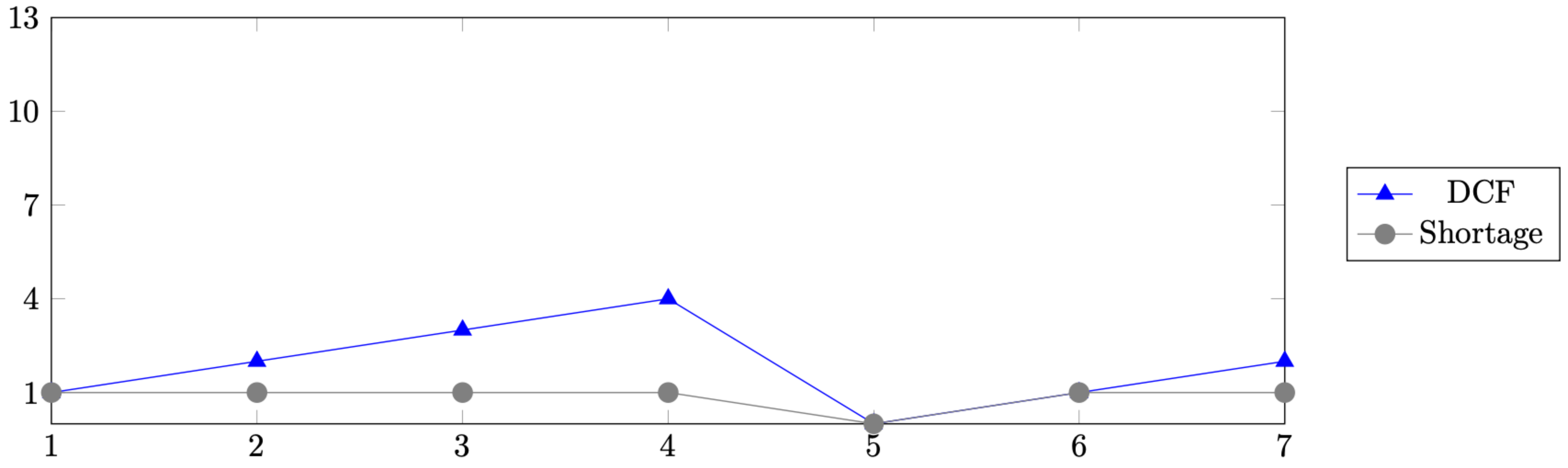
Deprivation cost

Periods	1	2	3	4	5	6	7
Shortage (u_{jn})	1	1	1	1	0	1	1



Deprivation cost

Periods	1	2	3	4	5	6	7
Shortage (u_{jn})	1	1	1	1	0	1	1
Deprivation Cost (z_{jn})	1	1 +1	1 +1+ 1	1 +1+ 1+1	0	1	1+1



Decision Variables

- $w_{jt} = \begin{cases} 1, & \text{If } u_{jt} > 0 \\ 0, & \text{Otherwise} \end{cases}$
- z_{jt} = Deprivation cost at demand node j at the end of period t

How to calculate deprivation cost?

Periods	1	2	3	4
Shortage (u_{jt})	15	30	10	0
Deprivation Cost (z_{jt})	15	15 +30	15 +30+ 10	0

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$$z_{jt} = \begin{cases} z_{j,t-1} + u_{jt}, & \text{if } w_{jt} = 1, \\ 0, & \text{otherwise} \end{cases} \quad j \in J, t \in T$$

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$$z_{jt} \geq z_{j,t-1} + u_{jt} - M(1 - w_{jt})$$

Objective function

$$\text{minimize} \quad \max_{j \in J} \left\{ \alpha_j \sum_{t \in T} z_{jt} \right\} \qquad (1)$$

Minimize the maximum deprivation cost among the shelter sites

Mathematical model

subject to:

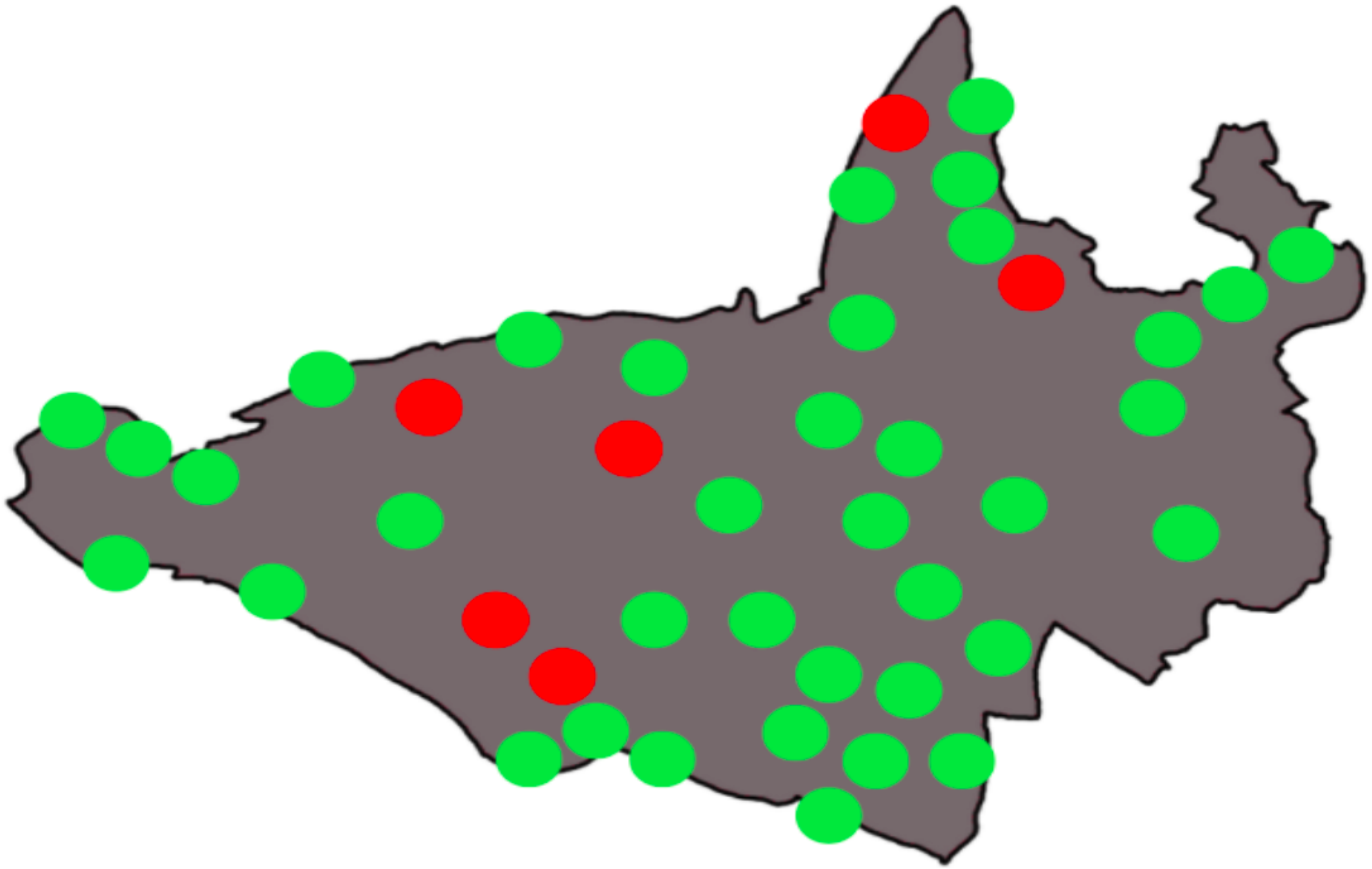
budget	$\sum_{i \in I} y_{it} \leq p_t,$	$t \in T$	(4)
depot capacity	$\sum_{j \in J} x_{ijt} \leq c_i y_{it},$	$i \in I, t \in T$	(5)
supply	$\sum_{j \in J} \sum_{i \in I} x_{ijt} = s_t,$	$t \in T$	(6)
coverage radius	$x_{ijt} \leq c_i a_{ij} y_{it},$	$i \in I, j \in J, t \in T$	(7)
flow balance	$v_{j,t-1} + \sum_{i \in I} x_{ijt} - d_{jt} = v_{jt} - u_{jt},$	$j \in J, t \in T$	(8)
relate *w* and shortage	$u_{jt} \leq w_{jt} d_{jt},$	$j \in J, t \in T$	(9)
	$w_{jt} \leq u_{jt},$	$j \in J t \in T$	(10)
relate *w* and inventory	$v_{jt} \leq (1 - w_{jt}) \sum_{\tau=1}^{t} s_\tau,$	$j \in J, t \in T$	(11)

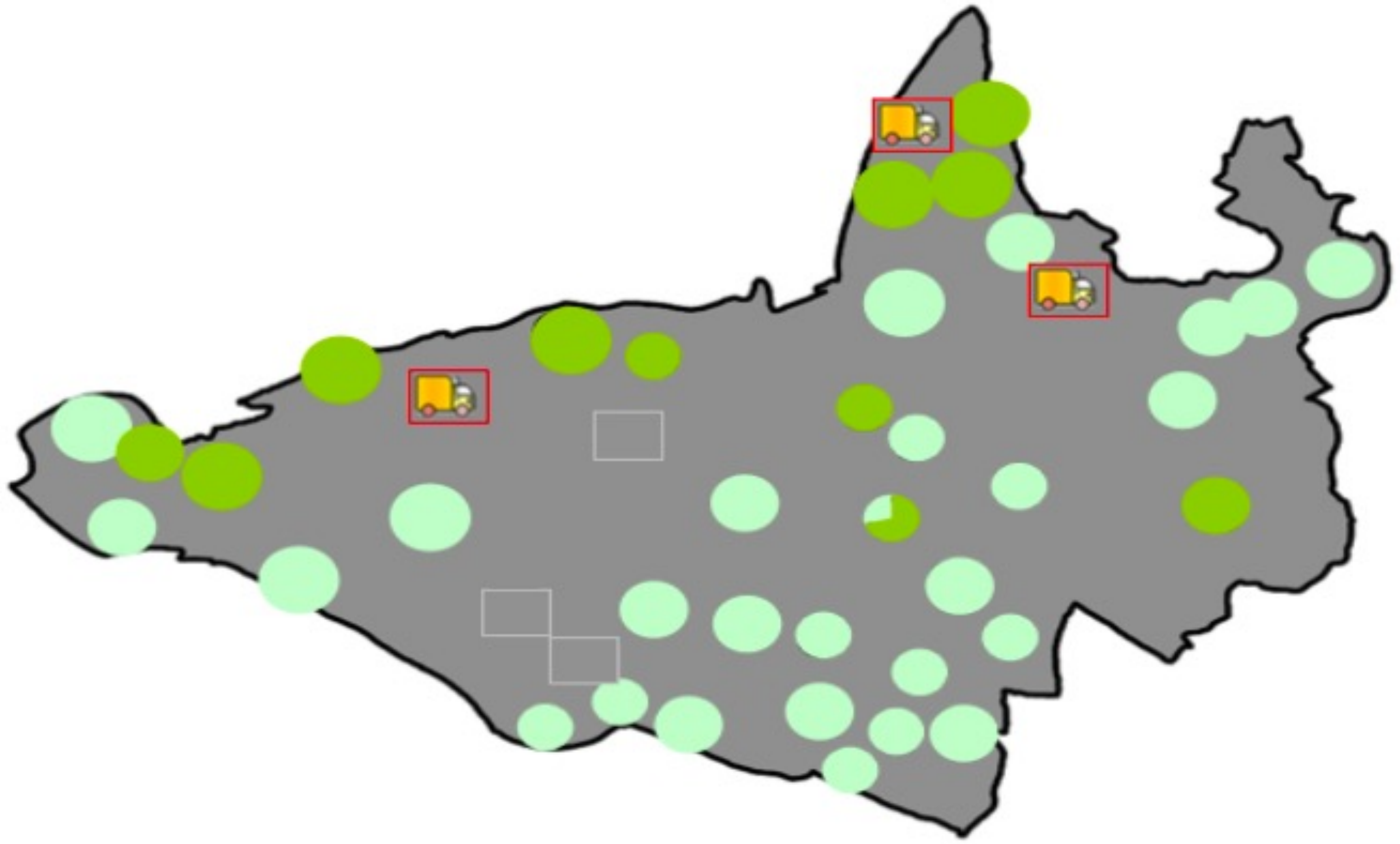
Mathematical model

deprivation cost	$z_{j,t-1} + u_{jt} - \sum_{\tau=1}^{t-1} d_{j,\tau}(1 - w_{jt}) \leq z_{jt}, j \in J, t \in T$		(12)
min-max objective linearization	$Z \geq \alpha_j \sum_{t \in T} z_{jt},$	$j \in J$	(13)
initial inventory	$v_{j0} = 0,$	$j \in J$	(14)
initial deprivation cost	$z_{j0} = 0,$	$j \in J$	(15)
domain	$y_{it} \in \{0,1\},$	$i \in I, t \in T$	(16)
	$w_{jt} \in \{0,1\},$	$j \in J, t \in T$	(17)
	$x_{ijt} \geq 0,$	$i \in I, j \in J, t \in T$	(18)
	$u_{jt}, v_{jt}, z_{jt} \geq 0,$	$j \in J, t \in T$	(19)

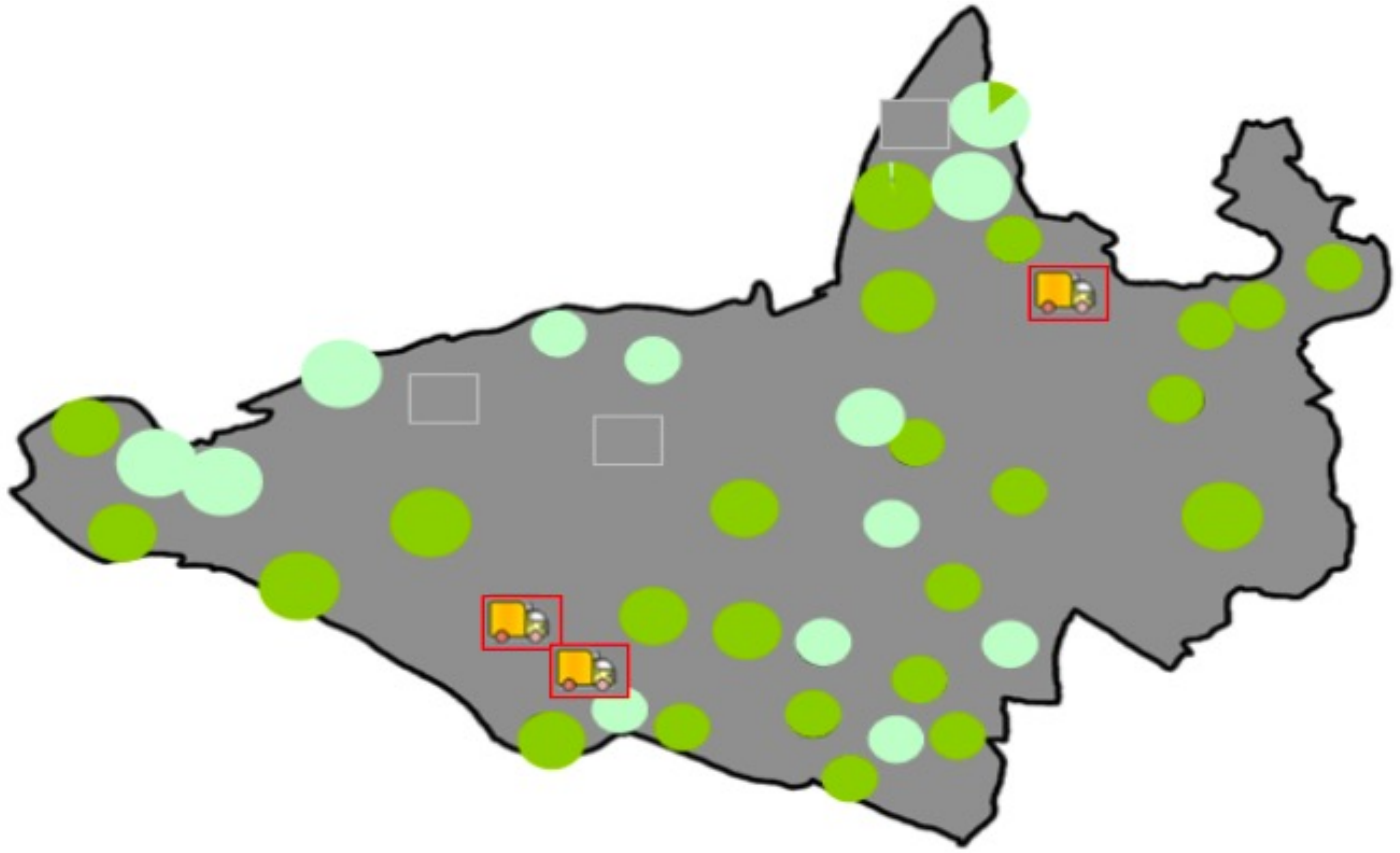
A case study: Kartal district of Istanbul

$|J| = 37, |I| = 6, |T| = 7$

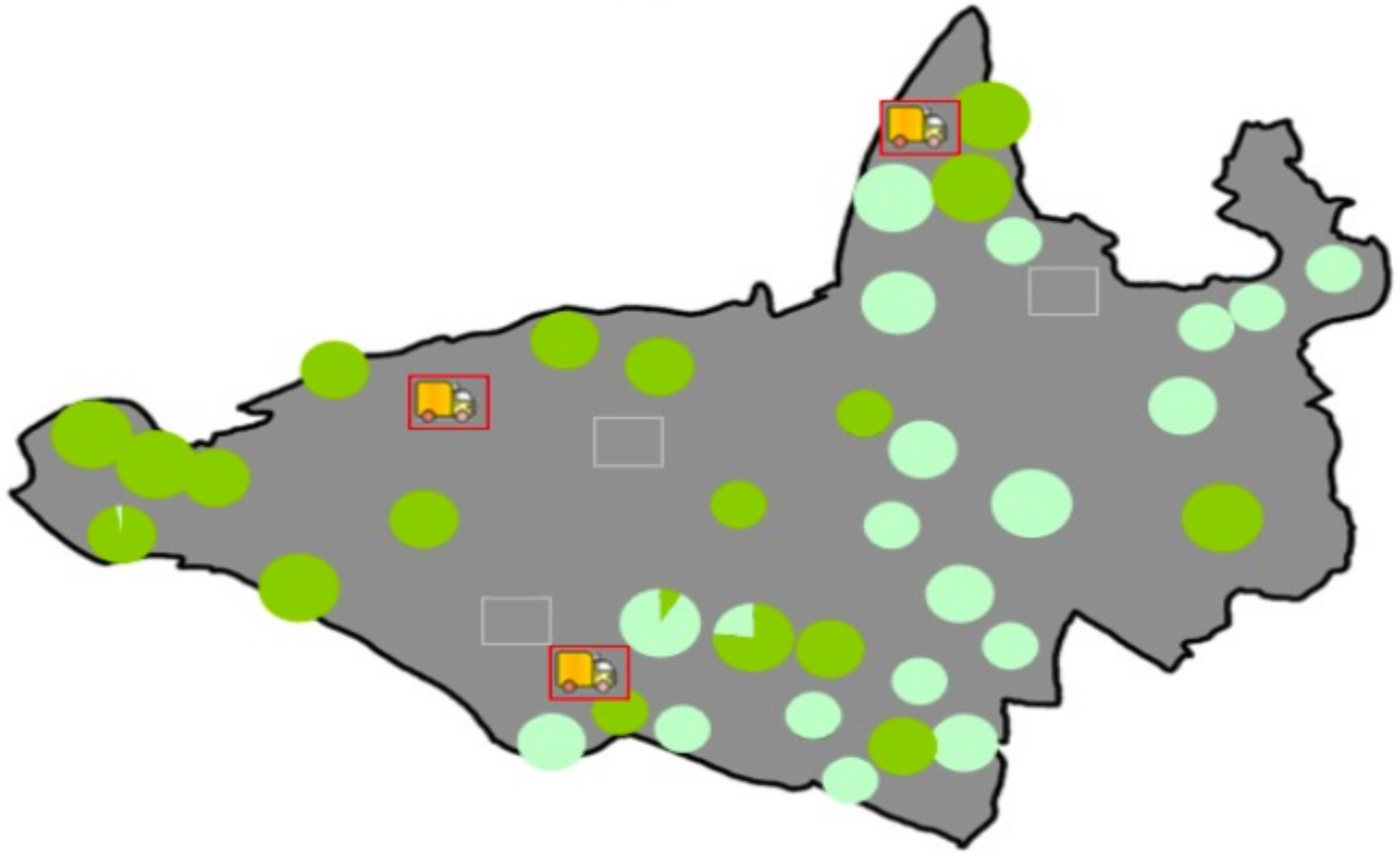




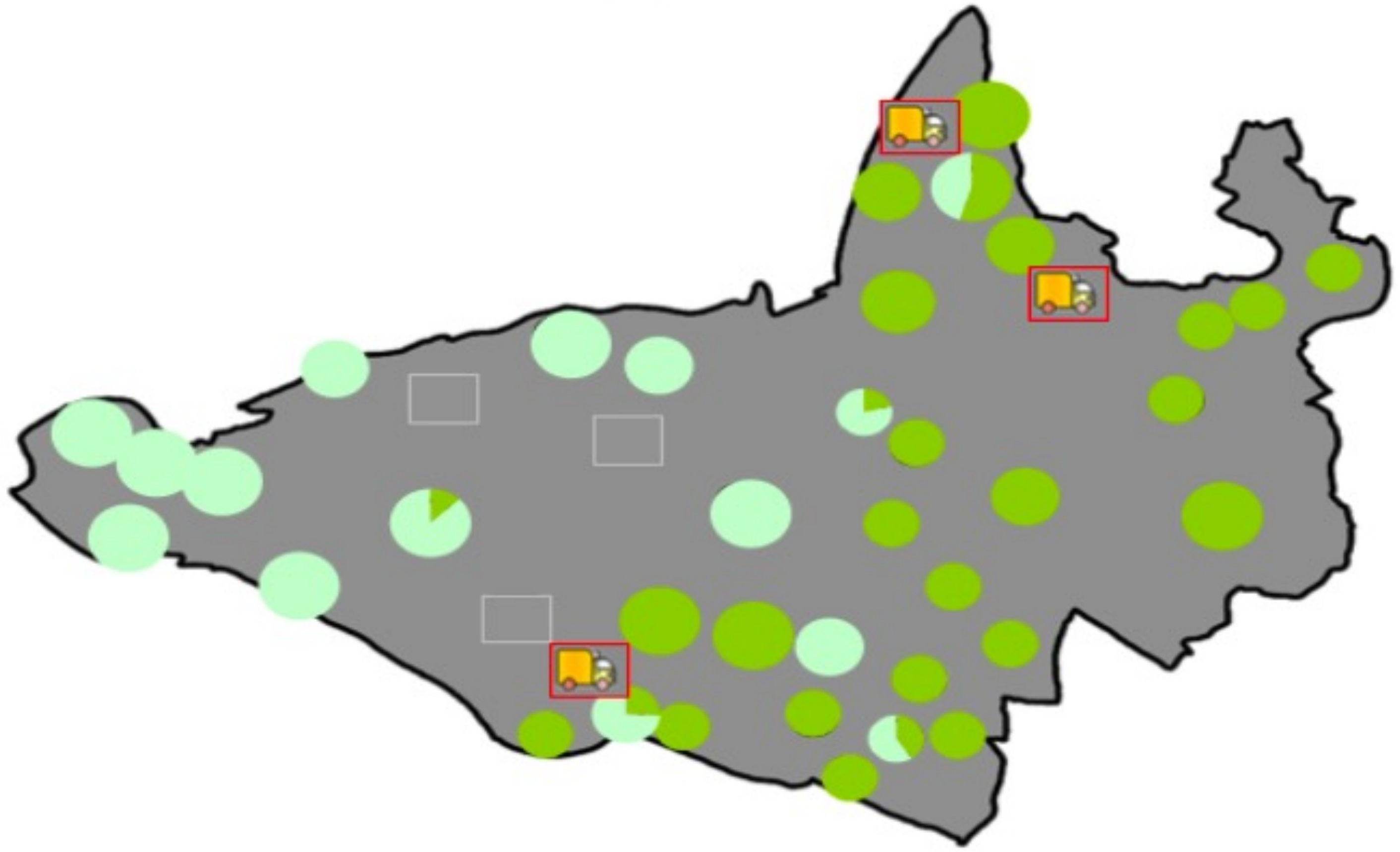
(a) $t = 1$



(b) $t = 2$



(c) $t = 3$



(d) $t = 4$

Value of mobilization

Static PoDs vs. dynamic PoDs

10% decrease in the objective function value

Conclusion

A sophisticated method to encourage equity during humanitarian operations

Amount distributed & timing of distributions

Mobile supply units