# Design of waste cooking oil collection center in Semarang City using maximal covering location problem: a finding from Semarang, Indonesia

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# Design of waste cooking oil collection center in Semarang City using maximal covering location problem: a finding from Semarang, Indonesia

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# Design of waste cooking oil collection center in Semarang City using maximal covering location problem: a finding from Semarang, Indonesia

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**Abstract.** Most waste cooking oil (WCO) in Semarang is still disposed of in landfills since there is an inadequate facility to collect those wastes. There are only three collection centers of WCO identified in Semarang. The alternative to sell WCO is also not the best option as the amount of WCO generated from households is less than the culinary enterprise. Thus, having a collection channel that can thoroughly cover all the supply points of WCO from the household in Semarang is a necessity. This research will design a collection channel to provide facilities so the waste can be appropriately managed. The analysis determines the number, location and capacity of each collection center, standard operating procedure of WCO collection, and the picking route. The number, location, and breadth of the collection center are determined using Maximal Covering Location Problem. The finding shows that to facilitate all the potential supply of WCO in scenario 1 with a range of 2 km mileage need 95 collection center. In contrast, in scenario 2, a distance of 1 km requires a collection center of 146 points. Previously, this study began by identifying community behavior towards waste cooking oil by surveying 347 households.

## 1. Introduction

The palm oil industry is an important industrial sector for Indonesia since it contributes significantly to Indonesia [1]. The allocation of palm oil as cooking oil causes a high amount of waste and is dangerous for the environment [2]. The issue of improper cooking oil waste management is attracting public concern in recent years [3]. It is because cooking oil waste production is carried out continuously and becomes a daily consumption. In China, the largest cooking oil waste producer, fast-food restaurants in large cities, can produce 15 liters of cooking oil waste every day [4]. One person has 3-5 kg of cooking oil waste in the Mediterranean country each year [5]. Improper handling of cooking oil waste can cause environmental pollution, especially in water and soil [6]. To a greater extent, mistakes in handling cooking oil waste can also damage the aquatic community. The oil layer in water will cover the surface and inhibit oxygen from diffusing [7].

Seeing the adverse effects arising from the mishandling of WCO on humans and the environment, there should be proper WCO's management procedures. Waste cooking oil can be collected and then utilized as a production unit for biofuels, soap, detergents, paints, or lubricants [8]. The process of collecting and recycling WCO waste is a solution contribution to reducing waste, reducing dependence on fossil fuel energy, and reducing pollutant emissions [9]. This concept adopts the concept of the circular economy (CE). Today, industries are starting to see this concept to increase competitive advantage [10]. One of the three CE principles is to keep the product or material usable [10].

Implementation of the CE concept starts with WCO management with the process of collecting WCO from the user. In practice, WCO is at a scattered point, such as from households, restaurants and hotels, so an optimal supply chain collection is needed so that the utilization of waste cooking oil can also be realized [11]. The management of waste cooking oil in Semarang City is still minimal. There are only three collection points of WCO in Semarang, namely in Tambakaji, Kalipancur, and Kalibanteng Kidul. The three points for collecting WCO in Semarang City are inadequate because of the long distance to reach communities in other regions and receive large WCO. The quantity of WCO produced on a national scale is 6,430,000 tons per year [12], so if it is proportional to Semarang's population, cooking oil waste in the city of Semarang is estimated at 40,630 tons per year. That means there are 34,210 tons of cooking oil waste that is discharged into waterways every year. This condition causes pollution to the environment [13], endangers human health [14] and harms economic potential because cooking oil waste will be wasted without being utilized [15].

Meanwhile, the use of WCO can provide economic, social and environmental benefits. From a financial perspective, WCO can be used as a product with added value [15]. From an ecological perspective, recycling cooking oil waste can reduce waste discharged into the environment [16]. From a social perspective, the use of WCO requires business people to create jobs [17].

This article aims to design a collection center to manage WCO. The design includes the number, location and capacity of collection centers by adopting the Maximal Covering Location Problem (MCLP) method [18]. The plan was made based on a cooking oil consumer behavior survey conducted on 347 households in Semarang City.

## 2. Methodology

The objective of this research is to design collection centers of WCO in Semarang, Indonesia. A survey was conducted in Semarang, Indonesia, the capital city of Central Java Province. This city has not implemented WCO collection yet and is considered one of the cities believed to have a rapid development associated with the food business.

### *2.1. Identify the flow mapping of waste cooking oil.*

Identify the flow mapping of WCO is done by surveying cooking oil consumers. The questionnaire used in this survey has two sections: the respondent's personal information in the first section, and the respondent's behavior in managing the WCO in the second section. Respondents of the survey are household. For n the first part, the information conveyed is the respondent's name, gender, age, educational background, marital status, and income (in IDR) per month, and location they are living. Secondly, the participants were asked about the intensity of reusing the oil, the treatment fort of WCO, the amount of WCO generated, and their understanding of the harm. The percentage of each answer must count to create the mapping.

The information about consumer behavior will determine how the WCO flow mapping. The questionnaire was used to identify community behavior in Semarang City using cooking oil and to manage its waste. The questionnaire was made by referring to Kabir et al. (2014) [19], with several adaptations adjusted to this study's information needs.

Research about consumer behavior is descriptive research. The minimum number of samples for descriptive analysis is 100 [20]. Thus, the respondents of this study were Semarang people who were randomly selected at least 100 people. Ensuring the questionnaire data will provide representative results, the respondents will be represented proportionally from each district.

### *2.2. Design of collection center*

Facility Location Problem (FLP) is used to map facilities such as distribution centers and warehouses, taking into account location and other input parameters such as facility capacity, fixed costs, and transportation costs [21]. As a useful method of locating facilities, FLP is widely used in real life.

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Various models have been developed to determine the location of facilities for diverse situations [22]. The use of FLP varies greatly depending on the decision maker's goals and the condition of use [23]. One of the FLP models often used is covering problem, in the form of Location Set Covering Problem and Maximal Covering Location Problem (MCLP) [18].

Church and ReVelle first introduced MCLP in 1973 at the North American Regional Science Council meeting [24]. The purpose of this model is to maximize demand covered by certain service distances by locating individual distribution facilities [21]. Thus, customers or clients are declared "covered" or covered if they are within a specific coverage distance from at least one facility [25]. MCLP also often plays a role as a decision-maker in the supply chain or supply chain, so that its use in practice is relatively numerous [26]. Some previous studies were using MCLP, such as; models and approaches in determining the location of medical equipment supply centers to respond the large-scale emergencies [27], and the development of FLP to determine treatment centers in large cities in the event of a disease outbreak [28]. Besides, to optimize the number of points demand covered by the optimal number of facilities [29], approaches to minimize uncovered demand [30], and finding the right location for refugees while flooding [31].

This study adopted the MCLP model to minimize the number of facilities that had to be erected but still provide comprehensive coverage of the cooking oil waste of the supply point. This research's decision variable is the number of collection centers, location, and capacity of each collection center. Meanwhile, the study's parameters are the supply of WCO in each village, the distance between villages, and the range of collection centers desired by the community in Semarang City.

Following is a model developed to determine the WCO collection center :

$$\mathrm{Min}\ \mathrm{Z} = \sum_{\mathrm{j}=1}^{\mathrm{m}} \mathrm{X_j} \tag{1}$$

$$\sum_{\mathrm{i}=1}^{\mathrm{m}} \mathrm{a_{ij}} x_{\mathrm{i}} \geq 1\,, i = 1, 2, \dots m \tag{2}$$

$$X_j \in [0,1] \forall j \in V \tag{3}$$

$$a_{ij} \in [0,1] \forall i, j \in V \tag{4}$$

$$Y_i \in [0,1] \forall i \in V \tag{5}$$

$$\mathrm{C}_j = \sum_{\mathrm{j}=1}^{\mathrm{m}} Y_i \mathrm{S_i} \tag{6}$$

Notation:

Z = number of collection centers

m = {1, 2, ..., | m |}: Number of villages

Xj = Whether or not point j is selected as a collection center

$\mathrm{X_j} = \begin{cases} 1 \text{ represents point j being the collection center } \forall \text{ j} \in \text{V} \\ 0 \text{ represents other conditions} \end{cases}$

aij = Whether or not the distance requirement is met

$\mathrm{a_{ij}} = \begin{cases} 1 \text{ represents distance i to j} \leq \text{D} \ \forall \text{ i, j} \in \text{V} \\ 0 \text{ indicates other conditions} \end{cases}$

D = range (km)

Cj = Collection center capacity at point j

Yi = Covered or not the supply of cooking oil waste at point i

$\mathrm{Y_i} = \begin{cases} 1 \text{ represents point i covered by collection center j } \forall \text{ i} \in \text{V} \\ 0 \text{ represents other conditions} \end{cases}$

Si = supply of waste cooking oil at point i

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This research used primary and secondary data. Preliminary data included data on the amount of cooking oil waste produced by households every month, distance data to the collection center that is still desired by the community, and WCO management behavior that currently occurs in societies in Semarang City. Secondary data included data on the number of households per villages and the distance between villages in Semarang City.

## 3. Results and discussion

### 3.1. *Consumer behavior survey results*

The number of respondents who were willing to fill out the questionnaire was 347 with an even distribution in all districts. Representative respondents from Banyumanik were 8.36%, Candisari 3.17%, Gajahmungkur 4.03%, Gayamsari 7.20%, Genuk 5.19%, Gunungpati 6.05%, Mijen 4.61%, Ngaliyan 8.36 %, Pedurungan 10.37%, West Semarang 8.36%, South Semarang 6.34%, Central Semarang 7.20%, East Semarang 4.03%, North Semarang 6.92%, Tembalang 5.48%, Tugu 4.32%.

The survey was performed on 347 households in Semarang. 47% of household reuses the same cooking oil twice, 23.3% once, 17.9% do not reuse, 10.4% three times and 1.4% more than three times. In the after-use phase, 97.7% of households produce WCO, while the other 2.3% do not produce WCO. 97.7% of the waste produced, and the most common behavior is to dispose of the cooking oil waste. The details of behavior are 66% to the drains, 8.6% to the land, and 15.8% to the trash. If it is proportionated to the amount of WCO generated in Semarang, 252,271 liters of WCO ended up in the water. It is because not everyone understands the impact caused by WCO's mistreatment. Only 54.9% of the participant understands the dangers of disposing WCO to landfills. Besides, many households who dispose of the WCO to drains claim that it is the easiest and most practical way because they only need to pour the leftover cooking oil directly from the frying pan into the sink when doing the dishes. The little amount of leftover oil makes them think that the impact will not be significant. If those tiny amounts of WCO are collected for the whole month, one household produces 0.973 liters of WCO.

Some information related to the design of the WCO collection center was also obtained from the questionnaire. For example, their willingness to collect WCO was 68.02%, unwilling, 13.54% and neutral 18.44%. The farthest distance from the collection point is 2.2 km. The preferred storage device is a plastic bottle of 58.50%. Alternative storage devices such as jerry cans 23.05%, cans 9.22%, plastic bags 3.46%, others 5.77%. Consumers prefer the village government to manage WCO (59.08%) than Non-Government Organizations (33.43%), the other party is 2.88%. The frequency of WCO collection is preferably done every month (40.06%). Whereas the different frequency two times every month is liked by 10.95%, every week 14.99%; there is no time limit of 31.99%; not willing to collect 2.02%.

### 3.2. *The result of the collection center design*

The results of the questionnaire concluded that the community preferred the village government to manage the WCO. This study chose the village as a supply point for WCO (i) and an alternative center for collecting WCO (j). The number of households in each village (n) was obtained from the Central Statistics Agency of Semarang. Data on the number of households is used to calculate the amount of WCO in a village (Si). Besides the number of households, other factors that influence the supply of WCO are the average WCO produced by households per month and the percentage of community participation. The conclusion that the WCO produced by households per month was around 0.97 liters from the questionnaire results.

In contrast, the percentage of community participation can be seen from the number of respondents who answered 3 (neutral), 4 (willing), or 5 (very willing) as much as 86.46%. Semarang City has 177 villages with 444,281 households. Thus there is a potential waste of WCO around 373,736 liters every month.

The distance between villages (aij) is obtained from Google Maps, assuming the distance from i to j equals the distance from j to i. The unit of distance used is km. For example, the distance from the Pudakpayung sub-district (i = 1) to the Gedawang sub-district (i = 2) is 4.5 km. The distance to the collection center (D) is the result of a questionnaire to the farthest distance they want; if there is a cooking oil waste collection facility, the answer is 2.2 km, which is then rounded to the nearest unit 2 km. The number (Z) and location (Xj) of the collection center are determined automatically using the Solver feature in Microsoft Excel 2013 with Equations (1) to Equation (5). The number and location of collection centers established in each village will determine each collection center's amount of capacity (Cj). The collection center's capacity depends on which kelurahan will be covered by the collection center (Yi) and how much cooking oil waste in the sub-district will be covered (Si). Calculation of collection center capacity using Equation 3. The unit of capacity in liters.

After calculating the Solver feature in Microsoft Excel 2013, the number of collection centers that must be established is 95. Table 1 contains information about the number, location, and capacity of the collection center. The largest capacity is the collection center in Tlogosari Kulon, which is 16,024 liters or 5,659 tons. With a holding drum capacity of 200 liters, it takes approximately 81 holding drums. Assuming the arrangement of holding drums is nine rows, and nine columns with a drum diameter is 58 cm, then the area of land needed is around 5.25 x 5.25 m. In contrast, the collection center with the least capacity is the collection center in Terboyo Kulon. This collection center's capacity is 146 liters or 0.051 tons, so that only one drum drum is needed.

It determines the collection center's capacity by the amount of waste cooking oil accommodated in the collection center. The amount of cooking oil waste that will be adjusted is influenced by two factors: distance to other villages and the number of households. Suppose a collection center is close to many other villages. In that case, the collection center will accommodate a lot of cooking oil waste from other villages, so the collection center's capacity will also be large. Conversely, if a collection center is far from other villages, the collection center will only hold less waste and even a smaller degree. In terms of population, the more households in a village, the more cooking oil waste will be generated, and the greater the capacity of the collection center to be established.

Conversely, the smaller the number of households in a village, the less WCO will be generated. The smaller the collection, The

better results reach in this study was developed by scenario 2. The parameter that was changed was the shorter distance that is 1 km. The number of collection centers that must be established is 146. The largest collection center capacity is 8,860 liters, namely in the Sendangmulyo village collection center. If converted into the number of holding drums, the total holding drums needed is 45. If it is assumed the drums will be arranged with nine columns and five rows, the whole land required is 5.65 m x 2.9 m. In contrast, the smallest collection center capacity is still the Terboyo Kulon collection center, with a total of 146 liters or one holding drum.

The difference between scenario 1 (maximum range of 2 km) and scenario 2 (maximum range of 1 km) results in different performance. Table 2 is a recap of the differences in scenarios 1 and 2. Scenario 2 has a shorter range, and the maximum total land is smaller than scenario one because collection points are spread over more issues/villages.

**Tabel 1.** The recapitulation of the number, location, and capacity.

| The District | Center | The Villages | $C_j$ (liter) | $\Sigma C_j$ (liter) |
|---|---|---|---|---|
| Banyumanik | 1 | Pudakpayung | 5106 | 31647 |
| | 2 | Jabungan | 2991 | |
| | 3 | Banyumanik | 9872 | |
| | 4 | Sumurboto | 8623 | |
| | 5 | Tinjomoyo | 2415 | |
| | 6 | Ngesrep | 2640 | |
| Candisari | 7 | Candi | 2625 | 12405 |
| | 8 | Jomblang | 1931 | |
| | 9 | Karanganyar Gunung | 3480 | |
| | 10 | Tegalsari | 1620 | |

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| The District | Center | The Villages | $C_j$ (liter) | $\Sigma C_j$ (liter) |
|---|---|---|---|---|
| Gajahmungkur | 11 | Wonotingal | 2749 | 12701 |
| | 12 | Bendanduwur | 770 | |
| | 13 | Gajahmungkur | 2937 | |
| | 14 | Karangrejo | 1475 | |
| | 15 | Lempongsari | 1367 | |
| | 16 | Petompon | 2574 | |
| | 17 | Sampangan | 3578 | |
| Gayamsari | 18 | Kaligawe | 4760 | 16703 |
| | 19 | Siwalan | 11944 | |
| Genuk | 20 | Gebangsari | 1768 | 25695 |
| | 21 | Genuksari | 9337 | |
| | 22 | Karangroto | 4712 | |
| | 23 | Muktiharjo Lor | 1026 | |
| | 24 | Penggaron Lor | 7388 | |
| | 25 | Terboyo Kulon | 146 | |
| | 26 | Terboyo Wetan | 385 | |
| | 27 | Trimulyo | 933 | |
| Gunung Pati | 28 | Cepoko | 4037 | 20800 |
| | 29 | Kalisegoro | 781 | |
| | 30 | Kandri | 954 | |
| | 31 | Ngijo | 946 | |
| | 32 | Pakintelan | 3265 | |
| | 33 | Patemon | 1029 | |
| | 34 | Plalangan | 920 | |
| | 35 | Pongangan | 1436 | |
| | 36 | Sadeng | 1476 | |
| | 37 | Sekaran | 1609 | |
| | 38 | Sukorejo | 2580 | |
| | 39 | Sumurejo | 1767 | |
| Mijen | 40 | Bubakan | 688 | 16367 |
| | 41 | Cangkiran | 1089 | |
| | 42 | Jatisari | 2858 | |
| | 43 | Kedungpane | 1248 | |
| | 44 | Mijen | 2389 | |
| Mijen | 45 | Ngadirgo | 1717 | 16367 |
| | 46 | Polaman | 2312 | |
| | 47 | Tambangan | 1343 | |
| | 48 | Wonolopo | 1869 | |
| | 49 | Wonoplumbon | 855 | |
| Ngaliyan | 50 | Bambankerep | 1544 | 26655 |
| | 51 | Beringin | 982 | |
| | 52 | Gondoriyo | 3152 | |
| | 53 | Kalipancur | 2741 | |
| | 54 | Ngaliyan | 1112 | |
| | 55 | Podorejo | 3972 | |
| | 56 | Purwoyoso | 3144 | |
| | 57 | Tambak Aji | 4595 | |

| The District | Centerr | The Villages | $C_j$ (liter) | $\Sigma C_j$ (liter) |
|---|---|---|---|---|
| Pedurungan | 58 | Wonosari | 1453 | 39436 |
| | 59 | Wates | 3960 | |
| | 60 | Palebon | 7353 | |
| | 61 | Pedurungan Kidul | 5125 | |
| | 62 | Plamongan Sari | 4341 | |
| | 63 | Tlogomulyo | 6593 | |
| | 64 | Tlogosari Kulon | 16024 | |
| Semarang Barat | 65 | Bongsari | 15325 | 41509 |
| | 66 | Kalibanteng | 15408 | |
| | 67 | Krobokan | 7926 | |
| | 68 | Tambakharjo | 755 | |
| | 69 | Tawangsari | 2095 | |
| Semarang Selatan | 70 | Barusari | 4290 | 18698 |
| | 71 | Lamper Kidul | 10593 | |
| | 72 | Mugassari | 3816 | |
| Semarang Tengah | 73 | Jagalan | 10611 | 19040 |
| | 74 | Sekayu | 8429 | |
| Semarang Timur | 75 | Kemijen | 3294 | 18325 |
| | 76 | Mlatiharjo | 5539 | |
| | 77 | Rejosari | 9491 | |
| Semarang Utara | 78 | Kuningan | 10015 | 26189 |
| | 79 | Panggung Kidul | 9845 | |
| | 80 | Tanjung Mas | 6328 | |
| Tembalang | 81 | Jangli | 1444 | 39906 |
| | 82 | Kedungmundu | 2479 | |
| | 83 | Kramas | 835 | |
| Tembalang | 84 | Meteseh | 6344 | 39906 |
| | 85 | Rowosari | 2699 | |
| | 86 | Sambiroto | 3224 | |
| | 87 | Sendangmulyo | 8860 | |
| | 88 | Tandang | 10730 | |
| | 89 | Tembalang | 3290 | |
| | 90 | Jerakah | 559 | |
| Tugu | 91 | Karanganyar | 1513 | 7659 |
| | 92 | Mangkang Kulon | 2366 | |
| | 93 | Mangkang Wetan | 536 | |
| | 94 | Randu Garut | 1362 | |
| | 95 | Tugurejo | 1323 | |

Waste cooking oil is brought from the house to the collection center using plastic bottles. Waste cooking oil and its container (plastic bottles) are put into a storage drum. The place used to store waste cooking oil in each collection center is a plastic drum made from High-density Polyethylene. The drum capacity is 200 liters with an outer diameter of 58 cm and a height of 98 cm. Close the lid tightly because this drum is equipped with a cover and an iron ring.

**Tabel 2.** Difference between scenarios 1 and 2.

| No. | Indicator | Unit | Scenario 1 | Scenario 2 |
|---|---|---|---|---|
| 1 | Range | km | 2 | 1 |
| 2 | Number of *collection center (CC)* | point | 95 | 146 |
| 3 | Maximum capacity in CC | liter | 16.024 | 8.860 |
| 4 | Maximum number of drums in CC | drum | 81 | 45 |
| 5 | Maximum land requirements in CC | $m^2$ | 32 | 17 |
| 6 | Total drum needed | drum | 1872 | 1873 |

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## 4. Conclusion

As many as 90.5% of households in the city of Semarang still dispose of WCO in landfills. This number is equivalent to 252,271 liters of cooking oil waste. WCO management requires an effort to collect WCO from every household spread throughout Semarang City. The design of the collection centers produces two scenarios with a range of 2 km and 1 km. Scenario 2 is more recommended because it has a shorter range with almost the same total drums. People prefer to collect WCO that has been put into plastic bottles to the nearest collection center once every month on a predetermined working day that is managed by the women community in the village government.

This study provides a theoretical contribution to the enrichment of the use of the MCLP method to collect cooking oil waste that is spread over an area. The WCO collection point's design provides managerial contributions for the Semarang city government to reduce WCO waste to minimize the environmental impact. Furthermore, the collection of WCO also improves the economic aspect because WCO waste can be recycled into more value-added products. This research is still limited to the determination of the WCO collection center. Further research is needed to design the optimal route to take WCO from the collection center to the WCO processing center. For more comprehensive research, an in-depth study on the recycling process's feasibility analysis into its derivative products.

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