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UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN

FACULTAD DE INGENIERÍA MECÁNICA Y ELÉCTRICA

COMPUTATIONAL EXPERIENCE WITH HEURISTICS FOR THE MAXIMAL COVERING LOCATION PROBLEM OF RECYCLING COLLECTION CENTERS IN NUEVO LEÓN, MÉXICO

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GROUP: 003

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Introduction

The covering location problem is often categorized as Location Set Covering Problem (LSCP) and Maximal Covering Location Problem (MCLP). In a classical MCLP, one seeks the location of a number of facilities on a network in such a way that the covered population is maximized. A facility covers a demand node, if it is established in a distance less than the threshold to the demand node. This pre-defined threshold is often called the coverage radius, which directly affects the solution of the problem. [1]

MCLP was first introduced by Church and ReVelle [2]on a network, and since then, various extensions to the original problem have been made. Normally, MCLP is considered whenever there are insufficient resources or budget to cover the demand of all the nodes. Therefore, the decision maker determines a fixed budget/resource to cover the demands as much as possible.

Problem description

The Maximal Covering Location Problem can be formally described as follows:

Data (input information):

- A set of demand points I, each with an associated population to be served a_i.
- A set of potential facility locations J.
- A coverage radius or maximum service distance S.
- A maximum number of facilities to be located p.

Decisions (variables):

- Decide which facility locations $j \epsilon J$ will be located.
- Decide which demand points are covered by the chosen facilities.

Optimization objective:

- Maximize the number of people served or covered within the desired service distance.

Constraints (feasible solution conditions):

- At most p facilities can be located.
- A demand point is considered covered if it is within distance S of at least one located facility.

Mathematical Model:

$$Maximize\ Z = \sum_{i \epsilon I} a_i * y_i$$

Subject to:

$$\sum_{j \epsilon N_i} x_j \geq y_i \qquad \forall i \epsilon I$$

$$\sum_{j \epsilon J} x_j = p$$

$$x_j \epsilon \{0,1\} \qquad \forall j \epsilon J$$

$$y_i \epsilon \{0,1\} \qquad \forall i \epsilon I$$

Where:

I = denotes the set of demand nodes.

J = denotes the set of facility sites.

S = maximum service distance.

d_{ij} = the shortest distance from node i to node j.

$N_i = \{ j \epsilon J \mid d_{ij} \leq S\}$ = set of facility sites that can “cover” demand node i.

a_i = population to be served at demand node i.

p = number of facilities to be located.

x_j = 1 if a facility is located at site j, 0 otherwise.

y_i = 1 if demand node i is covered, 0 otherwise.

Problem example

Population growth and industrialization in Nuevo León have significantly increased the generation of municipal and industrial solid waste. However, a large share of recycled materials (PET, cardboard, metals) does not reach collection centers because of the distance residents must travel to dispose of them properly.

In this context there is a clear need to decide where to locate a limited number of recycling collection centers so that the maximum possible amount of recyclable waste si captured within a maximum acceptable service distance.

We consider a set of municipalities *J*, each associated with an estimated amount pf recyclable waste generated per day (wj). The set of potential sites *I* coincides with these municipalities.

The goal is to open exactly *p* recycling centers in such a way that the total recyclable waste covered is maximized, where a minicpality is considered covered if it lies in a maximum distance *S* from at least one open site.

Small instance:

- Demand nodes (also candidate sites): A–F
- Weight = recyclable tons/day (objective weight)
- Parameters: p = 2 centers, S = 2 km service radius
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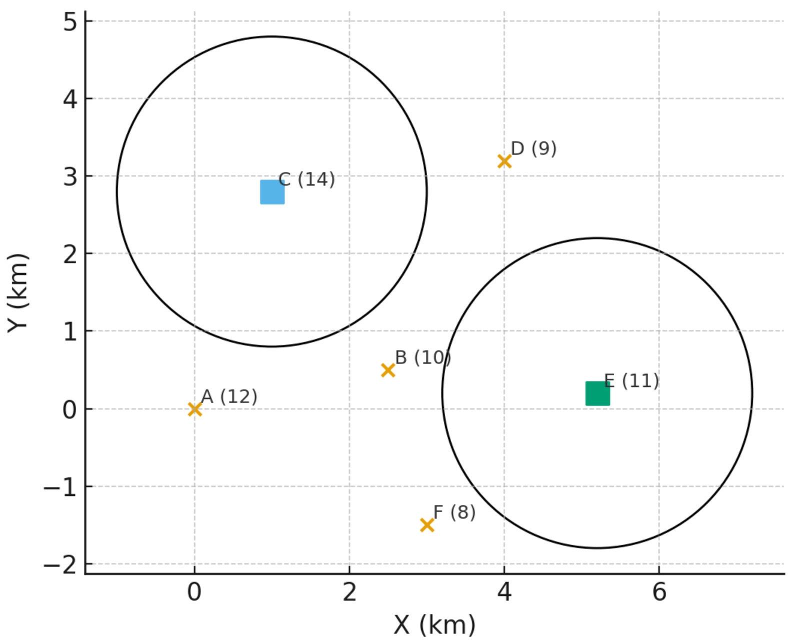
node	x	y	weight
A	0	0	12
B	2.5	0.5	10
C	1	2.8	14
D	4	3.2	9
E	5.2	0.2	11
F	3	-1.5	8

The image shows the feasible solution where we open at C and E; each circle is the 2 Km service radius.



- **Chosen open sites (feasible): {C, E}**
- **A demand node *j* is considered covered if at least one facility *i* in {C, E} is located within the service distance *S* of *j*.**
- **Objective value is equal to the sum of weights of covered nodes.**

Check coverage

node	weight	Covered by C or E?	Contribution
A	12	No	12
B	10	No	10
C	14	Yes	14
D	9	No	9
E	11	Yes	11
F	8	No	0

Z = 14 + 11 = 25

References

[1] S. D. M.H. Fazel Zarandi, «Science Direct,» 2011. [En línea]. Available: https://www.sciencedirect.com/science/article/pii/S1026309811002100. [Último acceso: 4 Septiembre 2025].

[2] C. R. R.L. Church, The maximal covering location problem, Baltimore, Maryland: Papers of the Regional Science Association, 1974.