HW 5

Disaster Case Report

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After our graduation from Georgia Institute of Technology, we have had the huge privilege to get hired into your company. As you know, we have discovered that the Federal Emergency Management Association does not have any emergency plan in case of a disaster case ! Imagine that today an Earthquake strikes Puerto Rico, what would happen to the thousands of people ? California is waiting for the Big One, Japan is waiting for Fukushimas's future, what about Puerto Rico? This study will tackle this issue.

I) Data

Before any analysis, we must gather all data needed. We want to thank our friend Arnold in the Census Bureau for his help gathering the data and our supervisor Bernard for HAZUS tool results that have provided to us some data in a case of a magnitude 8.0 earthquake 45 km off the coast of San Juan.

To achieve clarity and accuracy, we define :

Inputs:

- $i \in [1; 823]$
- $j \in [1; 56]$
- $d_{ij} = distance\ from\ track\ of\ people\ i\ to\ hospital\ j$
- $f_i = number\ of\ people\ in\ track\ i$
  This input is key in our study and will be discussed later
- $n_j = number\ of\ beds\ in\ hospital\ j$

Decision Variables:

- $X_{ij} = number\ of\ people\ from\ track\ i\ affected\ to\ hospital\ j$

II) Our models

1) Creating a model

Creating a model requires some assumptions to make sure it is as close as possible to the reality. Here are some questions we have answered to help us designing our model:

1. *What can you determine given the locations of each hospital and the locations of the people?*

With the location of each hospital and people, we know which track of people is the closest to any hospital so we know who will get to the hospital as soon as possible. Unfortunately, there are more people tracks than hospitals so some tracks could be left alone if we are not cautious…

2. *What would happen if everyone went to the same facility? Is there a way to determine in the model how many people go to the different facilities? How?*

If everyone went to the same facility, this facility will be overcrowded and not all people will be healed. What we are going to do is to allocate a maximum fraction of people that can potentially go to one hospital in order to widespread the total number of people in each tracks to the whole track of hospitals.

3. *What items can be maximized or minimized here?*

In our study, we find it best to minimize the total distance of each people going to the hospitals. Indeed, in a case of an emergency we don't want to widespread every people all over the country, we want them to get into the closest hospital as soon as possible !

4. *How would you estimate how many people need medical attention if HAZUS were not available? Would the constraints look any different?*

If Hazus were not possible, we would allocate a fraction for each track following a Gaussian distribution that means we will affect a constant α of damage for each track of people. For example, if $\alpha = 5\%$, that means that for each track of people, 5% of the track will need medical care.

For each case, we have used Python 3.5, OpenPyxl (to open spreadsheets) and PuLP 1.6 (to solve LP models).

2) Case 1 : save the closest people to hospital

A) Model

In this case, we are assuming that we are focusing on the objective function more than the constraints: we want to minimize the total distance for rescuers at all cost. We will save the closest people to each hospital in priority to avoid rescuers to cover great distances.

Obj Func.	$\min(\sum_{i=1}^{823}\sum_{j=1}^{56} d_{ij}x_{ij})$	Minimize the distance to people to hospital
Const.	$\forall i \in [1;823], \sum_{j=1}^{56} x_{ij} \leq f_i$	Only injured people go to hospital
	$\forall j \in [1;56], \sum_{i=1}^{823} x_{ij} = n_j$	Every bed in every hospital is used

B) Results

We see no interest in the optimal solution. If we say that we have an optimal solution 13000 what does that mean ? $\sum_{i=1}^{823}\sum_{j=1}^{56} d_{ij}x_{ij}) = 13000$ for sure but how can we analyse this ? This is why we have decided to plot the map of Puerto Rico :

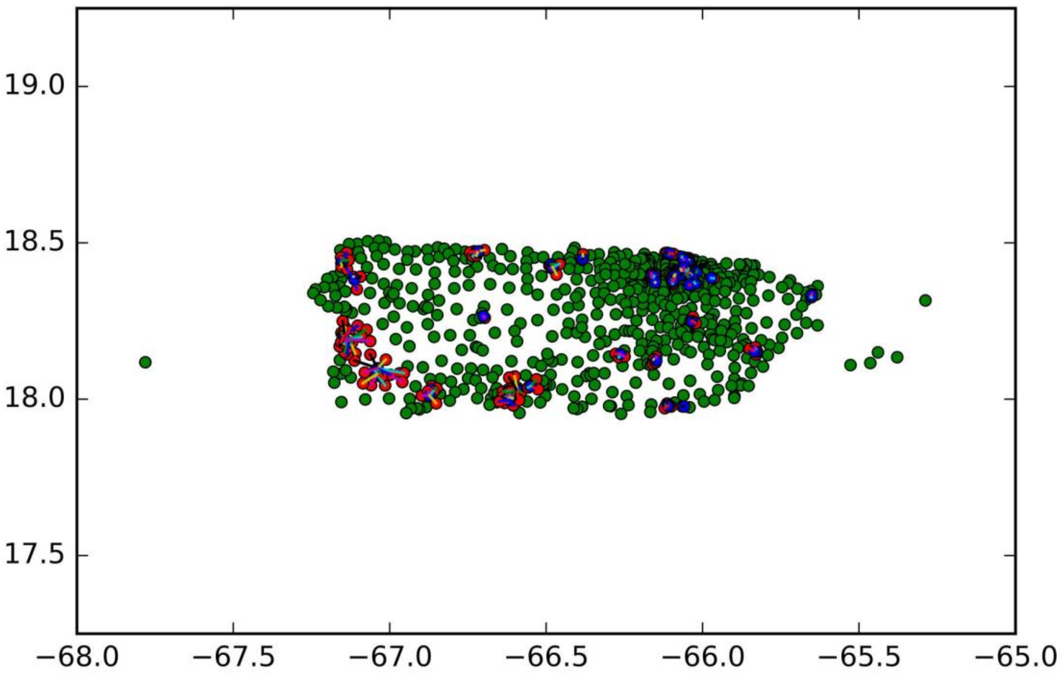

Figure 1 : on abscissa axis the longitude and on ordinate axis the latitude

Description:

- Green points : people of this track are not helped
- Red points : people of this track are helped
- Blue points : hospital
- Lines : people distance from i to hospital j

C) Analysis

Regarding our model, our first priority is to help people as close as possible from any hospital to minimize distances rescuers will cover. We see that indeed, the "lines" are not really big because we want to minimize the distances.

What is terrible with this solution is that we indeed minimize the distances, but the major part of tracks (and not people) are not helped : we only focus on the closest tracks. We need to improve this model so save as much people from many tracks and not in a few tracks, although the number of injured people helped remains the same.

3) Case 2 : every places must be served at least 10%

A) Model

In this model, we want that every place is served, we want that at least 10% people from each track is helped.

Obj Func.	$\min(\sum_{i=1}^{823}\sum_{j=1}^{56} d_{ij}x_{ij})$	Minimize the distance to people to hospital
Const.	$\forall i \,\epsilon\, [1;823], \sum_{j=1}^{56} x_{ij} \leq f_i$	Only injured people go to hospital
	$\forall j \,\epsilon\, [1;56], \sum_{i=1}^{823} x_{ij} = n_j$	Every bed in every hospital is used
	$\forall i \,\epsilon\, [1;823], \sum_{j=1}^{56} x_{ij} \geq 10\% \, f_i$	At least 10% people in each track is helped

B) Results

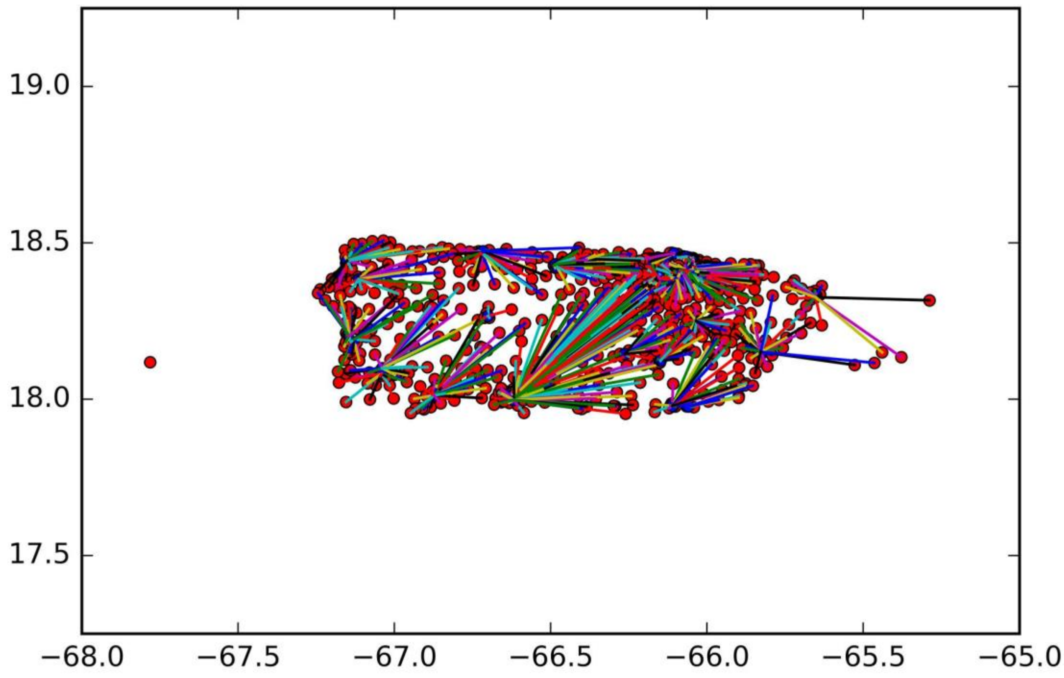

Figure 2 : on abscissa axis the latitude and on ordinate axis the longitude

It is important to notice that the red point in the left is not linked to any hospital because there is not injured people here.

C) Results

In this case, at least 10% people from each track is helped which is humanly better than in the previous case. Unfortunately, we see that some people from a couple of tracks must do a huge distance to be helped. The last case will focus on improving the total capacity of each hospital.

4) Case 3 : increase the number of beds

A) Model

In this case, we decide that in a case of an emergency, hospital prefer using stretchers instead of beds to improve their capacity. We have decided to multiply capacities for each hospital by 10. We now have more “beds/stretchers” than injured people.

Obj Func.	$\min(\sum_{i=1}^{823}\sum_{j=1}^{56} d_{ij}x_{ij})$	Minimize the distance to people to hospital
Const.	$\forall i \in [1;823], \sum_{j=1}^{56} x_{ij} = f_i$	There are more injured people than beds, so all injured goes to hospital
	$\forall j \in [1;56], \sum_{i=1}^{823} x_{ij} \leq n_j$	Capacity of each hospital

B) Results

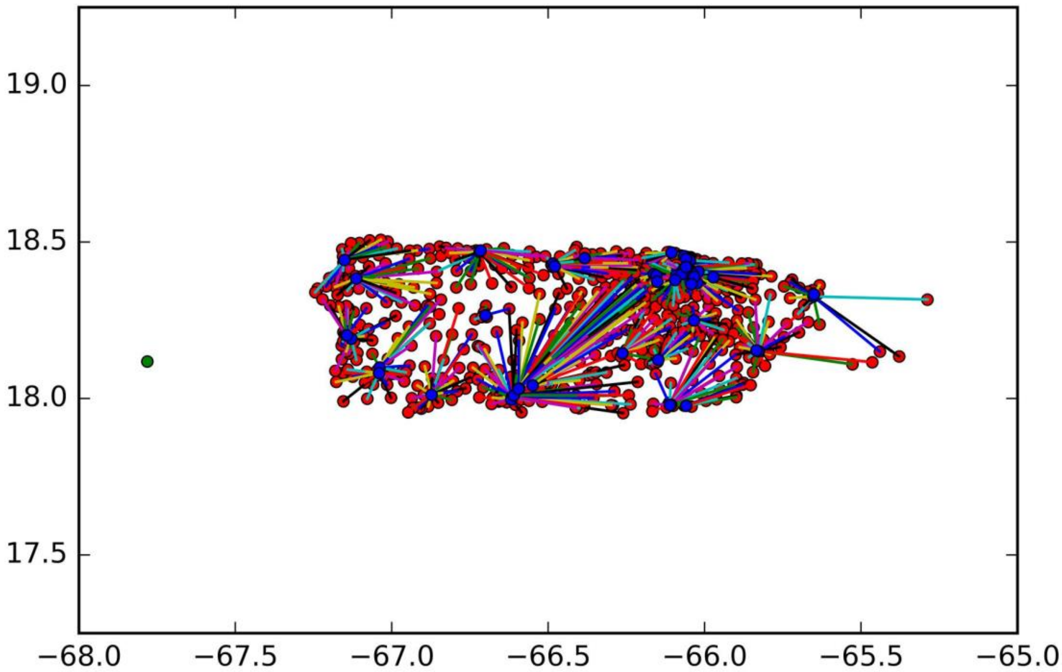

Figure 3 : on abscissa axis the latitude and on ordinate axis the longitude

C) Analysis

This case is an improvement of the previous case. We have more beds so less people must cover the all country to be helped. The cost will be greater than case 2 because we help every injured.

III) Conclusion

Case	**1**	**3**	**3**
Objective Function (it is NOT a cost !)	10343	96954	798911
Total number of people saved	8627 = total number of beds	8627 = total number of beds	78439 = total number of injured
Conclusion	The objective function is the best among the 3 cases but at what cost ? (human means)	At least 10% people from each track is helped but some must cover the whole country to be helped…	Costs are huge but everyone is saved !

Our conclusion in this case is to use stretchers in case of emergency, everyone will be saved. If we only want to optimize the cost (case 1), it would be 9 times less than case 2 and 80 times less than case 3 but it is unhuman.

We also notice that the critical area is in the north-east. The major part of the hospital is already concentrated in this particular area but it could be a good idea to build some beds to avoid injured people in this zone to go to the south.