TACTICAL NETWORK PLANNING FOR FOOD AID DISTRIBUTION IN KENYA

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BACKGROUND INFORMATION

- Suffering from food shortages
- Sub-Saharan Africa is the ONLY region in the world that is constantly suffering from widespread chronic food insecurity and persistent threats.
- because of **Seasonality and Assessment.**
- annual weather patterns, two dry and two rainy seasons cause frequent and regular shocks.

BIG PICTURE: PROBLEM DEFINITION

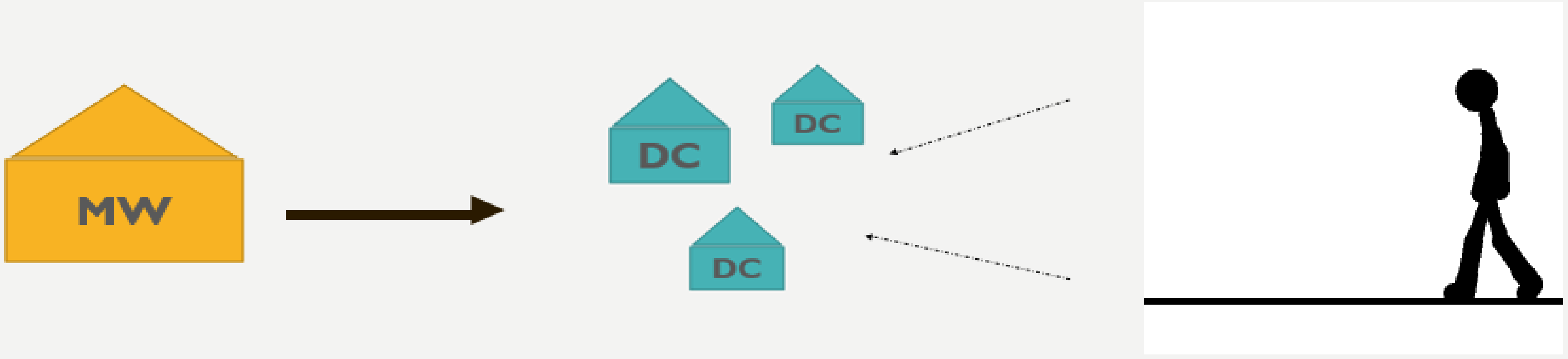
- Currently, rural households and communities developed strategies, like pastoralist livelihood systems.
- Migrate where water and pastures are more abundant

Food aid management → Highly complex supply chains.

All stakeholders: The World Food Programme ,
The Kenya Red Cross
and the beneficiaries.

- Problem is planning a network for food aid distribution.

- Food aid supply chains are composed of several FIXED main warehouses (MWs), located in strategic regions where primary storage infrastructure is available.
- Food then transports to Distribution Centers (DCs) from MWs, where it is informally stored and directly handed out to beneficiaries.
- DC's are TEMPORARY depots, such as…
- Each MW is used …



SOLUTION METHODOLOGY

- There are used three mathematical model (exact) with different objective functions in order to observe the problem from different perspectives.
  - **Model 1: Mathematical model based on social welfare cost**
    - Hybrid model between UFLP and a location covering problem, which considers the tradeoff between the fixed operating costs and distribution costs.
  - **Model 2: Classical location covering model**
    - Maximizes the need coverage for a given coverage radius and a given number of operating DCs
  - **Model 3: Minimize the number of DCs to cover all the beneficiaries**

MODEL 1

x_{ij}: the food aid proportion of population at i needing a hand-out from a DC at j, with $i \in V_1(r)$, and $j \in W_i(r)$;
y_j: a binary variable equal to 1 if and only if DC at j is in operation during the planning horizon, with $j \in V_2$.

minimize $\sum_{i \in V_1(r)} \sum_{j \in W_i(r)} \alpha_{ij} x_{ij} + \sum_{i \in V_1(r)} \sum_{j \in W_i(r)} \beta_j q_i x_{ij} + \sum_{j \in V_2} \gamma_j y_j$

Minimize the total welfare costs of all the stakeholders involved in the food distribution process

subject to

$$\sum_{j \in W_i(r)} x_{ij} = 1, \quad i \in V_1(r) \qquad (1)$$

Demand of each population is satisfied

$$x_{ij} \leq y_j, \quad i \in V_1(r), \quad j \in W_i(r) \qquad (2)$$

Population points can only be served from open DCs

$$x_{ij} \geq 0, \quad i \in V_1(r), \quad j \in W_i(r) \qquad (3)$$

$$y_j \in \{0, 1\}, \quad j \in V_2. \qquad (4)$$

Non negativity and integrality constraints.

MODEL 2

y_j: a binary variable equal to 1 if and only if DC located at j is in operation during the planning horizon, with $j \in V_2$;

z_i: a binary variable equal to 1 if and only if population point i, where the food aid need is of q_i tonne, is covered by at least one DC during the planning horizon, with $i \in V_1$.

$$\text{maximize} \quad \sum_{i \in V_1(r)} q_i z_i$$

Maximize the need coverage

subject to

$$z_i \leq \sum_{j \in W_i(r)} y_j, \quad i \in V_1(r) \tag{5}$$

Population points can only be served from open DCs

$$\sum_{j \in V_2} y_j = \overline{w} \tag{6}$$

Total number of opened DCs should be equal to w

$$0 \leq z_i \leq 1, \quad i \in V_1(r) \tag{7}$$

$$y_j \in \{0, 1\}, \quad j \in V_2. \tag{8}$$

Non negativity and integrality constraints.

MODEL 3

y_j: a binary variable equal to 1 if and only if DC at j is in operation during the planning horizon, with $j \in V_2$.

minimize w

subject to

$$\sum_{j \in W_i(r)} y_j \geq 1, \quad i \in V_1(r) \tag{9}$$

At least one DC should be opened

$$\sum_{j \in V_2} y_j = w \tag{10}$$

Total number of opened DCs should be equal to w

$$w \geq 0 \tag{11}$$

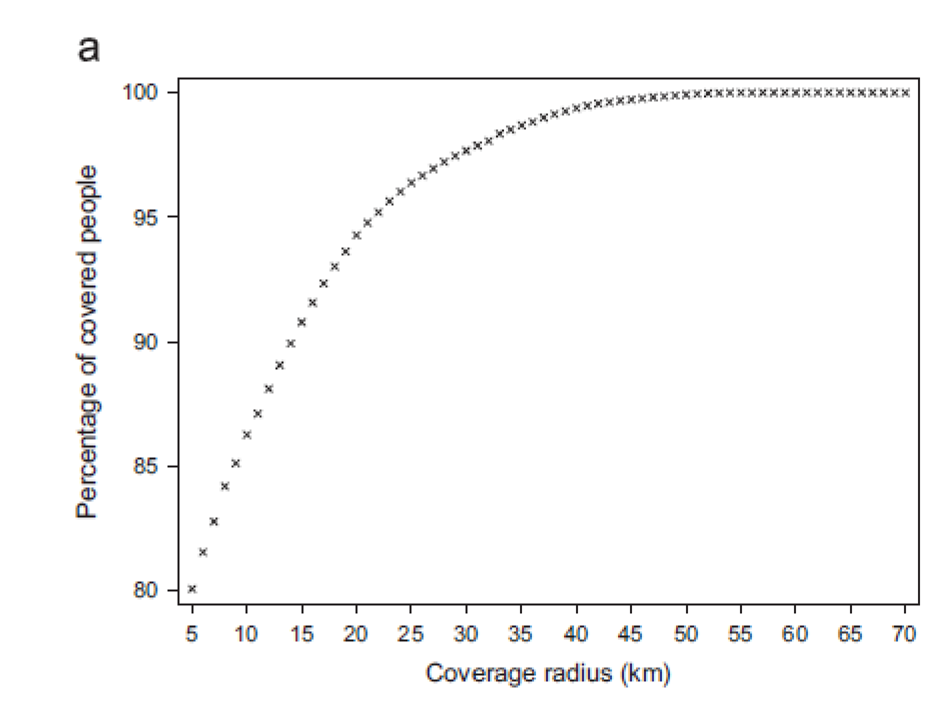
$$y_j \in \{0, 1\}, \quad j \in V_2. \tag{12}$$

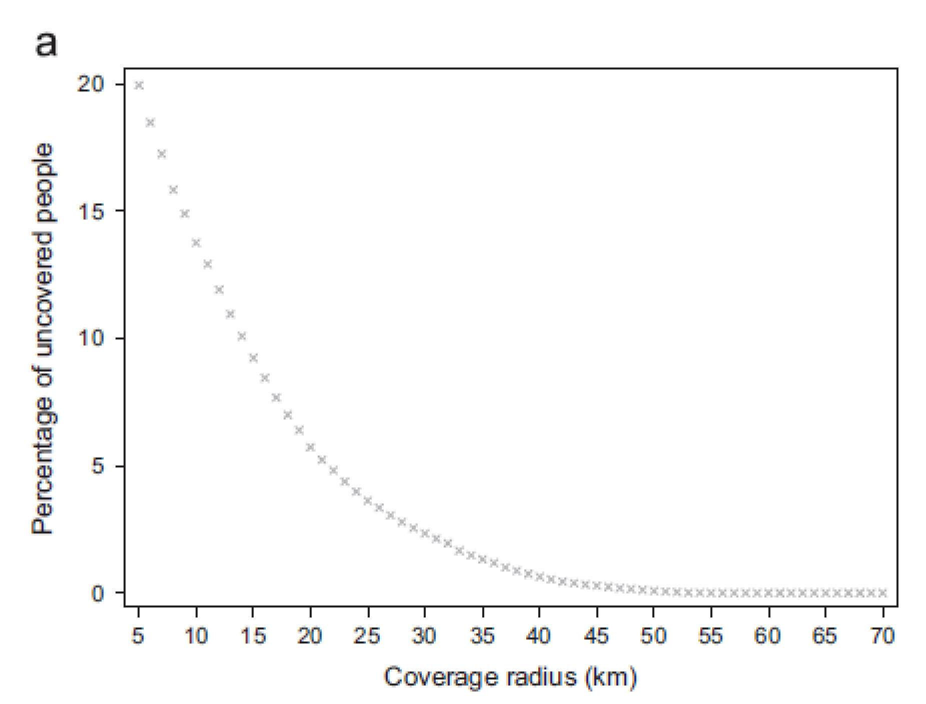
Minimize the number of DCs to cover all beneficiaries

Non negativity and integrality constraints.

COMPUTATIONAL RESULTS

- It is assessed the impact of the coverage radius on the percentage of people covered by changing r from 5 to 70 km.
- It is observed that in order to cover all the population, the coverage radius must be set to at least 55 km.





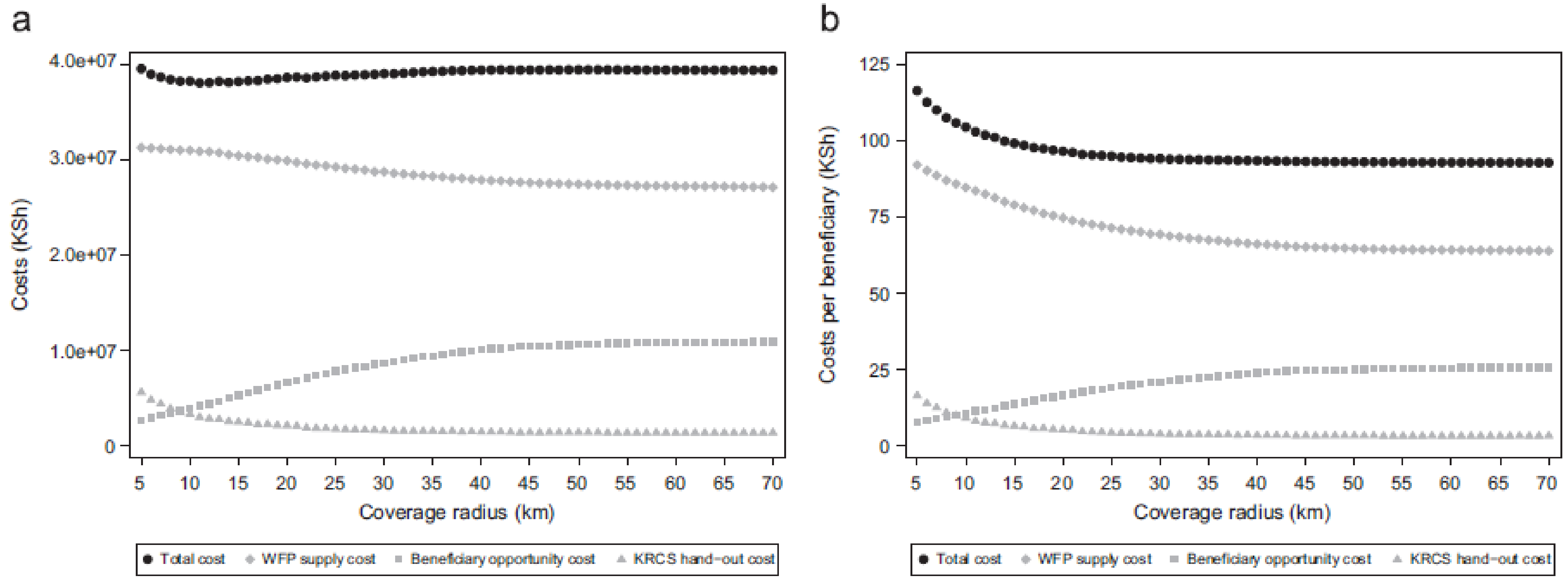
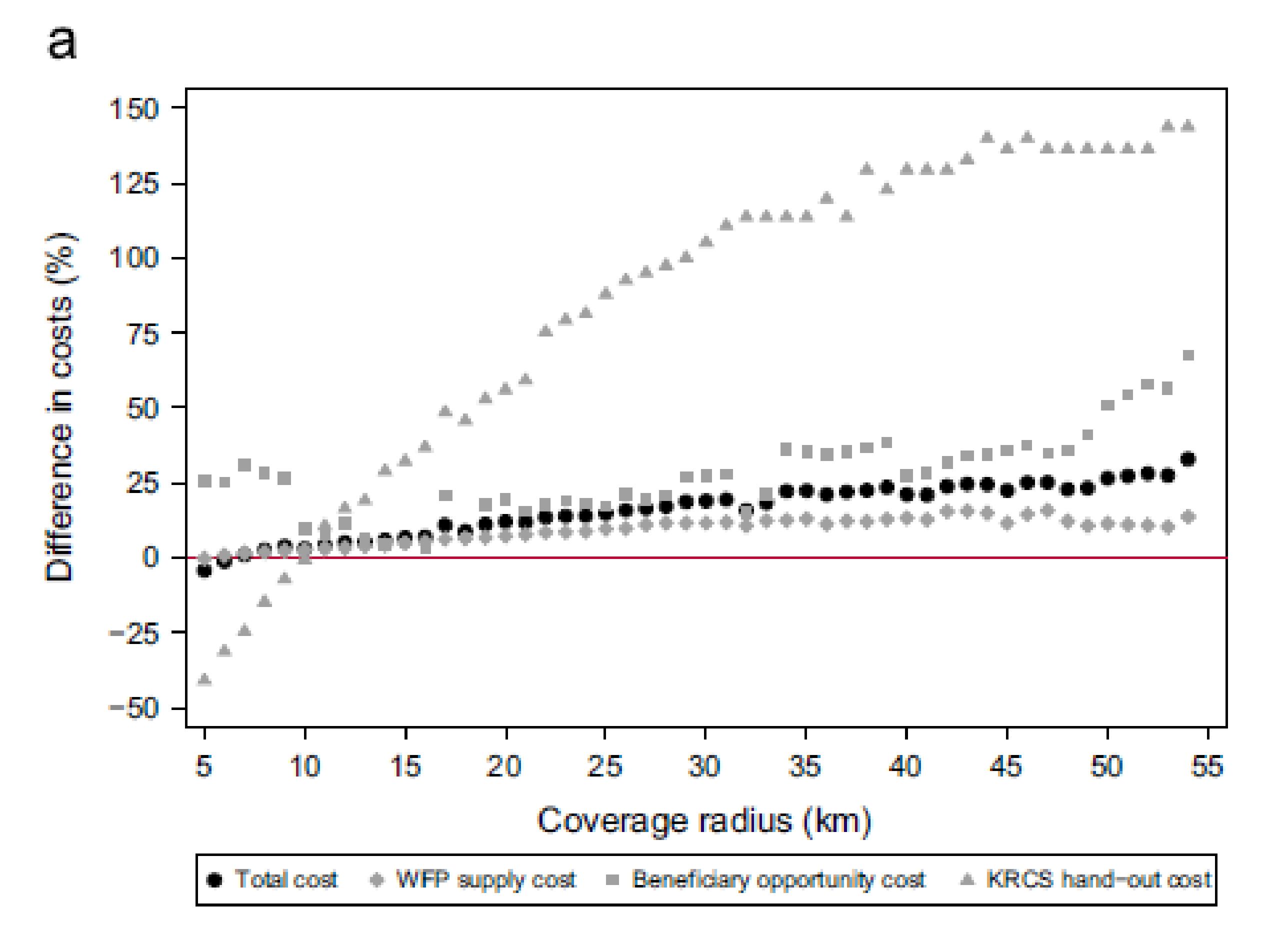


Fig. 7. Costs of solutions obtained with Model 1. (a) Total and stakeholder costs as a function of the coverage radius. (b) Cost per covered person as a function of the coverage radius.

- In Fig. 7a, the solution that minimizes the total welfare cost is obtained with r=12 km.
- In Fig. 7b, it is observed that the stakeholder costs decrease as the coverage radius increases. On the other hand the marginal costs tend to be close to zero when the coverage radius is larger than 17 km.
- Therefore, it is concluded that using coverage radius between 10 and 17 km yields most efficient solutions.

COMPERATİVE ANALYSES

- In order to determine behaviour of each term, we have solved the problem by minimizing each objective seperately;
- when we set $\alpha_{ij} = 0$ and $\beta_j = 0$, model 1 becomes model 3.
- Even though optimizing the total welfare cost yields larger percentages of increase the cost components when the coverage radius increases, single objective functions make the beneficiaries walk significantly more to collect their food. This seems to conflict with humanitarian principle.
- Therefore, we can conclude that model 3 does not give us beneficial solutions.



- Since there are currently 156 DCs in Garissa District, Model 2 is solved by fixing w=156.
- The figure shows the percentage decrease in stakeholder costs obtained by solving Model 1 as opposed to solving Model 2.
- It shows that solving Model 1 is more advantageous since Model 2 yields larger beneficiary opportunity and supply costs.

CONCLUSION FOR MODELS

- From the results of these experiments, it is concluded that solving a model that takes into account the welfare of all the stakeholders involved in food aid distribution, as it is done in Model 1, and taking the coverage radius ranging from 10 to 17 km generates cost efficient and fair solutions.

ADDITIONAL EXAMPLES

- «Facility location in humanitarian relief» by B. Balcik & B. M. Beamo

f_{sjk} proportion of item type k demand satisfied by distribution centre j in scenario s
Q_{jk} units of item type k stored at distribution centre j

$$X_j = \begin{cases} 1 & \text{if distribution centre } j \text{ is located} \\ 0 & \text{otherwise} \end{cases}$$

$$\max \sum_s \sum_k \sum_{l_k} \sum_{j \in N_s(l_k)} p_s d_{sk} w_k \alpha_k^{l_k} f_{sjk}$$

subject to

$$f_{sjk} d_{sk} \le Q_{jk} \quad \forall s \in S, j \in N, k \in K$$

$$\sum_{k \in K} \gamma_k Q_{jk} \le \mathrm{Cap}_j X_j \quad \forall j \in N$$

$$\sum_{j \in N} \left(F_j X_j + \sum_{k \in K} Q_{jk} g_{jk} \right) \le B_0$$

$$\sum_{k \in K} \sum_{j \in N} d_{sk} c_{sjk} f_{sjk} \le B_1 \quad \forall s \in S$$

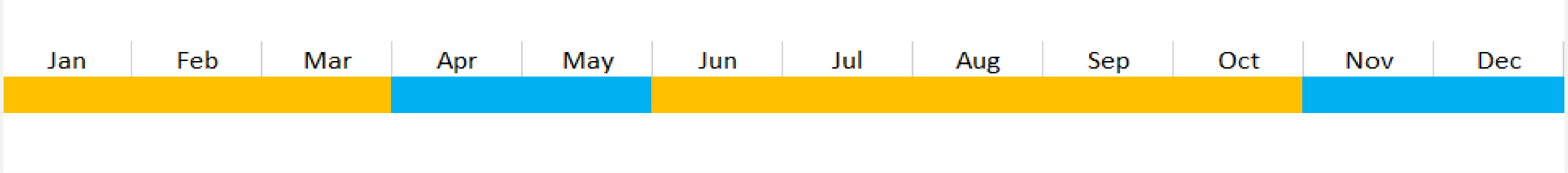
$$\sum_{j \in N} f_{sjk} \le 1 \quad \forall s \in S, k \in K$$

$$f_{sjk} \ge 0 \quad \forall s \in S, j \in N, k \in K$$

$$X_j \in \{0, 1\} \quad \forall j \in N$$

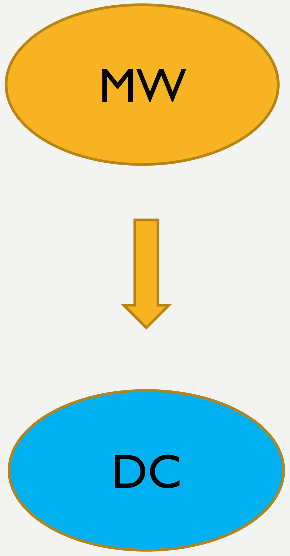
ALTERNATIVE ACTIONS

SHORTENING THE PLANNING HORIZON

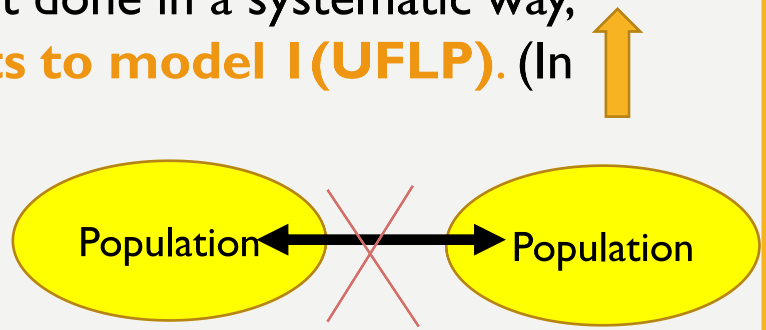


- Planning Horizon(6 months) can be reduced. More foreseeable demand, so less poverty.
- Irregular rainy seasons(longer or shorter)
- Uncertainty of demand because of the seasonality effect
- Problem is about preparedness phase of continuous relief operations
- Food insecurity=risk of hunger

SUPPLY-DEMAND MATCH



- Problem: migration
- DC's are temporary locations.
- In our case there are DC's, but amount of food aid allocation is not done in a systematic way, should be improved by **adding supply and demand constraints to model 1(UFLP).** (In current case, allocation is random)
- Elimination of **migration** → less fluctuation at demand



- No waste
- Exact amount q_i will be available in exact location i

- Additional parameter:

W_j = amount of food aid sent to DC j from a MW.

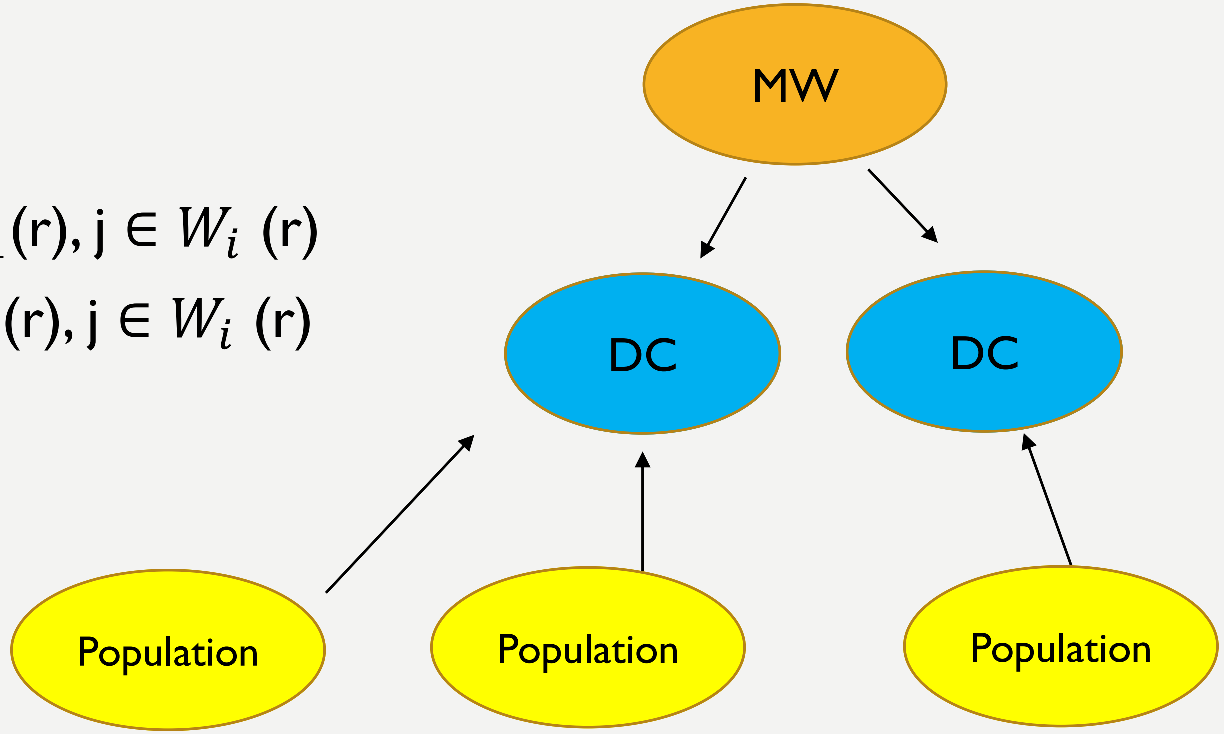
- Additional decision variable:

Z_{ij} = binary variable which is equal to 1 if population i is covered by DC j and 0 otherwise.

- **Additional contraint:**

$Wj * y_j \geq \sum_{i \in V1(r)} q_i * Z_{ij}$, $i \in V_1(r), j \in W_i(r)$

$X_{ij} \leq Z_{ij}$, $i \in V_1(r), j \in W_i(r)$



Additional Ideas

- **Aid goes to beneficiaries:** They may be prepared to immediate aid. In the case of severe drought, people cannot even walk the distance between their home and DC. (remember transportation vouchers)
- Reduction of transportation cost borne by beneficiaries. (more focus on humanitarian perspective)
- Meteorologists can be hired
- Information transparency(for accurate forecast)

COMPARISON IN TURKEY

- «Facility Location Problems – A Case Study For ATM Site Selection» by Müjde Erol Genevois, Derya Çelik Türkoğlu and Michele Cedolin.
- «The automated teller machine (ATM) site selection is a compelling decision for banks,. The main objective of the accurate ATM deployment is to minimize the cost without compromising customer satisfaction.»

$$Min \quad \left(\sum_{k=1}^{K}\sum_{l=1}^{L} c_{kl} \times d_l \times x_{kl} + \sum_{k=1}^{K} F_k y_k\right)$$

s.t

$$\sum_{k=1}^{K} x_{kl} = 1 \quad \forall l,$$

$$x_{kl} \le y_k \quad \forall k,l,$$

$$x_{kl}, y_k = 0,1$$

$k = 1,\ldots,K$ index of facility locations,

$l = 1,\ldots,L$ index of demand location,

c_{kl} = cost of shipping one unit of demand from facility k to demand l,

d_l = the # of units of demand at l,

F_k = fixed cost of opening / using facility k.

$$x_{kl} = \begin{cases} 1 \text{ if facility k serves demand l,} \\ 0 \text{ o/w} \end{cases} \quad y_k = \begin{cases} 1 \text{ if facility k "opened" (i.e. used),} \\ 0 \text{ o/w.} \end{cases}$$

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THANK YOU FOR LISTENING