**Saurabh Mehra**

# ISE 6984 Logistics, Assignment 3

Please run the model (file HEM-ANOR_orig.jl) on the data in Class Case_ANOR. Please describe what happens as you relax the x, the y, and the x and y variables, and when you remove the objective function. Include solve time in your description.

Now, we wish to modify the model such that it can handle multiple evacuating hospitals. Please do this and run the new model on the data in Class Case_ANOR_Multihosp. If you need to make any other assumptions please clearly specify them in your write-up. Describe the results, and the modifications you needed to make to the formulation. Try to produce a heuristic by solving this as a series of transportation problems and using their solutions in a greedy algorithm of your design (this heuristic does not need to be coded in Julia, you could use Excel and do in more manually). Please describe the algorithm in detail, as well as the results, comparing them with the model results.

Submit your results write-up via email, using a subject line of "ISE 6984 Assignment 3." The assignment is due April, 30th.

Q 1)

Please run the model (file HEM-ANOR_orig. jl) on the data in Class Case_ANOR. Please describe what happens as you relax the x, the y, and the x and y variables, and when you remove the objective function. Include solve time in your description.

Solution:

a) Relax x:

Solution count 7: 35.754 35.792 35.794 ... 36.5896

Optimal solution found (tolerance 1.00e-04)
Best objective 3.575400000000e+01, best bound 3.575380000000e+01, gap 0.0006%
Status: Optimal; Ofv = 35.754000000000005; SolveTime: 114.4959487915039

b) Relax y:

Solution count 1: 35.7538

Optimal solution found (tolerance 1.00e-04)
Best objective 3.575380000000e+01, best bound 3.575380000000e+01, gap 0.0000%
Status: Optimal; Ofv = 35.7538; SolveTime: 22.65839195251465

c) Relax x and y:

Solution count 6: 35.754 35.7648 35.774 ... 39.2333

Optimal solution found (tolerance 1.00e-04)
Best objective 3.575400000000e+01, best bound 3.575380000000e+01, gap 0.0006%
Status: Optimal; Ofv = 35.754000000000005; SolveTime: 408.55000495910645

d) Remove the **objective function:**

Solution count 1: 0

Optimal solution found (tolerance 1.00e-04)
Best objective 0.000000000000e+00, best bound 0.000000000000e+00, gap 0.0000%
Status: Optimal; Ofv = 0.0; SolveTime: 9.57944107055664

Q 2)

Now, we wish to modify the model such that it can handle multiple evacuating hospitals. Please do this and run the new model on the data in Class Case_ANOR_Multihosp. If you need to make any other assumptions please clearly specify them in your write-up. Describe the results, and the modifications you needed to make to the formulation. Try to produce a heuristic by solving this as a series of transportation problems and using their solutions in a greedy algorithm of your design (this heuristic does not need to be coded in Julia, you could use Excel and do in more manually). Please describe the algorithm in detail, as well as the results, comparing them with the model results.

Solution:

$$\sum_{i \in nEH} \sum_{j \in nRH} \sum_{p \in P} \sum_{v \in V} \sum_{t=1}^{T} R_{pvt}^{ij} \, x_{pvt}^{ij}$$

The objective function is to minimize the total evacuation risk which is dependent on threat and travel risk.

Subject to:

$$\sum_{i \in nEH} \sum_{v \in V} \sum_{t=1}^{T} x_{pvt}^{hi} = W_p^i, \qquad \forall h \in nEH, p \in P$$

This constraint ensures all patients are transported.

$$\sum_{i \in nEH} \sum_{v \in V} \sum_{t=1}^{T} x_{pvt}^{ij} \leq B_p^j, \qquad \forall j \in nRH, p \in P$$

This constraint ensures number of patients are less than or equal to the number of beds available.

$$\sum_{i \in nEH} x_{pvt}^{ij} \leq C_v y_{vt}^{ij}, \forall i \in nEH, j \in nRH, v \in V, t = 1, \dots, T$$

This constraint ensures that patient transferred by each vehicle type are less than the vehicle capacity.

$$\sum_{i \in nEH} v_{vt}^{i} \le N_v, v \in V, t = 1, \dots, T$$

This constraint ensures that all the vehicles assigned to each hospital are less than the total number of vehicles available for each type.

$$v_{vt}^{i} + \sum_{\substack{j \in nRH: \\ t > \tau^{ij}}} y_{v(t-\tau^{hi})}^{ji} + y_{v(t-1)}^{ii} = y_{vt}^{ii} + \sum_{i \in nRH} y_{vt}^{ij}, \forall i \in nEH, v \in V, t = 1, \dots, T$$

This constraint represents the conservation of flow over the planning horizon at each evacuating hospital.

$$\sum_{\substack{i \in nEH: \\ t > \tau^{hi} + 2\Upsilon_v}} y_{v(t-\tau^{ij}-2\Upsilon_v)}^{ij} + y_{v(t-1)}^{ii} = y_{vt}^{jj} + \sum_{i \in nEH} y_{vt}^{ji}, \forall j \in nRH, v \in V, t = 1, \dots, T$$

This constraint represents the conservation of flow over the planning horizon at each receiving hospital.

$$\sum_{j \in nRH} \sum_{v \in V} y_{vt}^{ij} \le L^{i}, \forall i \in nEH, t = 1, \dots, T$$

This constraint ensures that the number of vehicles loading at each hospital do not exceed the number of loading lanes available for each vehicle type.

$$x_{pvt}^{ij} \ge 0 \; and \; integer, \qquad \forall i \in nEH, v \in V, p \in P, t = 1, \dots, T$$

$$y_{vt}^{ij} \ge 0 \; and \; integer, \qquad \forall i \in nEH, j \in nRH, v \in V, t = 1, \dots, T$$

$$v_{vt}^{i} \ge 0 \; and \; integer, \qquad \forall i \in nEH, j \in nRH, v \in V, t = 1, \dots, T$$

$$\sum_{f=1}^{\min(2d,t)} \sum_{j \in nRH} \sum_{p \in P} x_{pv(t-f+1)}^{ij} \le N_v, \qquad \forall v \in V, \; j \in nRH, t = 1, \dots, T$$

**Assumptions for the model: -**

- Loading capacity at and rescue hospital is 6 at any time ‘t’.
- The loading time at each hospital is 1 time unit.
- Resources are shared between the hospital at all time.
- Some resources may be ideal at evacuating hospital at time ‘t’
- Total vehicle assigned altogether is initially defined at time t = 0, vehicles are already assigned to hospital
- Loading and unloading time is same for same type of patient at both receiving hospital and evacuating hospital.
- Each loading lane can accommodate all type of vehicles and do not change by the type of vehicles.

**Result**: -

Solution count: 28.764

Best objective 2.873900000000e+01, best bound 2. 873900000000e+01, gap 0.00003%

Status: Optimal; Ofv = 28.739; SolveTime: 700.57944107055664

**Heuristic for Multi Hospital Evacuating Problem:**

The Multi Hospital evacuation hospital can be considered as 2 subproblems:

1) **Assignment problem**: In this sub-problem, all the patients are assigned to the hospitals without considering the vehicle type used to transport the patients.
   The **objective function** would be to minimize the distance of patients from evacuating hospital to receiving hospital. This would also indirectly reduce the travel risk since it is dependent on the distance between the evacuating and receiving hospital.

   The constraints would be:
   i) A hospital bed should be assigned to each patient.
   ii) Each patient must receive one hospital bed.
   iii) The total number of people assigned should be equal to total number of patients.

2) **Transportation problem**: In this subproblem, each patient type is assigned to a vehicle type after each patient type is assigned to each receiving hospital. This problem will capitalize on the results obtained from the Assignment problem in terms of which patient type is assigned to which receiving hospital and would help assign patient type to vehicle types.
   The **objective function** is to minimize the evacuation risk which is dependent on travel risk and threat risk.

   The constraints would be:
   i) Each patient must be assigned to each vehicle type.
   ii) The total number of vehicles in the system must not exceed the max number of vehicles available of each type.
   iii) The number of vehicles coming in at evacuating hospital must be equal to number of vehicles going out.
   iv) The number of vehicles arriving at the receiving hospital must be equal to the number of vehicles leaving.
   v) Vehicles must satisfy the loading lane criteria.

All the assumptions made in the earlier optimal model must hold true for heuristic as well.

**Saurabh Mehra**