IE 709 : Assignment 1

Aakash Banik (16i190010) Gaurav Amrutkar (173190022)

Indian Institute of Technology Bombay

---

1. Solution 1

1.1. Part a

Minimum No. of Ambulances required to cover all locations within a response time threshold of 10 minutes is 3.

File: ex1a.py. **Output File: output1a.jpg**

Formulation:

We have 85 localities and 40 candidate locations for EMS Let, $x_i = 1$, if EMS is located at candidate location i ; 0 otherwise. i=1(1)40.

The objective function is given as:

$$minimize \sum_{i=1}^{40} x_i$$

subject to :

$$\sum_{i \in W_j} x_i \geq 1 \forall j = 1(1)85$$

$$x_i \in \{0, 1\} \forall i = 1(1)40$$

where, W_j is the set of all candidate locations around location j.

1.2. Part b

file: ex1b.py **Output File: output1b.jpg The plot is attached in the submission. The plot in general shows a non-increasing trend of the no. of ambulances with the increase in threshold time, which**

makes perfect sense because as the threshold time increases, it is intuitive that that the coverage of the ambulance increases and thus the no. of ambulances required decreases. It is to be noted that the solver provides a LPR solution for the threshold times in which the problem is infeasible[for threshold times= 4 and 5].

1.3. Part c

In part a, we found out 3 ambulances are required to cover all locations. Now we introduce other models to find a better redistribution of the ambulances. We will consider two different models in order to fine tune our solution.
In our first approach, we maximize the population to which the EMS service is to be provided.
Formulation 1:
Let, $x_i = 1$, if EMS is located at candidate location i ; 0 otherwise. i=1(1)40.
Let, $y_j = 1$, if j^{th} location is covered by at least one ambulance; 0 otherwise. j=1(1)85.
Let p_i be the population of the i^{th} locality. The objective function is given as:

$$maximize \sum_{j=1}^{85} y_j * p_j$$

subject to:

$$\sum_{i=1}^{40} x_i \leq 3$$

$$\sum_{i \in W_j} x_i \geq y_j \forall j = 1(1)85$$

$$x_i \in \{0,1\} \forall i = 1(1)40$$

$$y_j \in \{0,1\} \forall j = 1(1)85$$

where, W_j is the set of all candidate locations around location j.

Objective Value: 499449 Optimal solution: Ambulances should be placed at locations 6, 18 and 31.
file: ex1c_maxpopln.py Output: output1c_maxpopln.jpg

In our second approach we minimize the time required for the EMS service to reach a locality.
Formulation 2:
Let, $x_i = 1$, if EMS is located at candidate location i ; 0 otherwise. i=1(1)40. t_{ij} is the time taken to travel from the i_{th} candidate location to the j_{th} locality The objective function is given as:

$$minimize \sum_{i=1}^{40} \sum j \in W_j x_i * t_{ij}$$

subject to:

$$\sum_{i=1}^{40} x_i \leq 3$$

$$\sum_{i \in W_j} x_i \geq 1 \forall j = 1(1)85$$

where, W_j is the set of all candidate locations around location j.

Objective Value: 1047 Optimal solution: Ambulances should be placed at locations 23, 23 and 37.
file: ex1c_mintime.py   output: output1c_mintime.jpg

1.4. Part d

Suppose 5 more ambulances are available in our model, the constraint equation upper bounding the no. of ambulances would change from 3 to 8.
Solution for Formulation 1: Objective: 499449 Optimal Solution: Ambulances should be placed at locations 1, 14, 23, 24, 27, 38, 39 and 7.
file: ex1d_maxpopln.py   Output: outputex1d_maxpopln.jpg

Solution for Formulation 2: The solution remains exactly same as was obtained from part-c of question 1. Objective: 1047 Optimal Solution: Ambulances are placed at locations 22, 23 and 37.
file: ex1d_maxpopln.py   Output: output_minttime.jpg

2. Solution 3

2.1. Similarities and Differences in Setting of Study

Similarities:

In both the papers the authors have tried to throw light on the current status of Emergency Medical Services facility in the middle economy and the developing countries like India compared to the developed countries like USA . They also tried to explain its advantages, importance and need.

Differences:

In the first paper by Sharma, 2013 he has precisely observed the current status of EMS in India and compared to the other countries he have suggested the various suggestions in terms of the centralized ambulance system, training medical personnel etc. in coordination with EMS agencies, government, police and fire departments, private hospitals, and the community which will ultimately lead to the progress in the prehospital care of the patients. While in the paper by Sriram etal.,2017 they have studied the actual model of centralized EMS implemented by the GVK Emergency Management and Research Institute in the coordination with the government in the various southern states of Karnataka. They have found that the model was very useful and they also suggested that the similar model of centralized EMS should be implemented across the whole country which will result into the effective handling of emergency services.

2.2. Observations and Data

What Sharma observed that near about 47 of the maternal emergency patients are able to take the advantage of the EMS while in case of other emergencies the number is less than 20%. What sriram observed was in 2012, an average of 609,332 calls were handled each month; of those, 67,135 (11%) were considered emergency calls. From January to May 2013, 255,739 calls were considered medical emergencies. Out of these, 79% were on average considered medical emergencies. In Bengaluru, 5,433 individuals on average used the service from January to May 2013. The average response time in the state from January to May 2013 was 25 minutes; the average transport time (scene to hospital) was 33

minutes. In Bengaluru, average response time was 13 minutes and transport time was 22 minutes. In comparison, in rural Karnataka, the response time was 26 minutes and transport time was 31 minutes. They have observed precisely the various building blocks such as Service Delivery, Human Resource, Supply Chain, Information Technology/ Information Systems, Governance etc.

2.3. Key Problems

The problems faced in both the papers are almost similar. The Indian health care system generally lacks modern infrastructure and coordination. The poor continue to lack access to quality health care. Low literacy levels, high population density, and widespread corruption have led to inadequate standards of pre-hospital and in-hospital care. Affluent citizens do not trust health services provided by the government and prefer medical treatment at private hospitals that often maintain standards comparable to the developed world.

2.4. Suggestions

Paper 1- Centralized EMS EMS Training Standards Coordination between government, private hospitals, people etc.
Paper 2- The model implemented in the state of Karnataka is showing positive results and so should be implemented across the whole country.

IE 709

SOLUTION-2:-

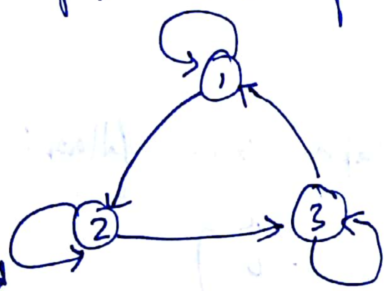
We will be constructing a small eg. where a set of n locations needs to be covered with minimum no. of ambulance service such that the optimal solution of the LP Relaxation problem is not an integer.

Consider $n=3$:-

So, we have 3 localities.

Let $x_i = \begin{cases} 1, & \text{if } \text{~~ith locality is covered by an~~ an ambulance service is situated at location } i \\ 0, & \text{ow.} \end{cases}$

The graph is as follows:-



The directed edges denotes which areas does the service cover. The graph can be represented by the following binary matrix which, where a_{ij} takes the value 1 if the service at i^{th} location also covers j^{th} location; 0 otherwise.

$$\begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \end{bmatrix}$$

The formulation of the above problem is given as:-

$$\text{Min} \sum_{i=1}^{3} x_i$$

subject to:

$$x_1 + x_2 \geq 1$$
$$x_2 + x_3 \geq 1$$
$$x_1 + x_3 \geq 1$$
$$x_i \in \{0,1\} \quad \forall i = 1,2,3$$

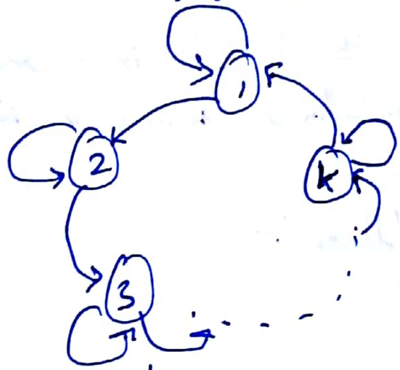
The above formulation would have resulted in an objective value of 2.

But if ~~the~~ we consider the LP Relaxation of the above problem, ~~it would~~ the objective would have been 1.5.

This pattern can be generalised for large n when <u>n is odd</u>.

for <u>n=k, where k is odd</u>.

~~The~~ We construct the graph as follows:—



The matrix form of the graph is as follows:

$$\begin{array}{c|c}
 & \begin{matrix} 1 & 2 & 3 & \cdots & k \end{matrix} \\
\begin{matrix} 1 \\ 2 \\ \vdots \\ k \end{matrix} & \begin{bmatrix} 1 & 1 & 0 & \cdots & 0 \\ 0 & 1 & 1 & 0 \cdots & 0 \\ \vdots & & & & \\ 1 & 0 & 0 & \cdots 0 & 1 \end{bmatrix}
\end{array}$$

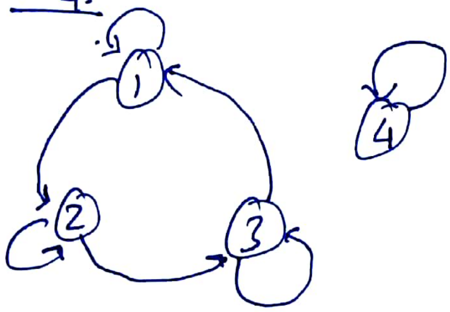
The ~~Integer~~ LP Relaxation of the above formulation would have given a non ~~integer~~ integer objective value.

Now, when n is even.

We construct our eg. by slightly modifying our previous case.

We put no edges [self connecting] in one of the node, and connect the other nodes in a similar fashion as done earlier.

for eg. $n=4$.



The matrix of the graph is as follows :-

$$\begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The formulation of the above problem is :-

$$\min \sum_{i=1}^{4} x_i$$

s.t.

$$x_1 + x_2 \geq 1$$
$$x_2 + x_3 \geq 1$$
$$x_3 + x_1 \geq 1$$
$$x_4 \geq 1$$
$$x_i \in \{0,1\} \quad \forall\, i = 1(1)4$$

The obj. value of the above problem is 3.
but the LPR would have ~~been~~ yielded an obj. value of 2.5.

The general case for $n =$ even can be constructed in a similar way.