OVERVIEW OF THE PROBLEM

Why ?

2619 accidents in last 2 yrs----
Hyderabad ORR

Fatal accidents were **4%** of total accidents

Every 10-minute delay in treatment is associated with a 6% increase in the odds of a poor outcome*

Objective: To reduce the number of fatal accidents by minimizing the response time.

How?

Reducing the travel time of Emergency Services.

By optimising the ambulance location with respect to historic accident data.

Ensuring Coverage of each accident locations.

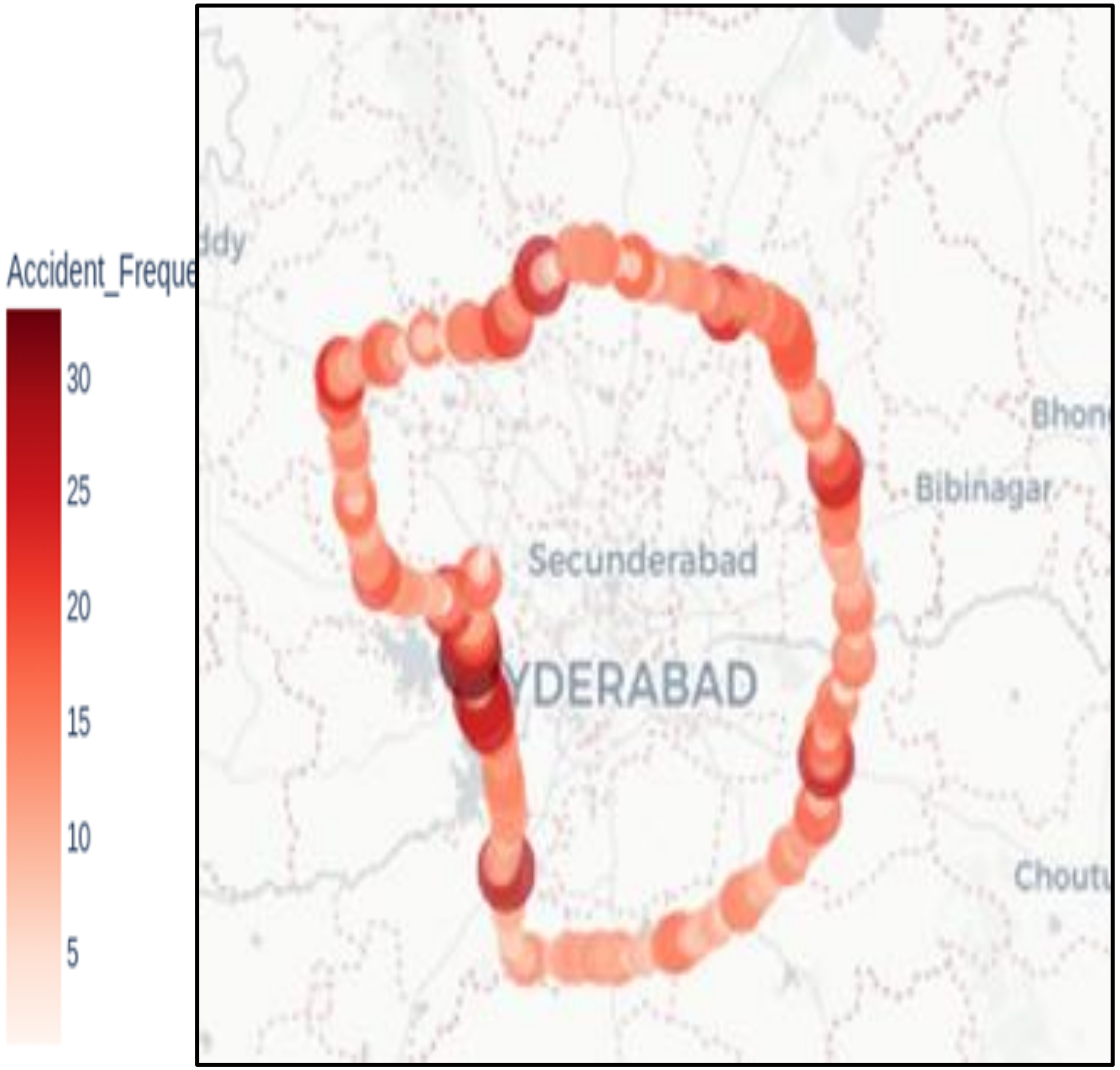
*Source- https://medicalxpress.com/news/2020-10-exploring-golden-hour-trauma-treatment.html

ACCIDENT DATA PREVIEW

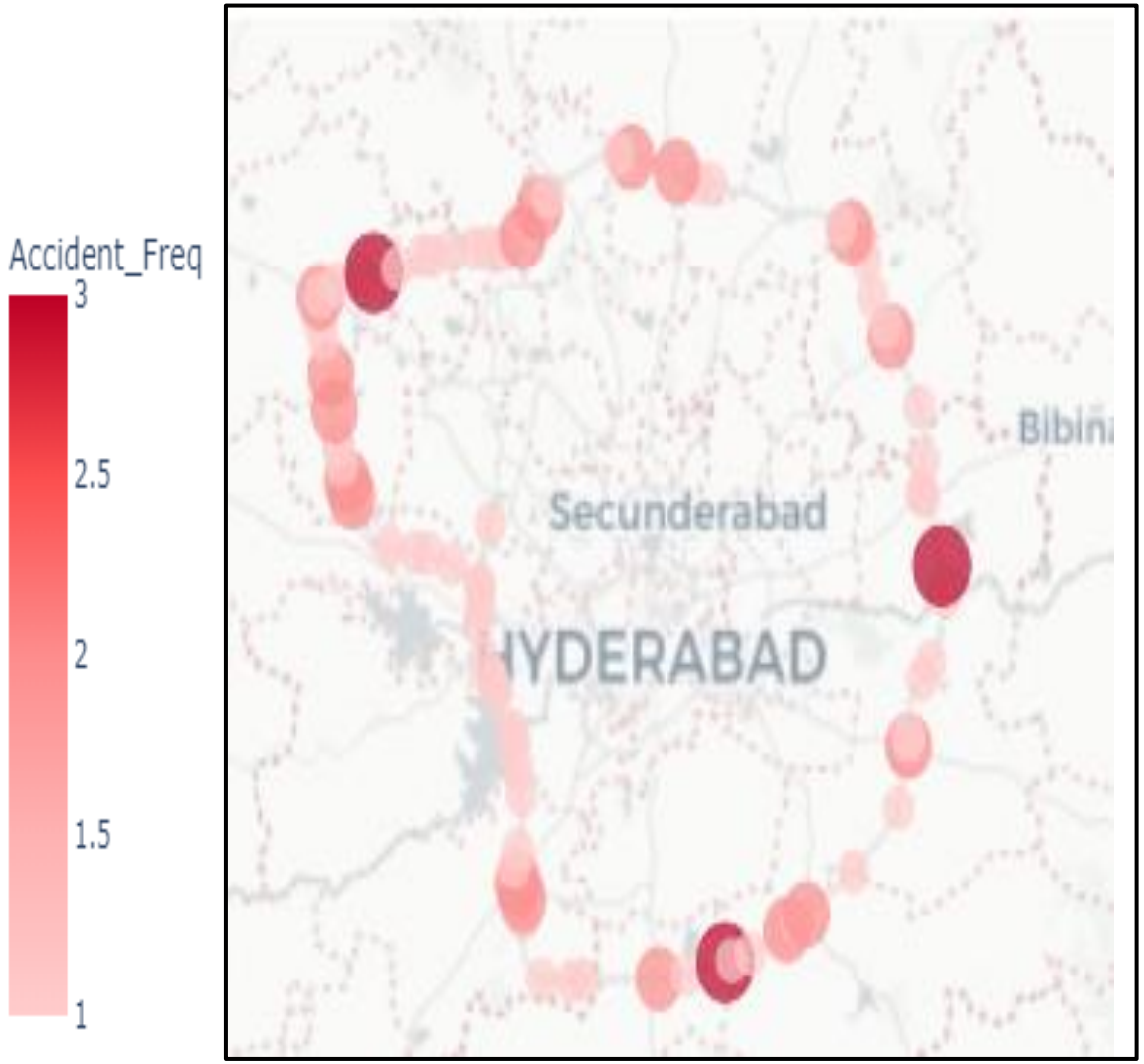
Date	Time	Exact Chainage	INNER/OUTER	Nature of Accident	Fatal	Major	Minor	Non-Injured	KM 's Covered	Ambulance Started Time:	Time when Incident Manangement Team reached at Site	Time when Incident Manangement Team cleared the Site	Details of Treatment & Shifting	Action taken Shifted to Trauma Care/Shited to Hospital/Treatment at Scene/Other
2 Jul 23	1:50	0.100	OUTER	Minor	0	0	1	1	46	01:51 AM	01:56 AM	04:24 AM	First aid given at Scene	Shifted to LIMS Hospital,Shamshabad
15 Aug 23	4:03	0.100	INNER	Non - Injury	0	0	0	1	4	04:04 AM	04:08 AM	04:29 AM	No Injuries	No Emergency
9 Nov 23	5:18	0.100	OUTER	Minor	0	0	2	0	24	5:30	5:42	5:40	First aid given at Scene	Treatment given at Trauma Center & Discharged
15 Oct 23	12:22	0.200	OUTER	Minor	0	0	1	2	37	12:28	12:36	12:43	First aid given at Scene	Shifted to Yashoda Hospital, Hitec City
29 Jan 24	3:54	0.000	Outer	Non - Injury	0	0	0	1	0				No Injuries, No Ambulance required	No Emergency
16 Mar 22	23:12	0.500	OUTER	Minor	0	0	2	0						
10 Apr 22	3:30	0.500	OUTER	Minor	0	0	1	0	18	4:36	4:40	10:30	O2 TERAPY.FIRST AED	NONE
4 Jan 24	14:11	0.500	Outer	Non - Injury	0	0	0	2	0				No Injuries, No Ambulance required	No Emergency
5 May 23	4:10	0.520	INNER	Non - Injury	0	0	0	1	46	04:06 PM	04:11 PM	04:30 PM	Right Lower Limb Fracture	Shifted to Sunrise hospital, Shamshabad
28 Oct 23	9:00	0.650	INNER	Non - Injury	0	0	0	1	0	N/R	N/R	9:28	No Injuries, No Ambulance Required	No Emergency
15 Jan 22	0:12	1.000	INNER	Minor	0	0	1	0						
1 Jun 23	8:31	1.000	INNER	Minor	0	0	1	0	33	08:32 AM	08:41 AM	08:55 AM	First aid given at Scene	Treatment given at Trauma Center & Discharged
8 Mar 24	8:36	1.000	Inner	Non - Injury	0	0	0	1	17				No Injuries, No Medical Emergency	No Emergency
28 May 24	11:55	1.000	Inner	Non - Injury	0	0	0	1	3				Small Lacerasion at Right Knee, First aid given	Treatment given at Trauma Center & Discharged
29 Apr 24	2:55	1.050	Inner	Non - Injury	0	0	0	1	-				No Injuries, No Ambulance Required	No Emergency
30 Apr 23	0:01	1.100	INNER	Non - Injury	0	0	0	1	8	12:03 AM	12:07 AM	12:13 AM	No Injuries, No Medical Emergency	No Emergency
30 Jan 22	2:00	1.200	OUTER	Minor	0	0	1	0						

MAPPING OF ACCIDENTS

All accidents with intensity

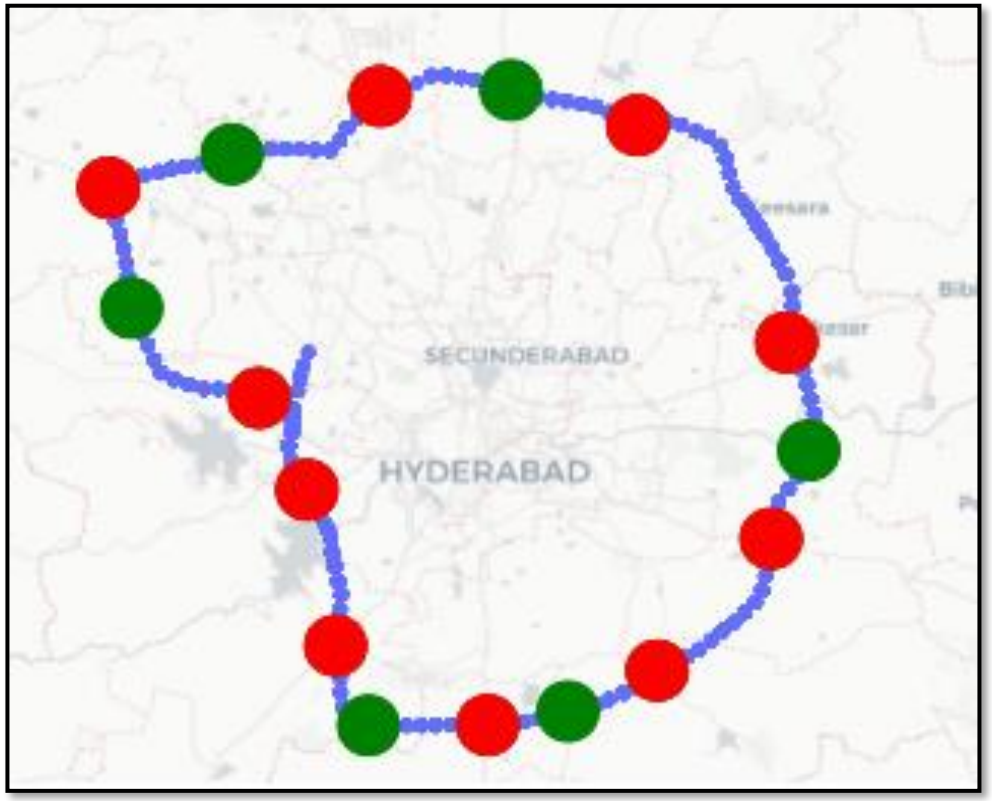


Fatal accidents with intensity



CURRENT & TOTAL AMBULANCE LOCATIONS

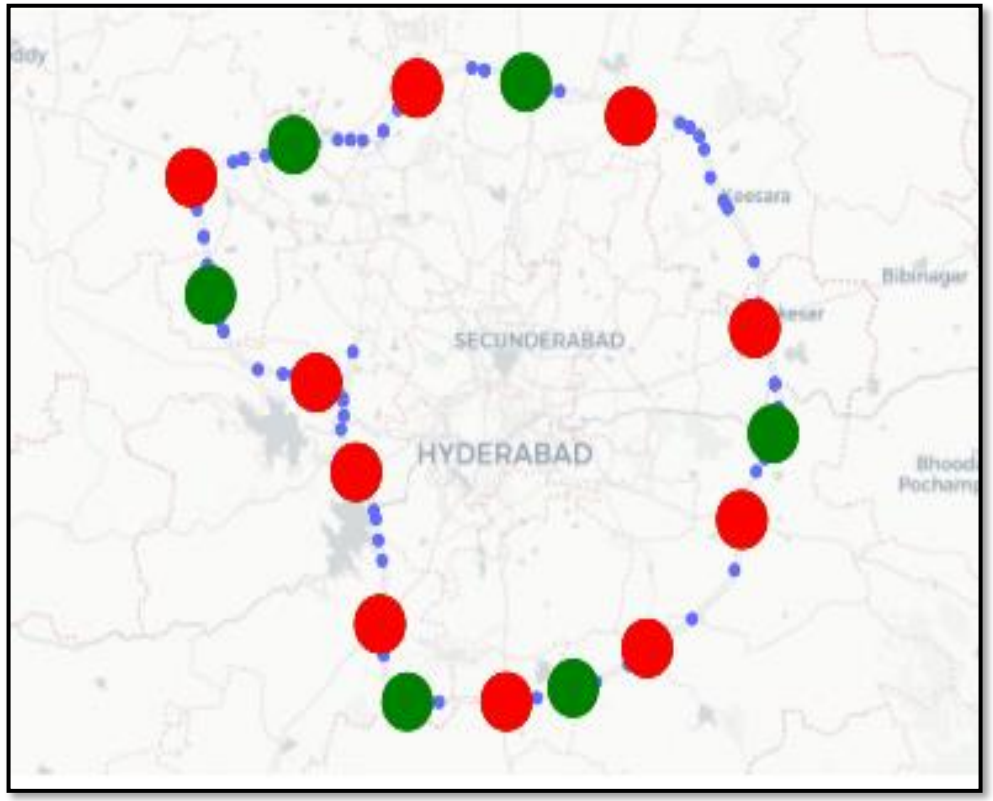
Hyderabad- ORR has 16 Trauma sources with 10 Ambulances over 157km length



All accident spots

Trauma Centre- Ambulance Deployed

Trauma Centre- No Ambulance



Fatal accident spots

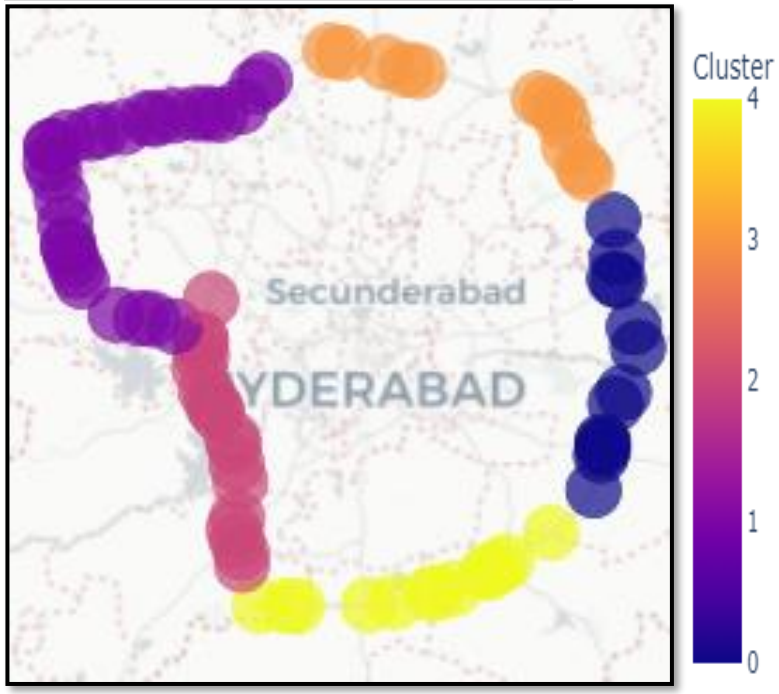
Trauma Centre- Ambulance Deployed

Trauma Centre- No Ambulance

CLUSTERING FATAL ACCIDENTS

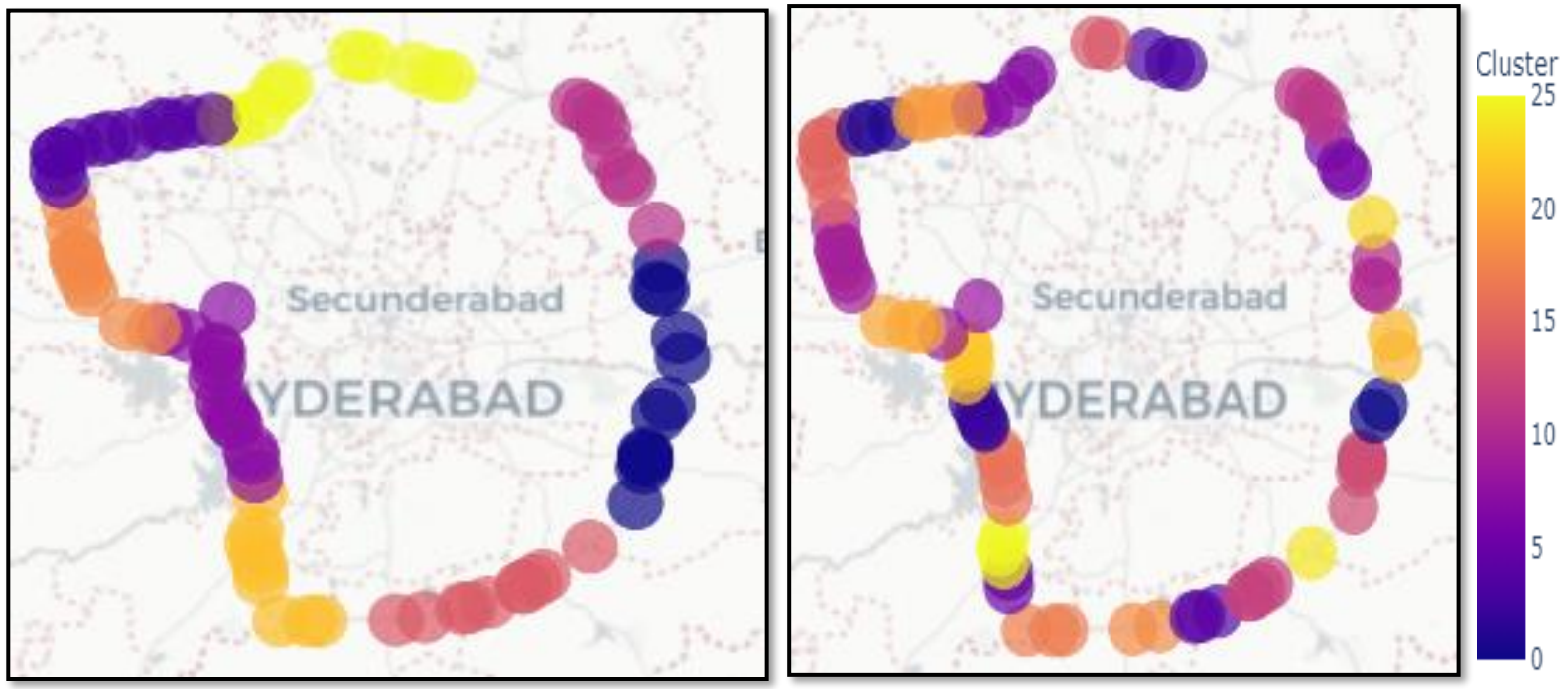
KMeans

With intensity



Clustering wrt Freq and Optimisation, N= 5 elbow point

Without intensity



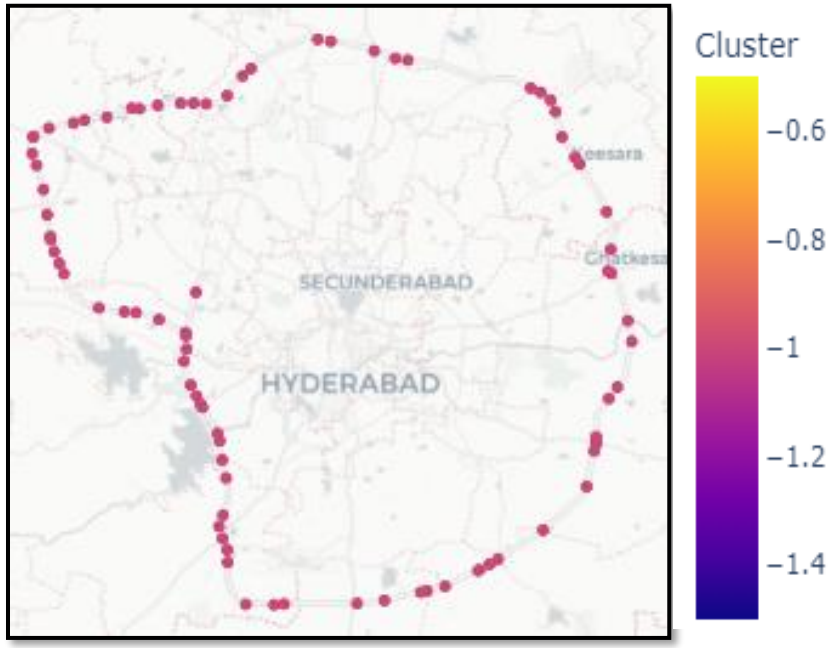
Clustering wrt Lat-Lon N=8 elbow point for Fatal acc. & N=26 for all accidents

N-> based on:
1- Silhouette Score | 2-Davies Bouldin Index

CLUSTERING FATAL ACCIDENTS

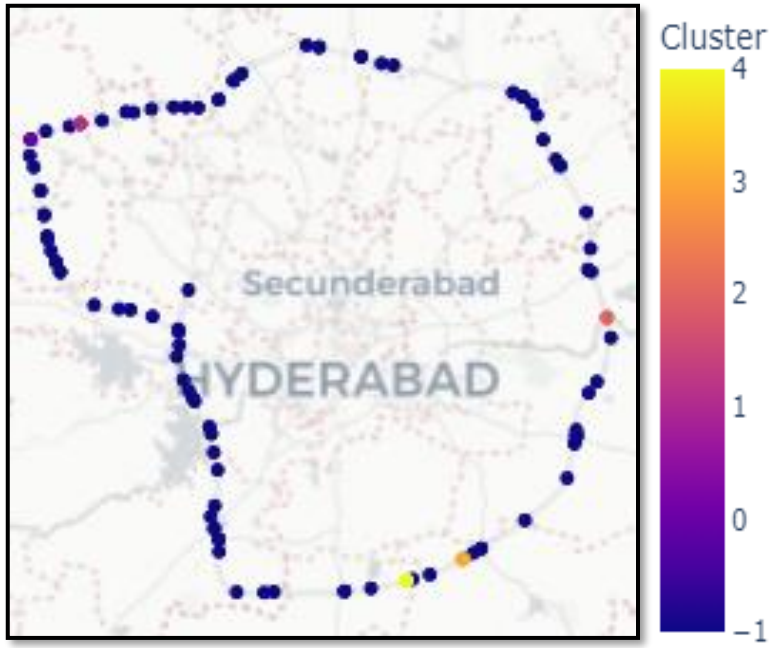
DBSCAN

With intensity



Clustering wrt Accident Freq leads to each data point classified as single cluster -1

Without intensity



Clustering with Lat Lon and 300m tolerance radii leads to -1 “no cluster” to most locations

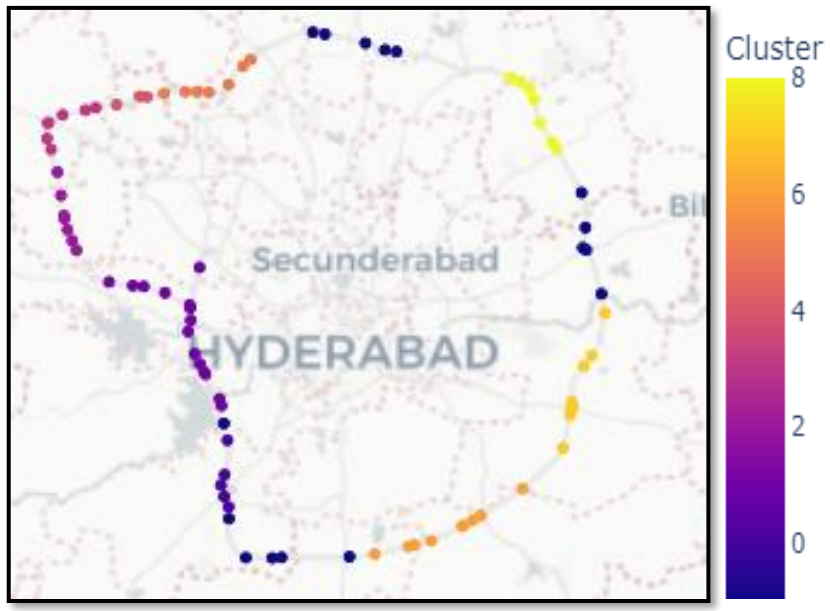
For ε= 350m leads to Silhoutte score= 0.94 and min no. of noises off all iterations

- ε – 300m
- min_sample=3

CLUSTERING FATAL ACCIDENTS

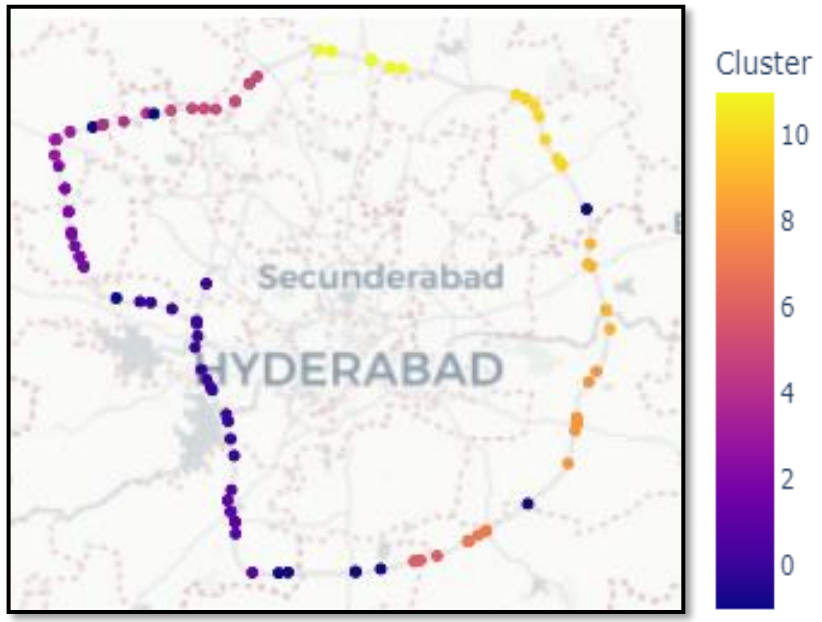
OPTICS

With intensity



N=8 for Clustering wrt. Accident frequency

Without intensity

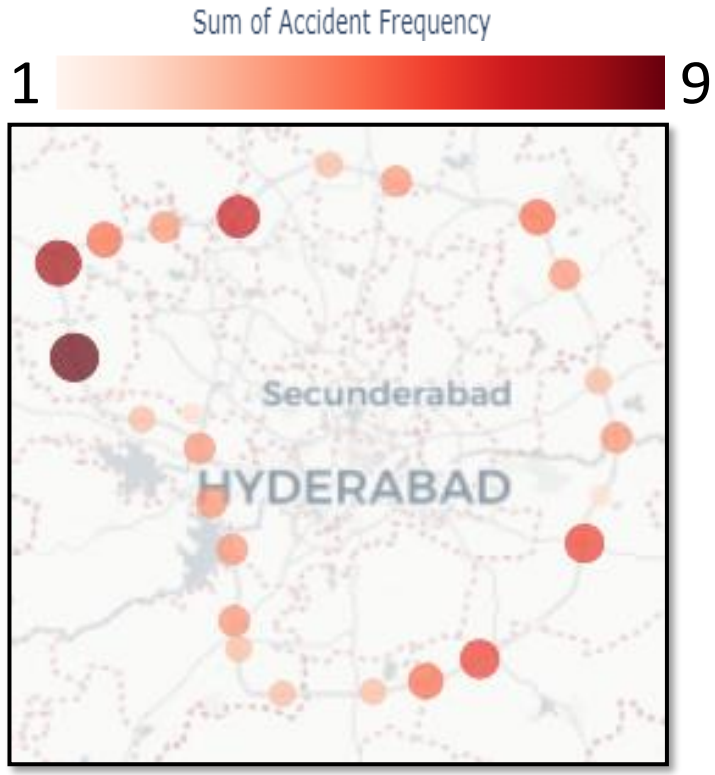


N=10 for Clustering wrt Accident Lat-Lon only.

- min_samples=5
- min_cluster_size=3

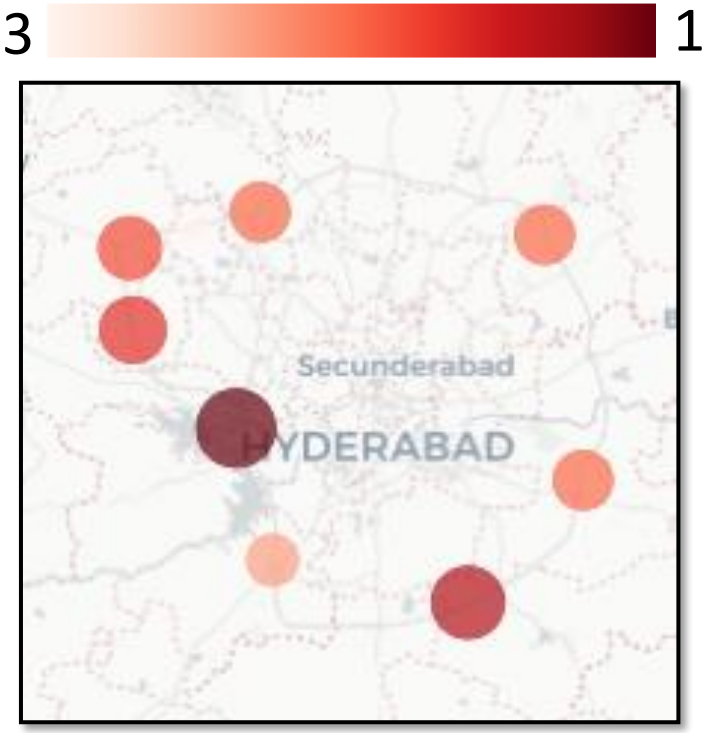
CENTROIDS OF EACH CLUSTER PLOTTED

KMeans | DBSCAN | OPTICS



Well defined clusters covering all the location

No centroid since labels -1



Only identified major points but did not account for other regions with potential accidents

OD DISTANCE-TIME MATRIX

1. Chainage based Distance Matrix

	s0-dp	s1-dp	s2-dp	s3-dp	s4-dp	s5-dp	s6-dp	s7-dp	s8-dp	s9-dp	s10-dp	s11-dp	s12-dp	s13-dp
0	66.575	78.225	69.625	61.125	49.355	39.925	31.025	10.575	2.625	4.565	17.775	23.875	29.375	38.125
1	24.760	12.860	4.260	4.240	16.010	25.440	34.340	54.790	62.740	69.930	73.560	67.460	61.960	53.210
2	11.085	22.985	31.585	40.085	51.855	61.285	70.185	66.065	58.115	50.925	37.715	31.615	26.115	17.365
3	51.900	40.000	31.400	22.900	11.130	1.700	7.200	27.650	35.600	42.790	56.000	62.100	67.600	76.350
4	43.200	55.100	63.700	72.200	72.730	63.300	54.400	33.950	26.000	18.810	5.600	0.500	6.000	14.750
5	24.200	36.100	44.700	53.200	64.970	74.400	73.400	52.950	45.000	37.810	24.600	18.500	13.000	4.250
6	70.000	58.100	49.500	41.000	29.230	19.800	10.900	9.550	17.500	24.690	37.900	44.000	49.500	58.250
7	36.700	24.800	16.200	7.700	4.070	13.500	22.400	42.850	50.800	57.990	71.200	77.300	73.900	65.150
8	77.340	65.440	56.840	48.340	36.570	27.140	18.240	2.210	10.160	17.350	30.560	36.660	42.160	50.910
9	11.500	0.400	9.000	17.500	29.270	38.700	47.600	68.050	76.000	73.510	60.300	54.200	48.700	39.950
10	77.150	67.650	59.050	50.550	38.780	29.350	20.450	0.000	7.950	15.140	28.350	34.450	39.950	48.700

2. API based Distance Matrix

	s0-dp	s1-dp	s2-dp	s3-dp	s4-dp	s5-dp	s6-dp	s7-dp	s8-dp	s9-dp	s10-dp	s11-dp	s12-dp	s13-dp
0	50.2070	62.2795	72.9537	61.2537	61.5134	52.5934	42.4348	23.9456	11.9002	5.9235	17.4293	24.2599	29.4527	37.4589
1	30.3690	21.5845	15.1772	16.0957	18.0842	27.1059	34.2700	57.1020	63.2172	71.2460	80.5129	73.3628	67.8280	75.8685
2	8.3585	20.4310	31.1052	32.2810	34.2938	41.1191	50.3292	39.4633	46.2386	38.5914	39.9241	32.7741	27.2393	35.2797
3	48.4581	56.2482	49.8410	39.1229	28.7288	20.4567	7.1333	29.9652	36.0804	44.1092	55.6150	62.4456	57.4355	65.4656
4	40.1279	52.2004	62.8747	64.0505	59.3448	55.2968	56.1878	37.6986	27.3239	22.2743	8.0589	0.8779	6.1055	14.1116
5	21.0950	33.1675	43.8418	45.0176	47.0303	48.1741	57.3842	44.1955	45.2922	37.6449	30.7141	23.5640	18.0292	26.0697
6	51.0109	60.2894	53.8821	43.1640	32.7700	24.4978	13.6913	11.8884	18.0036	26.0324	37.5382	44.3688	49.5616	57.5678
7	36.0677	35.3779	28.9706	18.2525	6.1327	15.1545	22.3186	45.1505	51.2658	59.2946	70.8004	69.0027	63.1352	71.1653
8	6.5471	14.8496	25.5238	25.9622	27.9750	39.3008	44.1609	40.0186	46.7940	39.1467	49.0890	41.9390	36.4042	44.4446
9	19.9616	0.5909	11.2772	29.3551	31.3435	40.3653	47.5294	56.6604	63.4357	55.7884	59.5378	52.3878	46.8530	54.8934
10	59.0474	67.9333	61.5261	50.8080	40.4139	32.1418	21.3353	19.9381	26.0533	34.0821	45.5879	52.4185	57.6113	65.6175

Comparison

1. The distance calculated with chainage considers the shortest distance clockwise and anti-clockwise
2. The distance calculated using OpenStreetMap takes shortest route from ambulance source to Demand Point

*Assumed V=110km/hr

OPTIMIZATION MODULE

4. Problem formulation

The double standard model (DSM) developed by Gendreau et al. (1997) has been used in this paper for South Delhi.

4.1. Sets

I – Set of accident locations → 26 - KMeans
J – Set of potential ambulance locations → 16

4.2. Parameters

a_i - Weight assigned to each demand node (cluster) i as the count of accidents → Weightage matrix calculated→ [2, 5, 4, 4, 5, 3, 4, 7, 2, 9, 3, 5, 6, 6, 3, 8, 4, 3, 3, 4, 3, 4, 4, 1, 1, 4]
t_{ij} $(or\ t_{ji})$ – Shortest travel time from i to j (or j to i) using historical data → Time Matrix calculated (Chainage, API based)
r_1 – Primary coverage standard (mins) → **[8,10,12,14,16,18,20]**

r_2 – Secondary coverage standard (mins) → **[12,14,16,18,20,22,24]**
α – Level of reliability → **[0.80,0.85,0.90,0.95,1.0]**
P – Number of ambulances to be located → **16**
p_j - Maximum no. of vehicles that can be located at each site j → **2**
n – Total number of accident sites (demand sites) → **26**
m – Total number of potential ambulance locations → **16**

4.3. Decision Variables

$z_i^k = 1$, if demand node i gets covered k times within r_1 time units and 0 otherwise →

```
for k in demand_points:
    k_times = pulp.lpSum(1 for j in source_locations if t_ij[(k,j)] <= r_1 and n_j[j] != 0)
    problem += k_times >= 1
    problem += z_i1[k] == 1 if k_times >= 1 else z_i1[k] == 0
```

$a_{ij}^1 = 1, if\ (t_{ji} \leq r_1)$ – A facility j covers demand at i within r_1 time units and 0 otherwise
$a_{ij}^2 = 1, if\ (t_{ji} \leq r_2)$ – A facility j covers demand at i within r_2 time units and 0 otherwise
n_j – Number of vehicles at site j

In this paper, the application of double standard model is done with the following assumptions:

- All ambulances are assumed to be available throughout the day.
- Ambulances are used for road traffic crashes only.

The formulation for the double standard model can be given as:

$$\textit{Maximize} \quad f = \sum_{i=1}^{n} a_i z_i^2 \tag{1}$$

$$\textit{Subject to} \quad \sum_{j=1}^{m} a_{ij}^2 n_j \geq 1 \quad \forall i \in I \tag{2}$$

$$\sum_{i=1}^{n} a_i z_i^1 \geq \alpha \sum_{i=1}^{n} a_i \tag{3}$$

$$\sum_{j=1}^{m} a_{ij}^1 n_j \geq z_i^1 + z_i^2 \quad \forall i \in I \tag{4}$$

$$z_i^2 \leq z_i^1 \quad \forall i \in I \tag{5}$$

$$\sum_{j=1}^{m} n_j = P \tag{6}$$

$$n_j \leq p_j \quad \forall j \in J \tag{7}$$

$$z_i^1, z_i^2 \in \{0,1\} \quad \forall i \in I \tag{8}$$

$$n_j \text{ is integer} \tag{9}$$

Difference from the paper

1. No spatial outliers in ORR data (Uniformly distributed data)
2. Clustering using ML Models no ArcGIS
3. Weights different for each location
4. Time matrix = Distance Matrix/v assumed
5. 2 time matrices calculated
6. Strain on each ambulance 2.6/dp while paper→ 4.13/dp

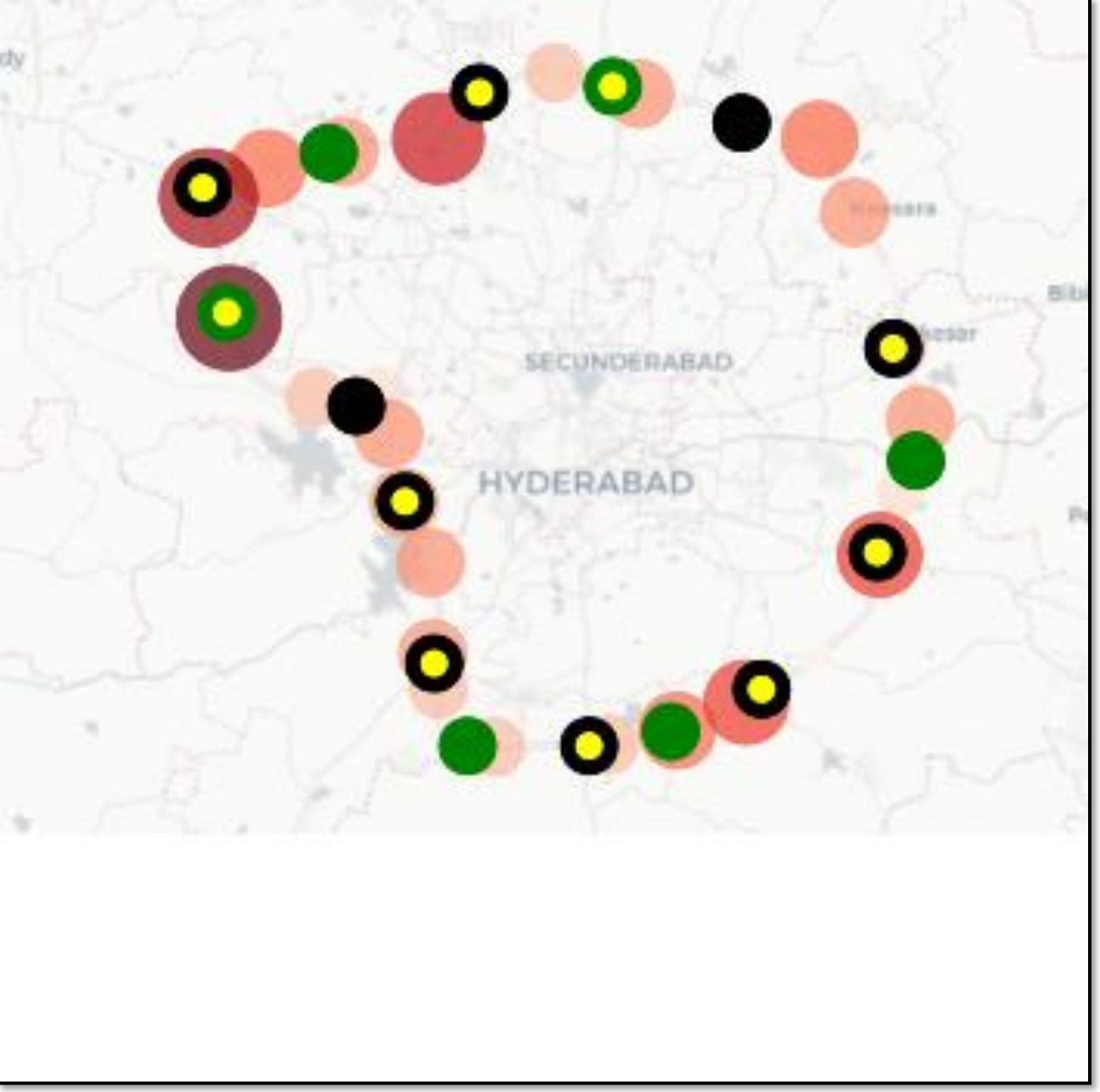
Variables understanding and assumptions

1. r2 – based on news article on ORR about avg response time 16mins
2. Alpha taken in range from 0.7 to 1.0 with 0.05 steps

ITERATIONS

Parameters changed in iterations:

- Number of Iterations (L)
- P_values=[6,8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20] ----> Total ambulances available
- Time_matrix=[time_np_chainage,time_np_orsm] ----- > choosing one of 2 time matrix ----> chainage/API based
- alpha=[0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 1.0] ------> level of reliability
- r1=[8,10,12,14,16,18,20] ---> Primary coverage time
  r2=[12,14,16,18,20,22,24] ----> Secondary coverage time



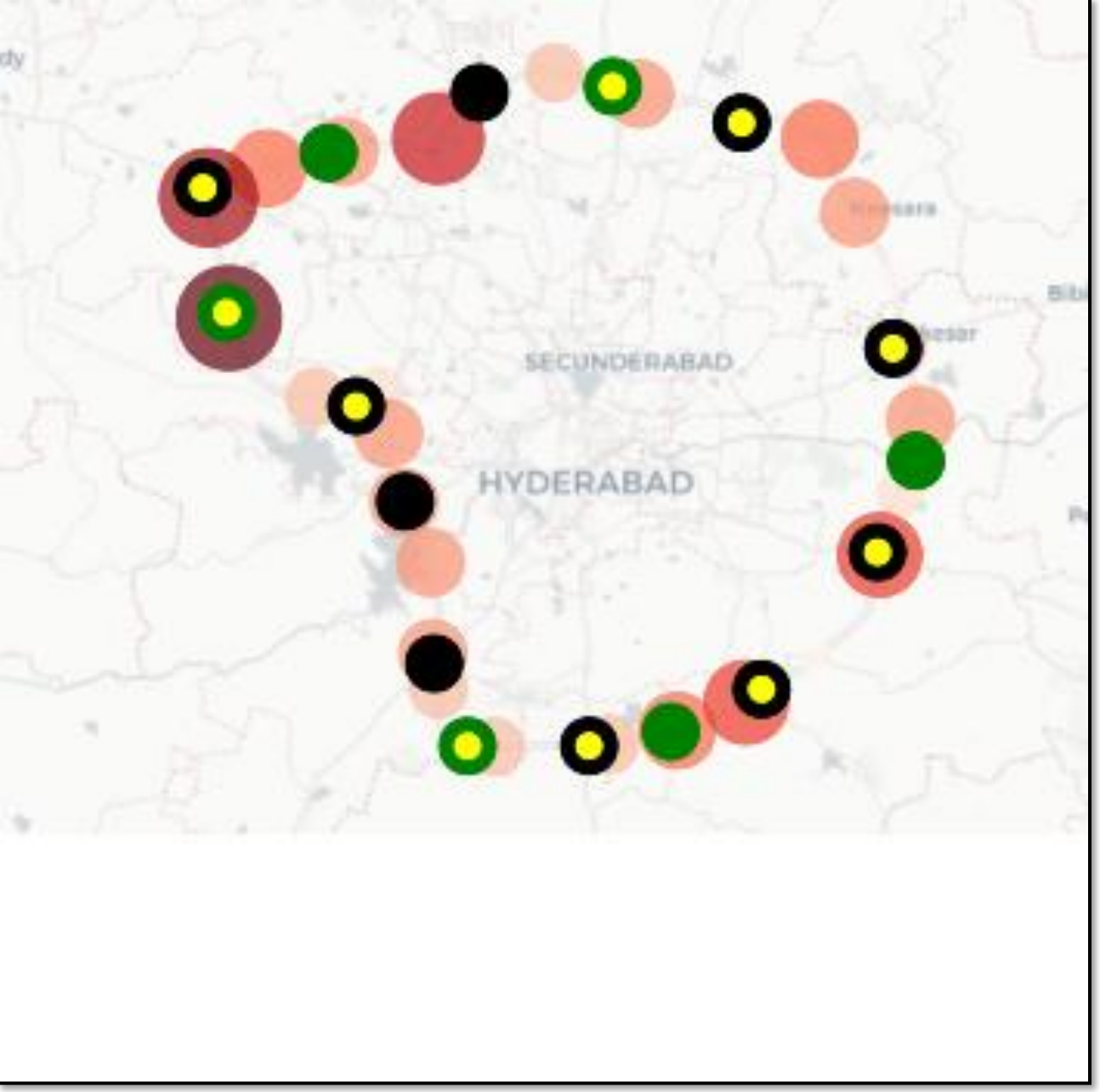
1

N=26
P=10
alpha=0.90
r_1= 8
r_2= 12

Trauma centers with no Ambulance deployment Before

Before Optimization Ambulance Location

After Optimization Ambulance Location



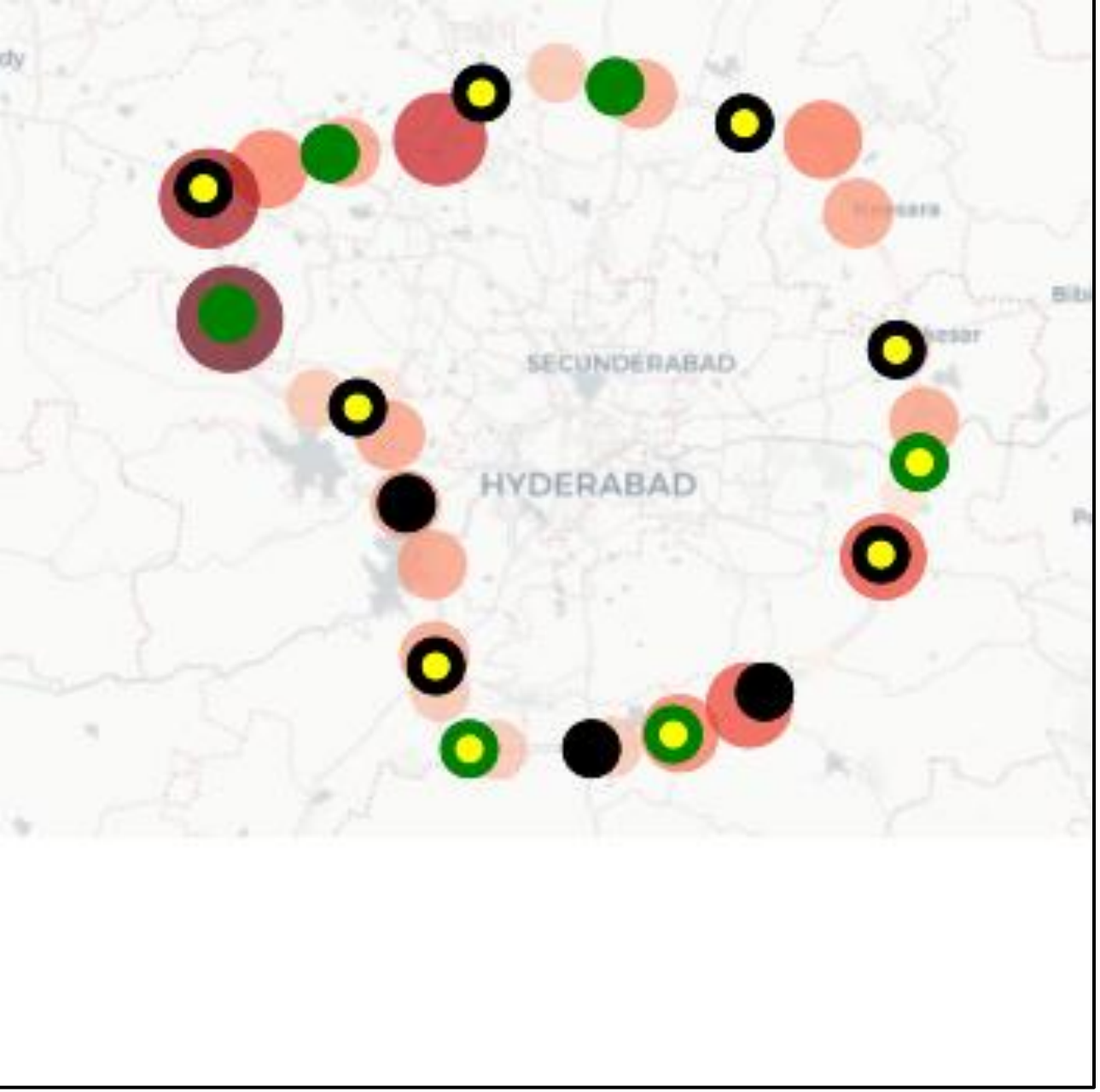
2

N=26
P=10
alpha=0.90
r_1= 10
r_2= 14

Trauma centers with no Ambulance deployment Before

Before Optimization Ambulance Location

After Optimization Ambulance Location



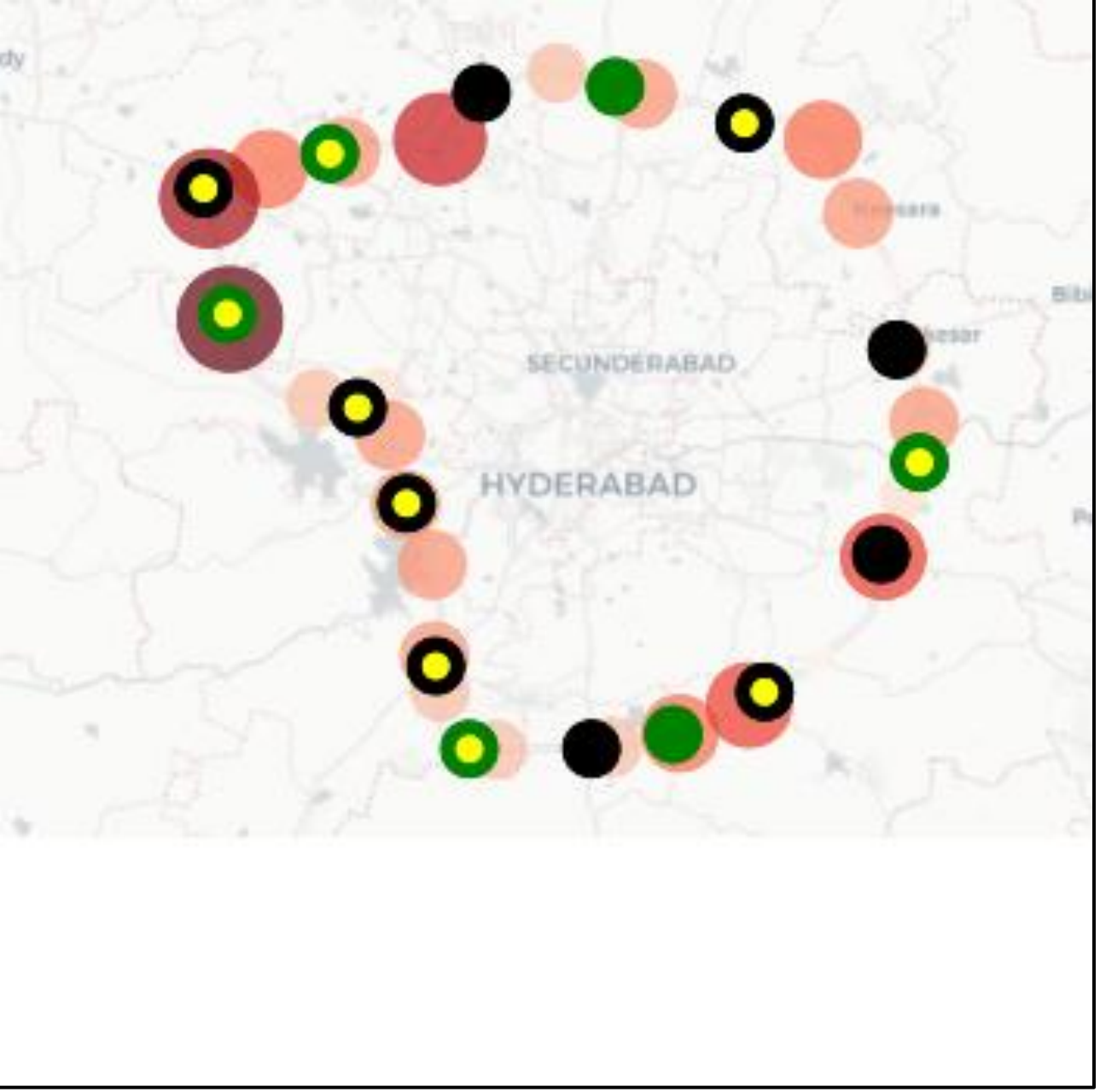
3

N=26
P=10
alpha=0.90
r_1= 12
r_2= 16

Trauma centers with no Ambulance deployment Before

Before Optimization Ambulance Location

After Optimization Ambulance Location



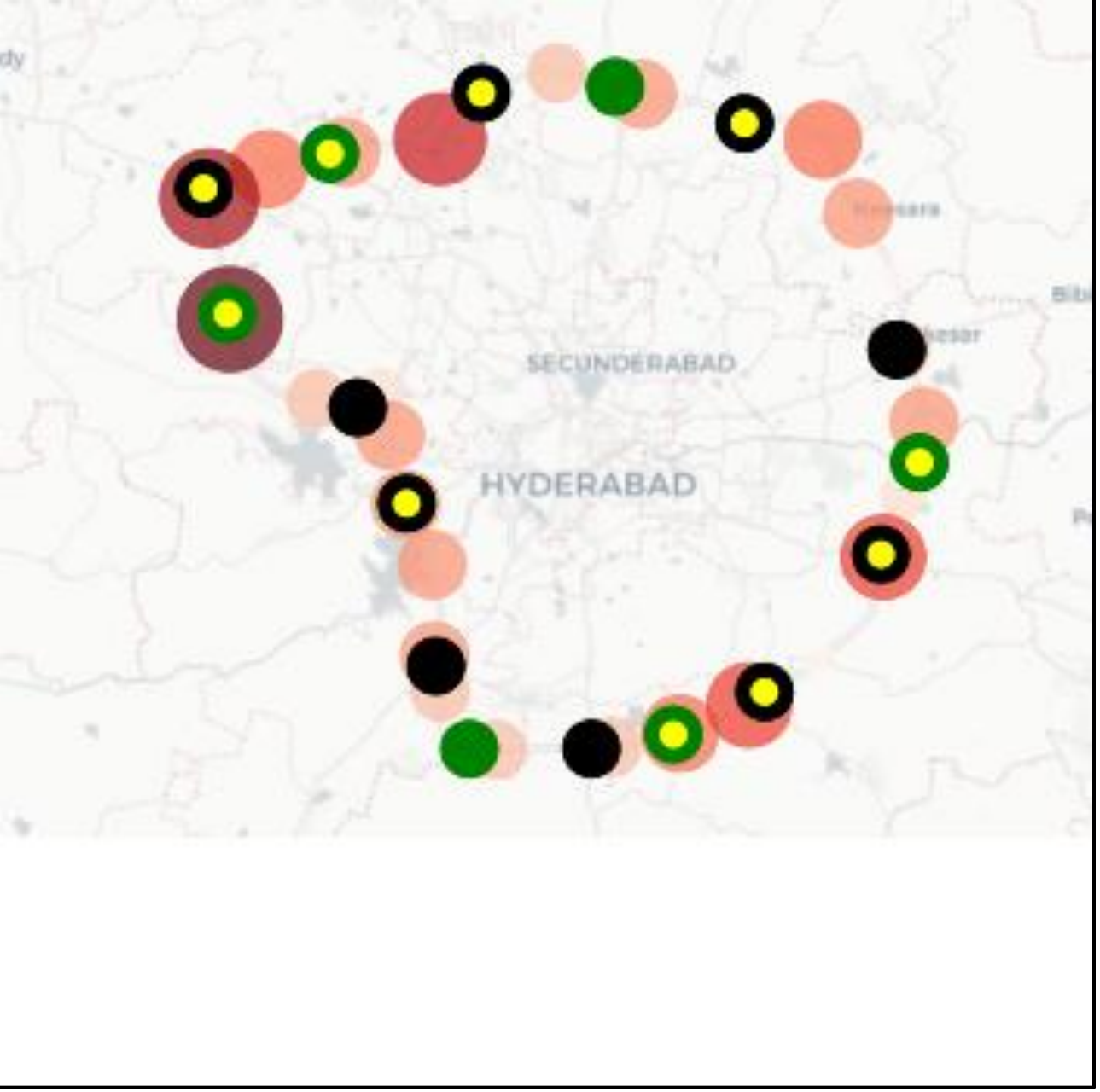
4

N=26
P=10
alpha=0.90
r_1= 14
r_2= 18

Trauma centers with no Ambulance deployment Before

Before Optimization Ambulance Location

After Optimization Ambulance Location



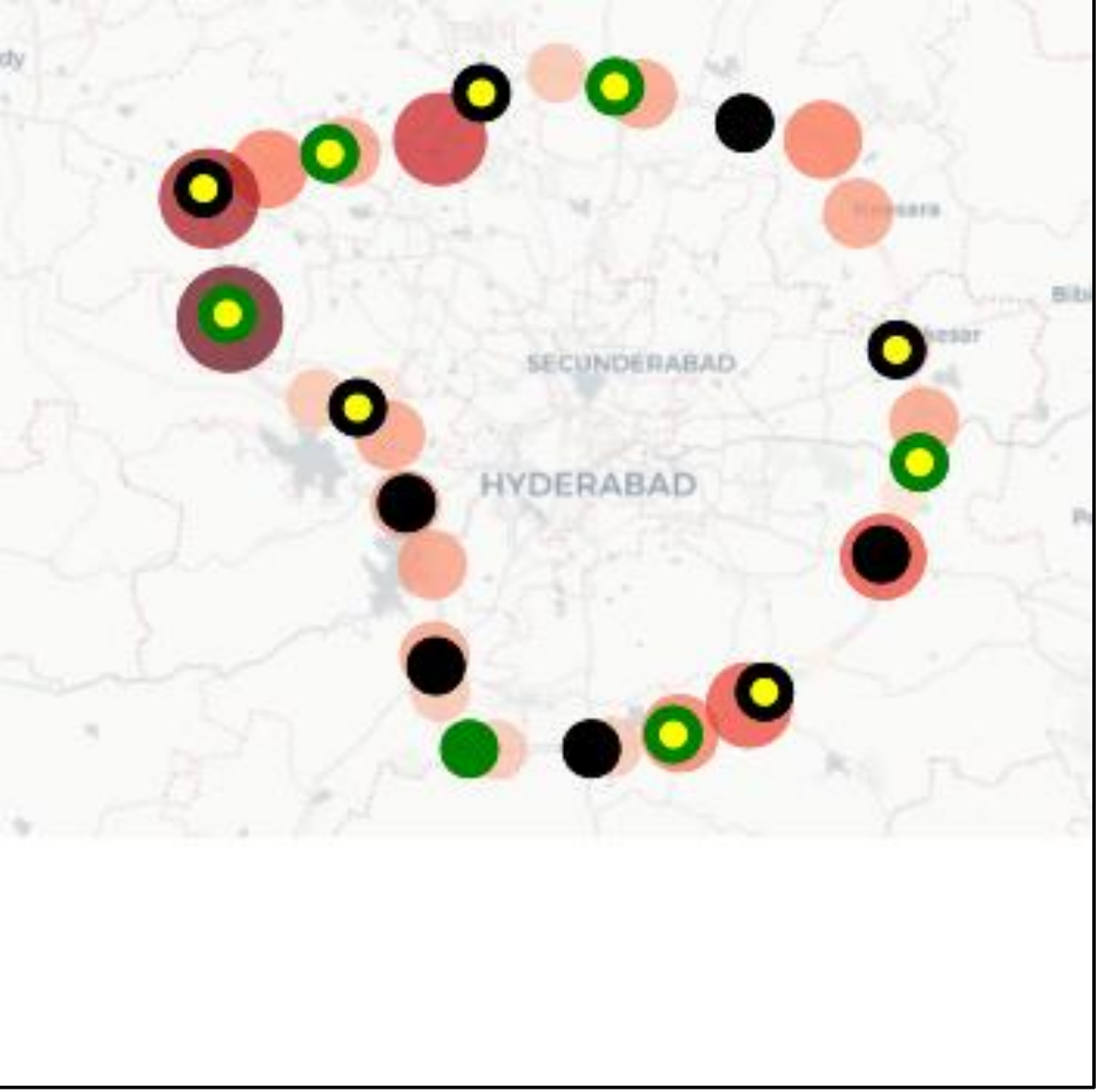
5

N=26
P=10
alpha=0.90
r_1= 16
r_2= 20

Trauma centers with no Ambulance deployment Before

Before Optimization Ambulance Location

After Optimization Ambulance Location



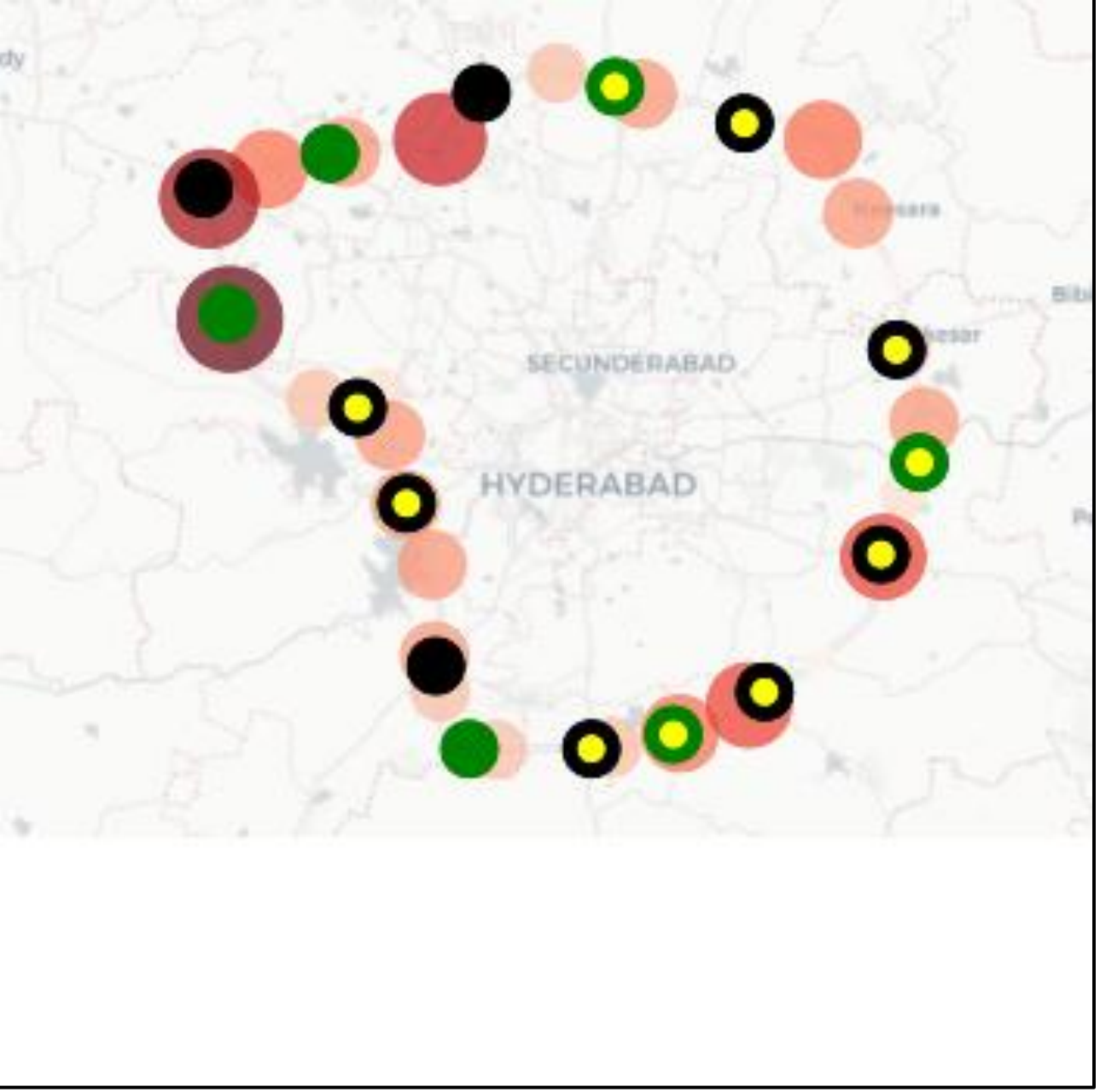
6

N=26
P=10
alpha=0.90
r_1= 18
r_2= 22

Trauma centers with no Ambulance deployment Before

Before Optimization Ambulance Location

After Optimization Ambulance Location



7

N=26
P=10
alpha=0.90
r_1= 20
r_2= 24

Trauma centers with no Ambulance deployment Before

Before Optimization Ambulance Location

After Optimization Ambulance Location

QUESTIONS

Q. 1- I have limited the total ambulances (P=10) and per site ambulances (pj=2). Does this affect the algorithm's output?

Q. 2- I used KMeans for clustering since the fatal accident dataset is uniformly spaced on the highway. Should I use DBSCAN instead, and if so, why?

Q. 3- I calculated the Time matrix using OpenStreetMap and chainage distances (clockwise and anti-clockwise, this considers the fact that for emergency, Ambulances can travel wrong direction for quicker response). Which approach is better?

Q. **4**- The value zik=1 if demand node i is covered k times within r1 time units, and 0 otherwise. What does k=2 mean? Does it refer to the secondary response time?

Q. 5- After using PuLP for optimization to maximize Σai*z2i , I am consistently getting a maximum value of 107.0, and 61.0 for other parameters. Given the objective is to maximize secondary coverage to all sites, is the maximum value better?

Q. 6- For optimization results, we get a max value of 107 (full coverage within 20 min). Should we choose the minimum $r1$ with max alpha or look at the plots on the map?