LOCATING PARKS WITH A MULTIOBJECTIVE OPTIMIZATION METHOD

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Professor Shahriari
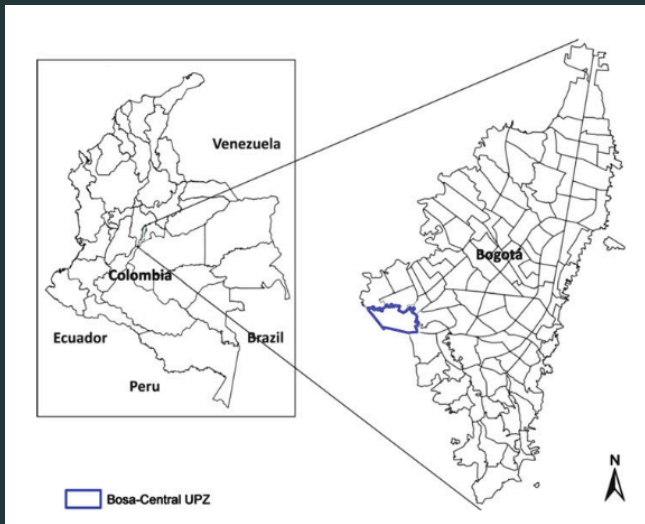
January 7, 2019

Pomona College

THE PROBLEM

· Large city
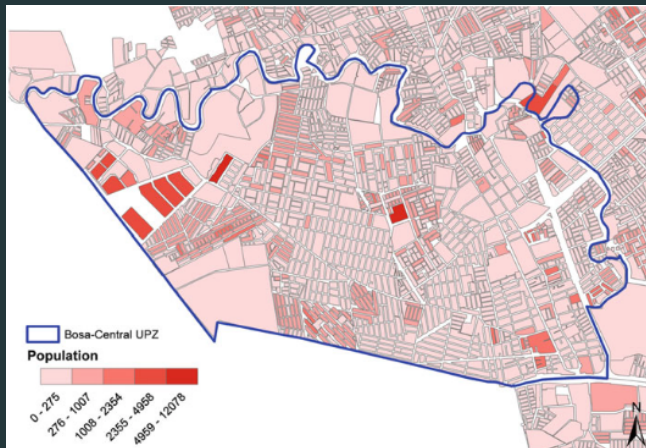
- Large city
- Sports and recreation master plan

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- Instituto Distrital de Recreación y Deporte

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- Instituto Distrital de Recreación y Deporte
- A challenge

Bosa-Central UPZ

BOGOTÁ, COLOMBIA

- Candidate parcels

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- Number of beneficiaries

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· Geographic coverage

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- Sidewalk and road accessibility
- Positive and negative externalities provided by nearby facilities
- Construction and parcel acquisition cost
- Competing objectives
- Community Based Operations Research

THE GROUNDWORK

- Mid-20th century development

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- Limited resources

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- Limited resources
- Competing activities

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- Optimal

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- Linear model

- Mid-20th century development
- Limited resources
- Competing activities
- Optimal
- Linear model
- Planning activities

$$
\begin{aligned}
\text{Maximize:} \quad & Z = c_1 x_1 + c_2 x_2 + \cdots + c_n x_n, \\
\text{subject to:} \quad & a_{11} x_1 + a_{12} x_2 + \cdots + a_{1n} x_n \leq b_1 \\
& a_{21} x_1 + a_{22} x_2 + \cdots + a_{2n} x_n \leq b_2 \\
& \qquad\qquad\qquad \vdots \\
& a_{m1} x_1 + a_{m2} x_2 + \cdots + a_{mn} x_n \leq b_m, \\
& x_1 \geq 0, x_2 \geq 0, \ldots, x_n \geq 0
\end{aligned}
$$

Maximize: $Z = c_1x_1 + c_2x_2 + \cdots + c_nx_n,$

subject to: $a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \leq b_1$

$a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \leq b_2$

$$\vdots$$

$a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \leq b_m,$

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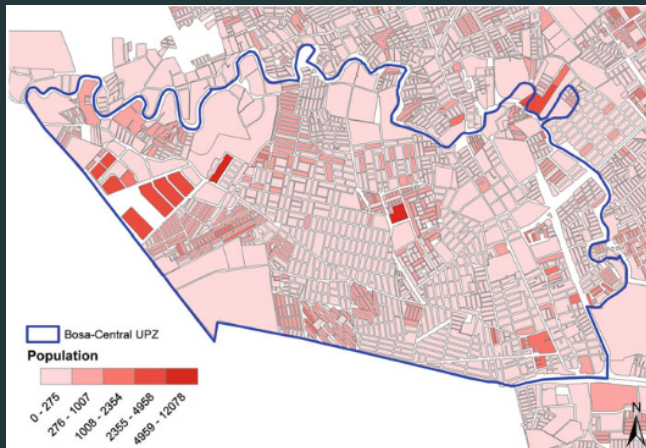
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THE MODEL

BOGOTÁ, COLOMBIA

Bosa-Central UPZ

Population
0 - 275 | 276 - 1007 | 1008 - 2354 | 2355 - 4958 | 4959 - 12078

- $m \times n$ grid

- m × n grid
- One block = one square

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- Every block same size

- m × n grid
- One block = one square
- Every block same size
- Service area of a block is all bordering blocks (excluding candidate parcels)

· Maximize geographical coverage

- Maximize geographical coverage

  f_1

- Maximize geographical coverage
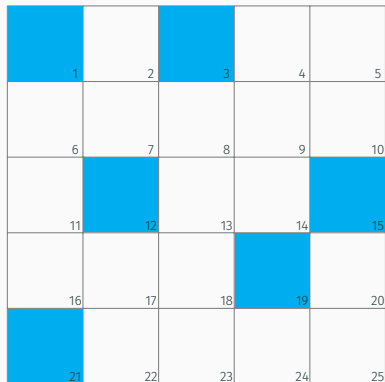 f_1
- Maximize people serviced

- Maximize geographical coverage

  f_1
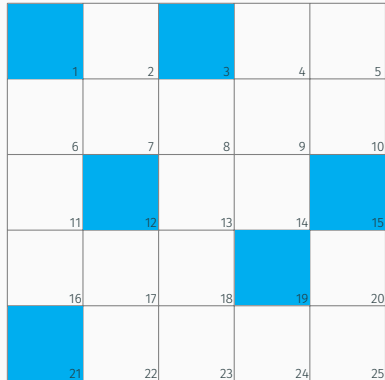- Maximize people serviced

  f_3

This is our 5×5 grid city
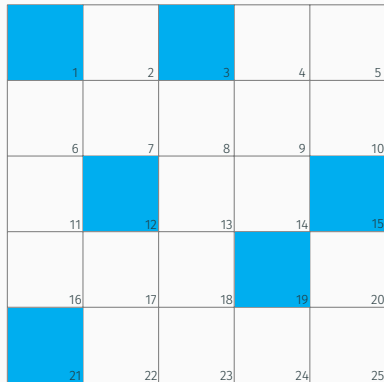
- Candidate parcels

- Candidate parcels: $\mathcal{I} = \{1, 3, 12, 15, 19, 21\}$
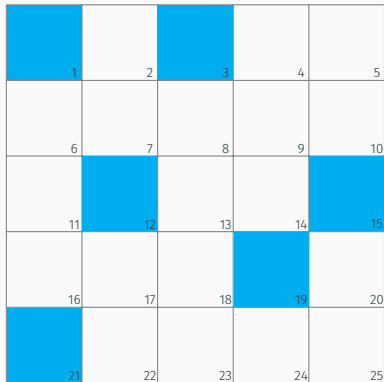
- Candidate parcels: $\mathcal{I} = \{1, 3, 12, 15, 19, 21\}$; y_i, $i \in \mathcal{I}$
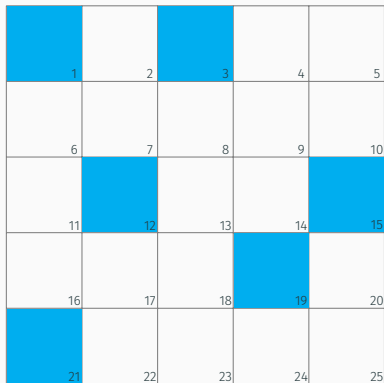
- Candidate parcels: $\mathcal{I} = \{1, 3, 12, 15, 19, 21\}$; $y_{19} = 1$
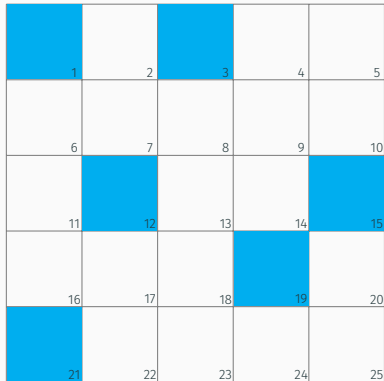
Which candidate parcel will maximize geographical coverage?
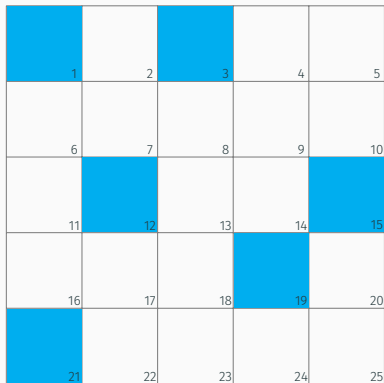
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Candidate 12
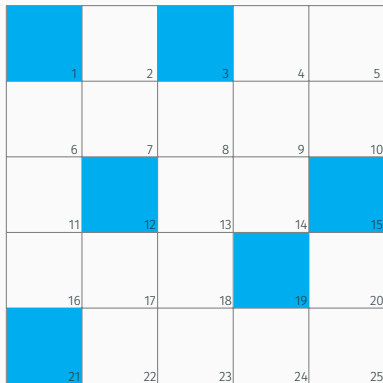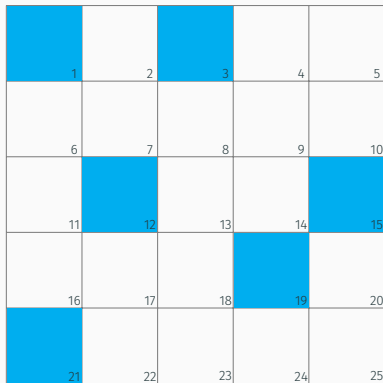
- $\mathcal{J} = \{2, 4, 6, 7, \ldots, 23, 24, 25\}$

- $\mathcal{J} = \{2, 4, 6, 7, \ldots, 23, 24, 25\}$, the set of all blocks that would benefit from the construction of a new park
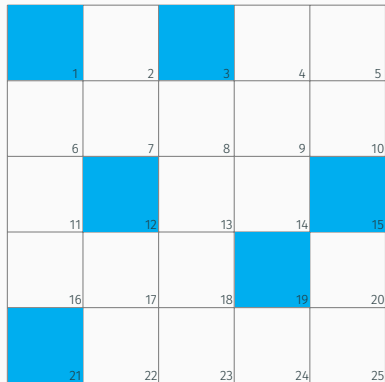
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- z_j, $j \in \mathcal{J}$, 1 if block j is serviced by a selected parcel, 0 otherwise

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- $z_2 = z_6 = z_7 = 1, \quad z_4 = z_8 = z_9 = \dots = z_{24} = z_{25} = 0$
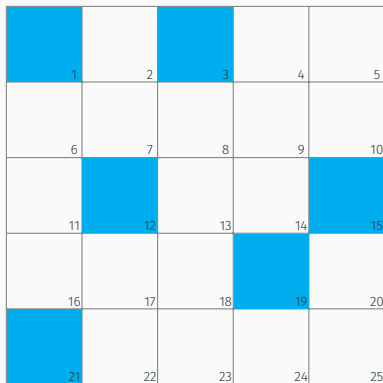
- $\mathcal{J} = \{2, 4, 6, 7, \ldots, 23, 24, 25\}$
- z_j, $j \in \mathcal{J}$, takes on value 1 if block j is serviced by a selected parcel, 0 otherwise
- $\mathcal{W}_j$, $j \in \mathcal{J}$, the set of candidate parcels that serve block j
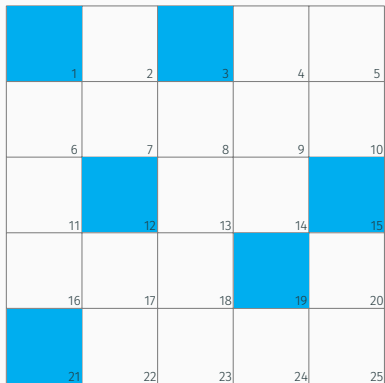
- $\mathcal{J} = \{2, 4, 6, 7, \ldots, 23, 24, 25\}$
- $z_j, \quad j \in \mathcal{J}$
- $\mathcal{W}_7 = \{1, 3, 12\}$

> $z_j = 1$ if block j is serviced by a selected parcel, 0 otherwise
>
> $y_i = 1$ if candidate parcel i is selected to become a park, 0 otherwise

$$\max f_1 = \sum_{j \in \mathcal{J}} z_j$$

$$\text{subject to } z_j \leq \sum_{i \in \mathcal{W}_j} y_i, \quad j \in \mathcal{J}$$

$$|\mathcal{W}_j| z_j \geq \sum_{i \in \mathcal{W}_j} y_i, \quad j \in \mathcal{J}$$

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	200		200	30
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40	100	150	160	20
6	7	8	9	10
40		150	140	
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Which candidate parcel will maximize the number of beneficiaries?

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$p_i, \quad i \in \mathcal{I}$

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Which candidate parcel will maximize the number of beneficiaries and the geographic coverage?

THE SOLUTION STRATEGY

· Maximize geographic coverage

- Maximize geographic coverage
- Maximize number of beneficiaries

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$$\max f_3 = \sum_{i \in \mathcal{I}} p_i y_i$$

$$\text{subject to } z_j \leq \sum_{i \in \mathcal{W}_j} y_i, j \in \mathcal{J}$$

$$\left| \mathcal{W}_j \right| z_j \geq \sum_{i \in \mathcal{W}_j} y_i, j \in \mathcal{J}$$

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$$f_1^*$$

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$$f_1^* = 8 \text{ blocks}$$

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$$f_3^* = 810 \text{ people}$$

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- α_k maximum acceptable deterioration for objective k
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- α_1 = 40% means objective function 1 must be at least 60% as optimal as the solution acquired in isolation

$$\max f_3 = \sum_{i \in \mathcal{I}} p_i y_i$$

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$$p_{\max} \geq \sum_{i \in \mathcal{I}} y_i$$

$$\sum_{j \in \mathcal{J}} z_j \geq (1 - \alpha_1) f_1^*$$

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	200		200	30
1	2	3	4	5
40	100	150	160	20
6	7	8	9	10
40		150	140	
11	12	13	14	15
40	50	130		80
16	17	18	19	20
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21	22	23	24	25

50	55		40	60	85	65	120	105	95	85		65	45	
	50	45	60	110	120	95	110		100	65	75	40	45	30
80	75	55	70	105	130	115		105	115	80	50	65	50	
165		65		65	80	95	110	105		70	55	45		25
225	200	70	75	100		100	105	120	105	55		20	25	15
250	120		85	105	100	110	70	80	70	65	50	15	5	10
200	100	180	155	125	105	80		95	75	40	45	35		15
250			145		235	100	80	135	95	70		50	45	20
300		265	205	235	505	500	245	175	80	85	65	30		25
305	255	275	215	225	400	405	410	500	305		45	50	40	30

50	55		40	60	85	65	120	105	95	85		65	45	
	50	45	60	110	120	95	110		100	65	75	40	45	30
80	75	55	70	105	130	115		105	115	80	50	65	50	
165		65		65	80	95	110	105		70	55	45		25
225	200	70	75	100		100	105	120	105	55		20	25	15
250	120		85	105	100	110	70	80	70	65	50	15	5	10
200	100	180	155	125	105	80		95	75	40	45	35		15
250			145		235	100	80	135	95	70		50	45	20
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Maximum number of blocks = 40

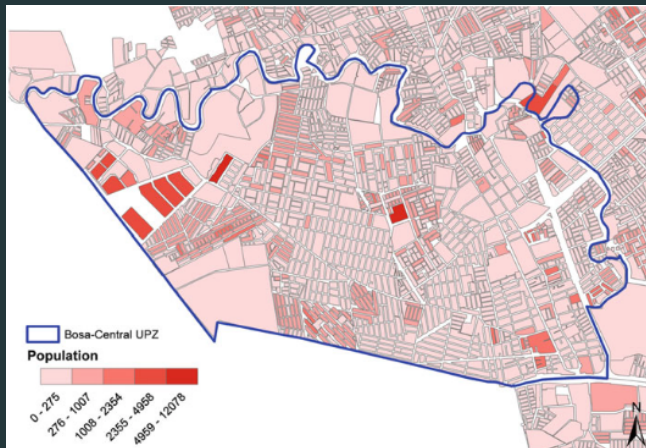| 50	55		40	60	85	65	120	105	95	85		65	45	
	50	45	60	110	120	95	110		100	65	75	40	45	30
80	75	55	70	105	130	115		105	115	80	50	65	50	
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Maximum number of blocks = 40

Maximum number of beneficiaries = 6690

$(1 - \alpha_1)$	Allowable deterioration	# beneficiaries (% of max)	# blocks served (% of max)
0.9	0.1	5855 (87.5)	37 (92.5)
0.85	0.15	6035 (90.2)	35 (87.5)
0.8	0.2	6345 (94.8)	33 (82.5)
0.75	0.25	6395 (95.6)	30 (75.0)
0.7	0.3	6575 (98.2)	28 (70.0)
0.65	0.35	6575 (98.2)	28 (70.0)
0.6	0.4	6640 (99.3)	25 (62.5)
0.55	0.45	6690 (100)	22 (55.0)

BOGOTÁ, COLOMBIA

$$\max f_1 = \sum_{j \in \mathcal{J}} z_j$$

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$$\max f_2 = \sum_{i \in \mathcal{I}} \left(\sum_{\{k \in \mathcal{E}_{\mathcal{P}} : d_{ik} \leq r^e\}} \left(1 - \frac{d_{ik}}{r^e}\right) y_i - \sum_{\{k \in \mathcal{E}_{\mathcal{N}} : d_{ik} \leq r^e\}} \left(1 - \frac{d_{ik}}{r^e}\right) y_i \right)$$

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$$\max f_3 = \sum_{i \in \mathcal{I}} p_i y_i$$

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$$\max f_3 = \sum_{i \in \mathcal{I}} p_i y_i$$

$$\max f_4 = \sum_{i \in \mathcal{I}} v_i y_i$$

$$\max f_1 = \sum_{j \in \mathcal{J}} z_j$$

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$$\max f_1 = \sum_{j \in \mathcal{J}} z_j$$

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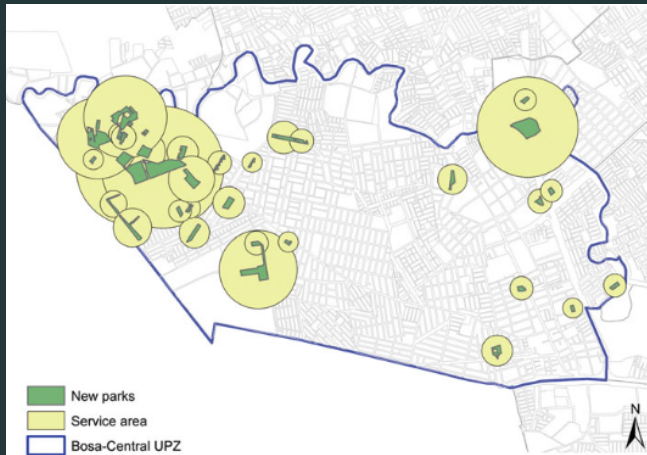
$$\max f_3 = \sum_{i \in \mathcal{I}} p_i y_i$$

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$$\min f_6 = \sum_{i \in \mathcal{I}} (c_i^l + c_i^b) y_i$$

New parks
Service area
Bosa-Central UPZ

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THE CONCLUSION

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- Difficult process!

THE END

QUESTIONS?