LOCATION OF RECYCLING BINS USING COVERING FACILITY LOCATION MODEL IN NILAI, MALAYSIA

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Keywords: covering location, solid waste management, recycling

1. Introduction

Sustainable waste management systems can be achieved by improving recycling activity among the public. However, public participation is among the biggest challenges (Khamaruddin et al., 2019), as it is initiated through separation at the source activity. To encourage this activity at the household level, it is critical to provide adequate and easily accessible recycling bins in a convenient location. However, establishing these locations is challenging (Woodard et al., 2004), and once implemented, the facility location is difficult to change in the immediate term (Owen & Daskin, 1998). For these reasons, a covering facility location model by Jamiron et al. (2021) is utilized to optimally locate the required facilities with sufficient capacity levels, with an emphasis on optimizing demand coverage.

2. Methodology

For this study, the covering model by Jamiron et al. (2021) is used. The model is as follow:

<u>Notation – Sets, Indices, Parameters, and Input Variables</u>

i : set of demand location, at most *I*

j : set of recycling bin location, at most *J*

k : number of recycling bin location located at each location *j* at most *K*

$dist_{ij}$: distance between demand *i* and recycling bin location *j*

D : maximum travel distance between demand *i* and recycling bin location *j*

M : maximum recycling bin's locations in the selected area of study

P : maximum allowable recycling bins at area of study

$a_{ij} = \begin{cases} 1 & if\, dist_{ij} \leq D \\ 0 & if\, dist_{ij} > D \end{cases}$

d_i : expected amount of waste generated of population at location *j*

q_{jk} : busyness level of having *k* bins at each recycling bin location *j*

Decision variables

$x_j = \begin{cases} 1 & if\, a\, recycling\, bin\, is\, located\, at\, j \\ 0 & otherwise \end{cases}$

$y_{ik} = \begin{cases} 1 & if\, demand\, at\, location\, i\, is\, covered\, with\, k\, bins \\ 0 & otherwise \end{cases}$

Model Formulation

$$Max \sum_{i}^{n} \sum_{j}^{m} \sum_{k}^{K} d_i q_{jk} y_{ik} \tag{1}$$

subject to:

$$\sum_{k}^{K} y_{ik} - \sum_{j}^{m} a_{ij} x_j \leq 0 \quad , \forall i = 1, 2, \ldots, n \tag{2}$$

$$\sum_{j}^{m} x_j \leq P \tag{3}$$

$$\sum_{k}^{K} y_{ik} \leq 1 \quad , \forall i = 1, 2, \ldots, n \tag{4}$$

$$\sum_{k}^{K} \sum_{i}^{n} k \cdot y_{ik} \leq M \tag{5}$$

$$k \geq y_{ik} \quad , \forall i = 1, 2, \ldots, n \tag{6}$$

$$\sum_{k}^{K} y_{ik} = a_{ij} x_j \quad \forall j = 1, 2, \ldots, m; \forall i = 1, 2, \ldots, n \tag{7}$$

Objective function of the model represented by (1) is to maximize the amount of demand *i* served by the selected *j* recycling bins location with the available *k* bins. Constraints of the model are from (2) - (7). Equation (2) assures that the chosen recycling bins locations can serve demand at location *i*. Equation (3) limits the number of recycling bins in an area of study at maximum of *P* locations. Equation (4) limits the designated *k* bins for each demand at location *i*. This constraint also specifies the total allocation of bins at the selected recycling bins location *j* while ensuring sufficient bin capacities. Equation (5) limits the total allowable recycling bins at the area of study at *M* bins. Value of *M, however,* has no limit on bins allocation since this totally depends on the decision-makers preferences. Equation (6) ensures there is(are) recycling bin(s) designated for each demand area *i*. Both constraints are useful in ensuring the total recycling bins located at the area of interest are sufficient with the amount of demand, at the same time, giving an insight of possible solutions to the decision-makers. Equation (7) ensures that the chosen recycling bin location meets local demand.

Jamiron et al. (2021) conducted their study in the Johor municipal area, while we focused on the Nilai municipal area (as shown in Figure 1). Six potential locations are selected, which are Taman Awam Nilai, Aeon Mall Nilai, Station Batang Benar, Nilai Indoor Stadium, Universiti Sains Islam Malaysia (USIM), and Pasar Borong Nilai 3. These locations are selected based on accessibility to the public.

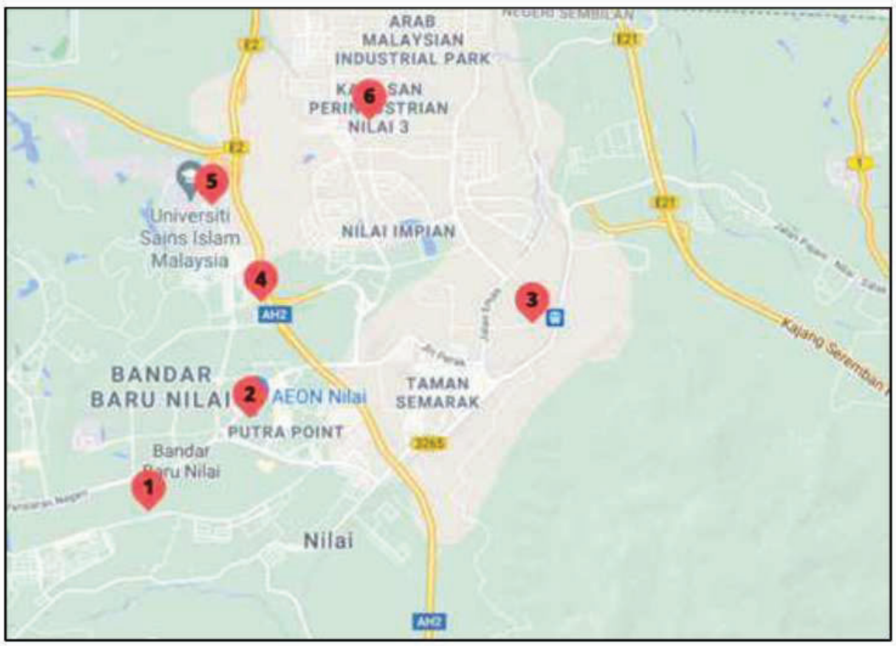

Figure 1. Selected area of study, Nilai, Malaysia.

3. Results and Discussions

Figure 2 shows the relationship between percentage of coverage based on variations of D = 4, 9, and 14 minutes, M = 1, 2, 3, 4, 5, 6, 7, 8 bins, and several combinations of P locations and kept k = 1 at all times. Based on Figure 2, the system performance on percentage of demand covered is presented, based on *P*, *D*, and *M* values. From figure 2,decision-maker can allocate one (1) bin (k = 1) at two (2) recycling bin locations (P = 2) to achieve 100% of demand coverage, with a maximum travel time of nine minutes (D = 9).

K=1					
D	M	P	Recycling Bins's Location	Percentage of coverage	Total Recycling Bins Allocation
4	4	3	2,3,6	50.00%	4
		4	2,3,6	50.00%	4
	8	3	2,3,6	50.00%	4
		4	2,3,6	50.00%	4
		5	2,3,4,5,6	50.00%	4
		6	2,3,4,5,6	50.00%	4
		7	2,3,4,5,6	50.00%	4
		8	2,3,4,5,6	50.00%	4
9	4	1	3	50.00%	4
		2	2,3	50.00%	4
		3	2,3	50.00%	4
		4	2,3	50.00%	4
	8	1	3	87.50%	7
		2	2,3	100.00%	8
		3	2,3	100.00%	8
		4	2,3	100.00%	8
		5	2,3,4	100.00%	8
		6	1,2,3,4,5,6	100.00%	8
		7	1,2,3,4,5,6	100.00%	8
		8	1,2,3,4,5,6	100.00%	8
14	4	1	2	50.00%	4
		2	2,4	50.00%	4
		3	2	50.00%	4
		4	1,2,4	50.00%	4
	8	1	2	75.00%	6
		2	2,4	87.50%	7
		3	2	100.00%	8
		4	1,2,4	100.00%	8
		5	1,2,4	100.00%	8
		6	1,2,3,4,5,6	100.00%	8
		7	1,2,3,4,5,6	100.00%	8
		8	1,2,3,4,5,6	100.00%	8

Figure 2. Percentage of coverage based on variations of *D*, *M*,*P* and k = 1.

Figure 3 shows the relationship between percentage of coverage based on variations of D = 4, 9, and 14 minutes, k = 1, 2, and 3 bins, and M = 1, 2, 3, 4, 5, 6, 7, 8 bins. We kept *P* at a maximum total of 8 recycling bin locations. Figure 3 focused on illustrating the system performance in percentage of demand covered based on *k*, *D*, and *M* values. From Figure 3, when k = 1, the percentage of cover is increased whenever *M* and *D* increase. It can be seen that the covering for D = 4 remained unchanged when M = 4 and onwards. When k = 2 and D = 4, the demand percentage is at 100%. However, as *D* increases, the covering percentage decreases, so even *M* values are increasing. Interestingly, when k = 3, 100% coverage is unachievable for all *D* and *M* values. This is most probably due to having three bins (k = 3) with a limitation on the total allowable bins (*M*) that restricts the optimal output. From Figure 3, in general, all three inputs (*k*, *D*, and *M*) contribute significantly to the percentage of demand covered. From this analysis, it can be concluded that the higher percentage of coverage level for the area of study can be achieved even with a smaller value of *k* and *M*.

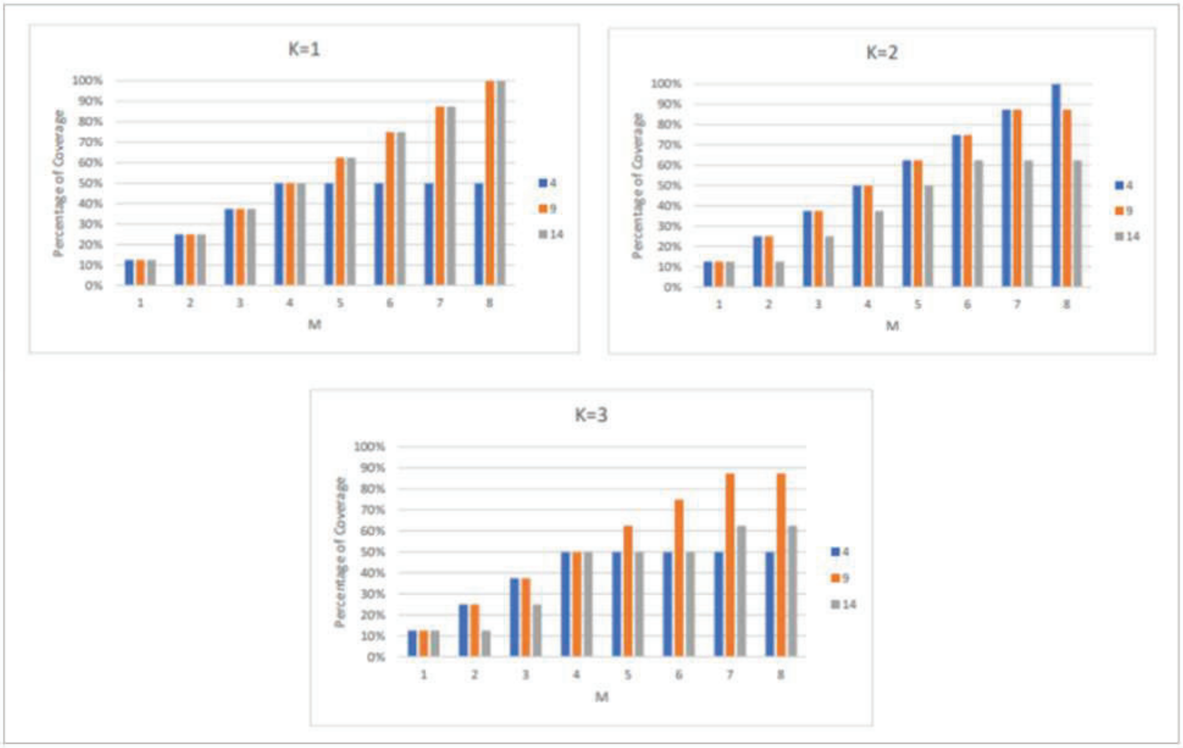

Figure 3. System performance on percentage of demand covered based on *k*, *D*, and *M* values.

4. Conclusion

This study aims to select the recycling bin location by using the covering model of Jamiron et al. (2021) focusing on Nilai, Negeri Sembilan, Malaysia. As a result, only two locations are needed to cover the entire selected area of study, j_2 (AEON Mall Nilai) and j_3 (Station Batang Benar, Nilai) with a total of eight (8) recycling bins allocated at both sites. It was also discovered that all inputs play an important role in obtaining optimal solutions, and it can be concluded that the higher percentage of coverage level for the area of study can be achieved even with a smaller value of *k* and *M*. This means, even with a smaller number of bins allocated in the study area, the chances of the majority area of demand being covered are higher.

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