CS166 Final Project

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The codes can also be found here.

Feedback and Grading

I would like to receive feedback general and broad in scope.

Model Description

This project models a waste removal optimization scenario. It models a road system, represented by a network, that connects farms, the waste removal company, and waste drop-off sites. The model is inspired by real-life data from the City Farm Movement in London. Among about a dozen city farms located across London, this project is based on 11 city farms located closely around central London. Figure 1 shows the description of each city farm, including its name, postcode area, and size. Figure 2 shows the location distribution of each farm within a map divided by postcode area in blue boundaries. The circles represent the farms and are color-coded based on postcode area.

	Farm name	Postcode area	Size (in acres)
1	Kentish Town City Farm	NW	4
2	Freightliners City Farm	N	2.5
3	Hackney City Farm	E	1.5
4	Spitalfields City Farm	E	1.3
5	Stepney City Farm	E	3
6	Surrey Docks Farm	SE	2
7	Mudchute City Farm	E	32
8	Newham City Farm	E	10
9	Woodlands Farm Trust	DA	89
10	Vauxhall City Farm	SE	1.5
11	Deen City Farm	SW	5

Figure 1. A table containing the 11 city farms used as the model's data.

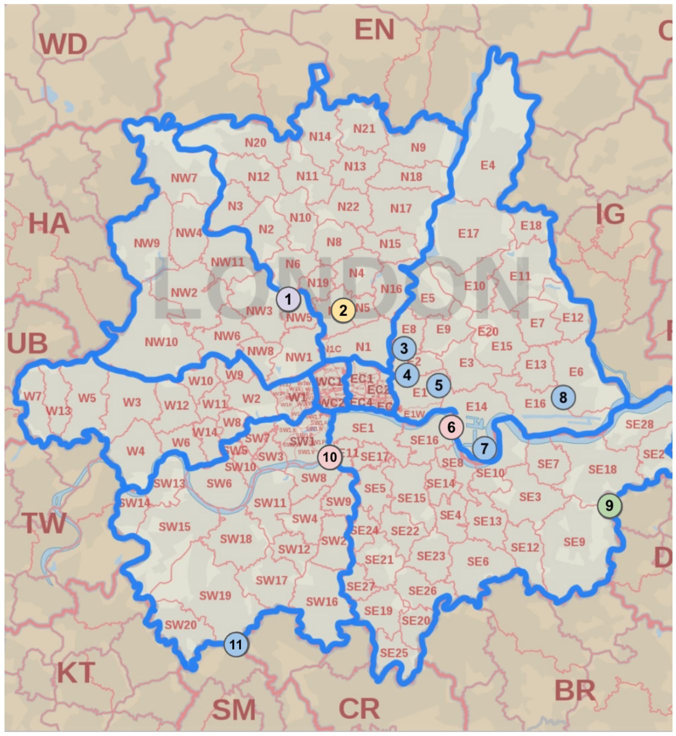


Figure 2. A map representing the farms as color-coded circles based on postcode area.

Figure 3 is identical to Figure 2 but with the map in the background removed. It is an initial mockup representing the London city farms as a network, with the circles (farms) acting as nodes without any edges connected yet. In addition to the farm nodes, nodes representing the company headquarters ("HQ") and waste drop-off sites will be added.

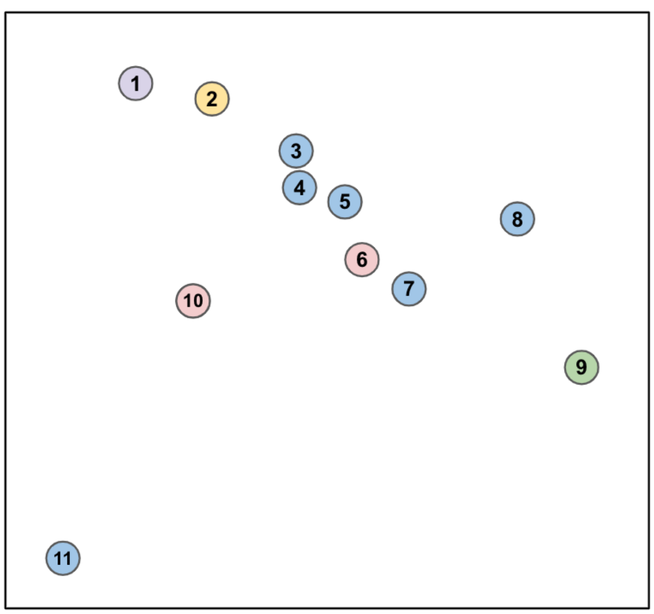


Figure 3. An initial mockup of the London city farms represented as a network.

Assumptions and Estimations

Here are some assumptions related to the model and scenario:

- For convenience, we assume all 11 farms are fruit/vegetable farms, whereas some are actually animal farms.
- Newham City Farm (Node 8) permanently closed a few months ago, but we ignore this fact and assume it operates.
- As the model is based on real-life data of city farms in London, the locations of the farms are fixed. We will represent these locations as coordinates, picturing the farms positioned in a coordinate plane. For example, if Node 11 is (0, 0), Node 1 is approximately (1, 8) considering its relative position from Node 11. The purpose of assigning coordinates is to graph the farms within their fixed positions later. Thus, the relative relationships of each farm's coordinates are more important than the actual coordinate values.
    - The distance between two farms can be calculated using the formula for computing the distance between two coordinates. For instance, the distance between Node 11 and Node 1 in the model is $\sqrt{(0-1)^2 + (0-8)^2} = \sqrt{65} \approx 8.06$, whereas the actual distance is about 12 miles. Thus, we can divide or multiply 12/8.06 ≈ 1.49 to convert the distance in the model (in coordinates) from and to the actual distance (in miles).
- Each truck has a finite capacity for carrying waste.
- Each truck has a finite fuel supply. When running low on fuel, it needs to return to the HQ to refuel.
- The waste removal company wants to optimize time and profit by driving as little as possible between farms and conserving fuel.
- A truck might drive to another farm, wait at the current farm (using time but not fuel), go to a waste drop-off site, or return to the HQ where it can refuel.

Here are further approximations and estimations made for more realistic modeling:

- The farms in our model are fruit/vegetable farms. According to the World Wildlife Fund, about 26% of the total production of fruit/vegetable farms is waste (WWF-UK, 2021). In this project, we round this number and assume 25% of a farm's total production is waste.

- For a decent harvest year, the average yearly vegetable yield per acre is 19,650 pounds per acre (New England Vegetable Management Guide, n.d.). In this project, we round this number and assume a yield of 20,000 pounds per acre.
- Assuming our model is a good harvest year, the above numbers can be used to calculate the average waste per acre: 20,000*25% = 5,000 pounds per acre. As this is the yearly waste, the average daily waste produced by farms is 5,000/365 ≈ 13.7 pounds per acre.
- As the waste removal company values saving money, we assume the company uses a small-sized dump truck, which can transport around 13,000 to 15,000 pounds (Lynch Truck Center, n.d.). In this project, we assume the truck's capacity is 14,000 pounds.
- A dump truck can go about 5 to 6 miles per gallon of gas (Badger Truck & Auto Group, n.d.). In this project, we assume it can go 5.5 miles per gallon.
- Small- to medium-sized trucks have 30 to 40-gallon gas tanks (Melillo, 2021). In this project, we assume the gas tank capacity is 35 gallons.
- The fuel price changes based on a normal distribution with a mean of 6.13 and a standard deviation of 0.57. This is based on the 2022 average diesel price (1.62 GBP per liter ≈ 6.13 GBP per gallon), minimum diesel price (1.49 GBP per liter ≈ 5.64 GBP per gallon), and maximum diesel price (1.79 GBP per liter ≈ 6.78 GBP per gallon) in the UK (GlobalPetrolPrices.com, n.d.).
    - The difference between the average and minimum is $6.13 - 5.64 = 0.49$ and between the average and maximum is $6.78 - 6.13 = 0.65$. The standard deviation 0.57 is the average of these differences (i.e., the average of 0.49 and 0.65).

Another key aspect of this model is the uncertainty of the waste production rate of each farm. While we can approximate the average amount of daily waste per farm by using the 13.7 pounds waste per acre benchmark and applying it to each farm depending on its size (in acres), it is possible for farms to produce much less or more than the average amount.

This project incorporates this uncertainty by assuming that each farm's waste production rate follows a normal distribution with the mean equal to the average amount of waste. Also, we assume that each farm can have as little as zero waste per day (minimum) and as much as twice the average amount of waste per day (maximum). This defines the range of the normal distribution. To ensure that the probability of reaching these extrema is not too low, the standard deviation is big ($\frac{1}{2}$ of the average amount of waste) so that the tails of the distribution are heavy.

For example, the size of Farm 1 (Kentish Town City Farm) is 4 acres. Therefore, Farm 1 will produce 4*13.7 = 54.8 pounds of waste every day on average. The minimum waste it can produce every day is 0 pounds, and the maximum is 54.8*2 = 109.6 pounds. The parameters to represent this waste production rate as a normal distribution are a mean of 54.8 and a standard deviation of 54.8/2 = 27.4.

Figure 4 shows a histogram of the random samples generated from this distribution. In other words, Figure 4 shows the distribution of the amount of daily waste produced by Farm 1 based on our assumptions. As expected, the average is around 54.8, and it is possible to have zero waste production as well as double the average waste production. Figure 5 shows the parameters related to the waste production rate for all 11 farms.

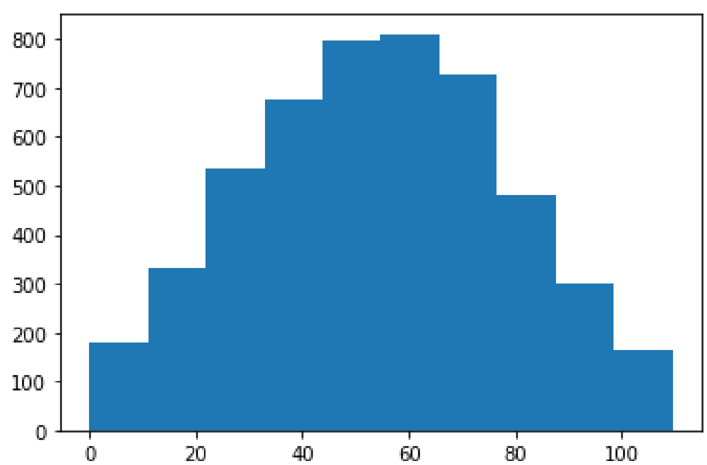


Figure 4. A histogram showing the daily amount of waste produced by Farm 1, plotted by random samples generated from Farm 1's waste production distribution.

	Farm name	Size (in acres)	Average daily waste	Standard deviation	Minimum daily waste	Maximum daily waste
1	Kentish Town City Farm	4	54.8	27.4	0	109.6
2	Freightliners City Farm	2.5	34.3	17.13	0	68.5
3	Hackney City Farm	1.5	20.6	10.28	0	41.1
4	Spitalfields City Farm	1.3	17.8	8.91	0	35.6
5	Stepney City Farm	3	41.1	20.55	0	82.2

6	Surrey Docks Farm	2	27.4	13.7	0	54.8
7	Mudchute City Farm	32	438.4	219.2	0	876.8
8	Newham City Farm	10	137	68.5	0	274
9	Woodlands Farm Trust	89	1,219.3	609.65	0	2,438.6
10	Vauxhall City Farm	1.5	20.6	10.28	0	41.1
11	Deen City Farm	5	68.5	34.25	0	137

Figure 5. A table containing the parameters related to each farm's waste production rate which follows a normal distribution within a specified range.

Therefore, these assumptions hold when dealing with fruit/vegetable farms that are harvested in decent years and when a fixed portion of their productions is consistently waste. Also, the company must use a small-sized dump truck with a consistent fuel mileage with fixed waste collection capacity and gas capacity. The assumptions may not hold in circumstances where such conditions are not satisfied.

Implemented Strategies

The goal of this project is to compare different strategies the waste removal company can implement to determine a reasonable waste collection schedule and route that optimizes time and profit by minimizing distance moved and fuel consumed. To achieve these optimization goals, the main outputs to be measured and compared are the following:

- Distance moved by the truck (yearly)
- Amount of fuel moved by the truck (yearly)
- Amount of money spent on fuel (yearly)

The first output is related to the "time" the company aims to optimize, while the remaining two outputs are related to the "profit" the company aims to optimize. As the first two outputs are proportional to each other (i.e., more distance requires more fuel), the third output helps us better optimize for profit as it incorporates the uncertainty aspect of fuel price that can change on a daily basis. We will run the simulation multiple times over a 1-year time period so that the company can understand the expected long-term outcomes of different strategies.

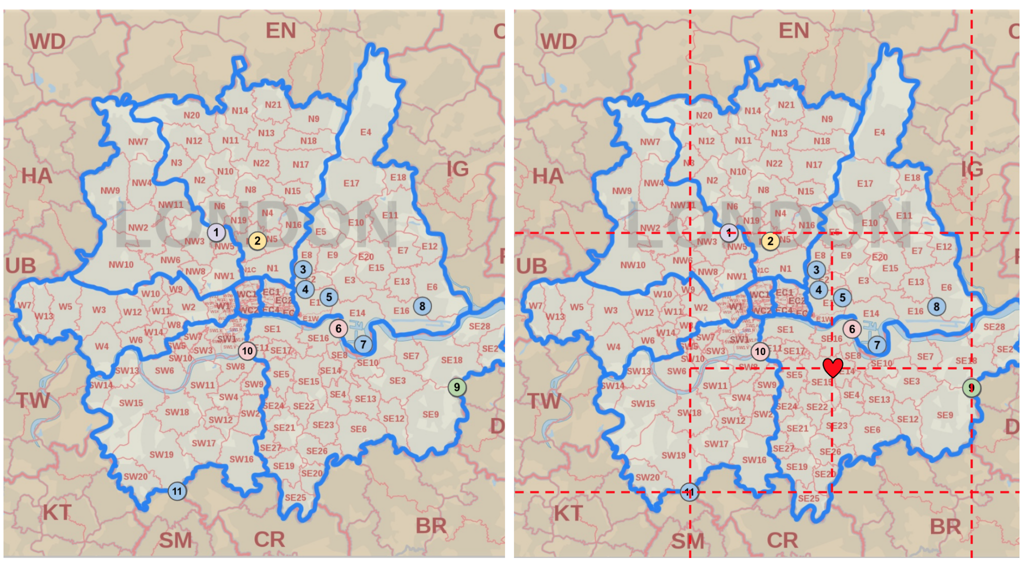
There are two main strategies to be implemented and compared. The first strategy allocates the company resources by geographically dividing London without considering each farm's waste production rate. The second strategy allocates the company resources efficiently by prioritizing farms with relatively more waste production without considering the geographic locations of the farms.

Strategy 1: Allocation based on Geographic Area

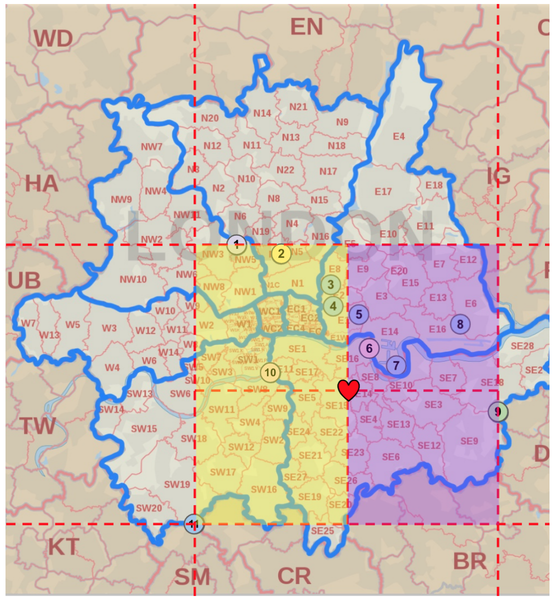
Overview of Strategy 1

The first strategy divides the entire area where all the 11 farms are located into two areas, places the company headquarters in the center, and allocates one waste drop-off site and one truck per divided area. The following explains this in detail:

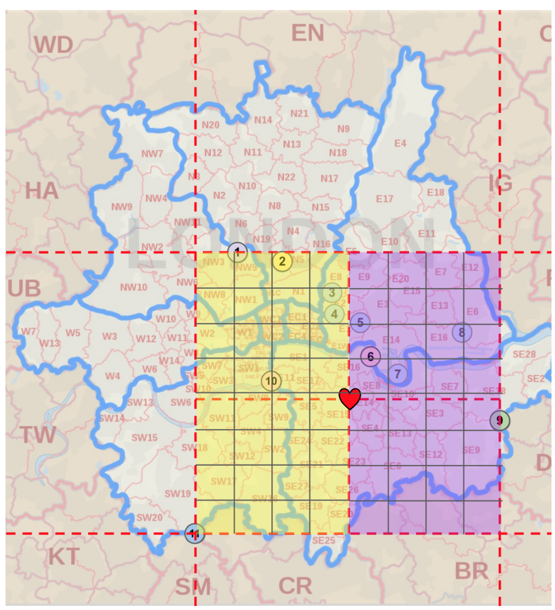
- **Step 1**: Draw a horizontal line passing through the topmost farm (Farm 1) and bottommost farm (Farm 11). Draw a vertical line passing through the leftmost farm (Farm 11) and rightmost farm (Farm 9). This forms a square-like area; we place the company headquarters (shown as a red heart icon) in the center of this area. The left is the original map and the right is the map that shows the square-like area.



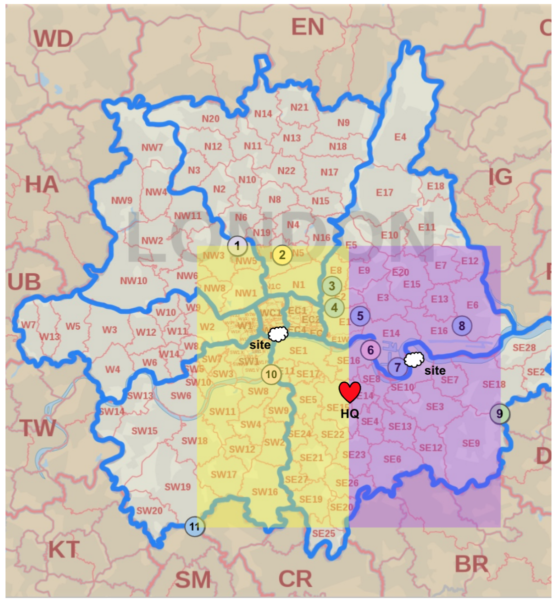
- **Step 2**: Divide the square-like area into two sub-areas: left (yellow) and right (purple). The left area contains six farms (Farms 1, 2, 3, 4, 10, 11), and the right area contains five farms (Farms 5, 6, 7, 8, 9).



- **Step 3**: Treat the two areas as separate coordinate planes on a grid so that the position of each farm can be represented as coordinates. For example, in the left area, Farm 11 is (0, 0) and Farm 1 is (1, 8), and the company headquarters is (4, 4). For example, in the right area, Farm 5 is (0, 6), Farm 6 is (0.5, 5), and the company headquarters is (0, 4).



- **Step 4**: Within each area, treat each node (farm) as vertices and connect them to shape a polygon. The computed coordinates of the centroid of the polygon are the position of the drop-off site (shown as cloud icons). The figure below is the final version of the allocations of Strategy 1.



In conclusion, Strategy 1 places two waste drop-off sites in London: one at the centroid of the left area and the other at the centroid of the right area. Furthermore, two trucks operate in total: one in the left area and the other in the right area. As the two trucks only operate within their designated areas (either left or right), they have different collection schedules and routes based on the farms they visit.

Strategy 1 also has specific "waste collection days" in which the trucks visit *all* farms in their designated area rather than trucks visiting only some farms every day or skipping farms. As the trucks operate based on such waste collection cycles, it is possible for them to return to the headquarters with the waste loaded if their capacity is not full yet.

Strategy 1 Implementation: Waste Collection Route

We first assume that all nodes (farms, drop-off site, and headquarters) in each area are fully connected to each other. This assumption implies that a truck can move to any node from any node. Based on this, we consider all possible routes of visiting all the farms within the area with the starting node fixed as the headquarters since the truck must always start from the headquarters. The shortest route is then found by summing the distances between the nodes.

For the left area, (Headquarters → Farm 4 → Farm 3 → Farm 2 → Farm 1 → Farm 10 → Farm 11) is the shortest route to visit all six farms. For the right area, (Headquarters → Farm 7 → Farm 6 → Farm 5 → Farm 8 → Farm 9) is the shortest route to visit all five farms.

We use this shortest route to remove some of the edges of the graph so that all farms are connected to the drop-off site and headquarters but only connected to neighboring farms. Figure 6 shows the final network of the left and right areas, respectively. The numbers on the edges represent the distance between nodes. We can see that the relative positions of the nodes in the network roughly align with the actual positions on the map.

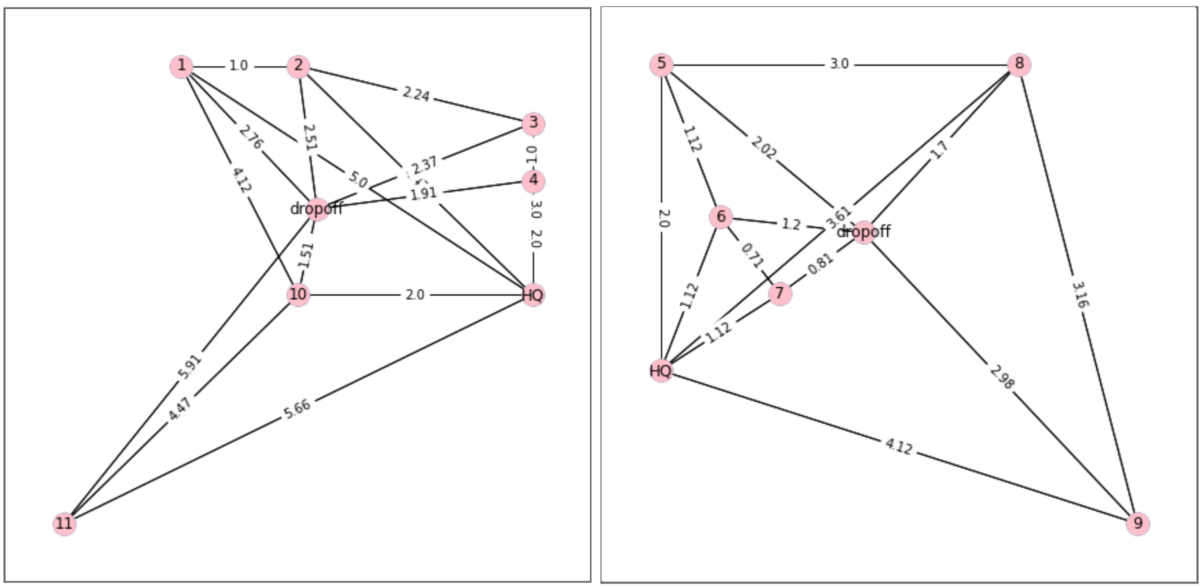


Figure 6. The final network of the London city farms in the left and right area, respectively.

Strategy 1 Implementation: Waste Collection Schedule

Because each area contains farms of different sizes—and thus—different waste production rates, the waste collection schedule also differs. For example, Figure 7 summarizes the list of farms belonging to the left area, along with their average, minimum, and maximum daily waste production. This shows that the six farms produce an average of 216.5 pounds and a maximum of 432.92 pounds of waste every day.

Since we assumed that the truck's capacity is 14,000 pounds, the truck should visit all farms every 14,000/216.5 ≈ 64.68 days if the farms produce an average amount of waste and every 14,000/432.92 ≈ 32.34 days if the farms produce a maximum amount of waste. To be risk-averse, the latter value is chosen as the waste collection cycle to prevent farms from being overloaded with waste. Thus, the trash collection day for the left area is every 32 days.

	Farm name	Average daily waste	Minimum daily waste	Maximum daily waste
1	Kentish Town City Farm	54.8	0	109.6
2	Freightliners City Farm	34.3	0	68.5
3	Hackney City Farm	20.6	0	41.1
4	Spitalfields City Farm	17.8	0	35.6
10	Vauxhall City Farm	20.6	0	41.1
11	Deen City Farm	68.5	0	137
	Total	**216.5**	**0**	**432.92**

Figure 7. The list of farms in the left area and their average, minimum, and maximum waste production.

The same logic applies to the right area. Figure 8 summarizes the list of farms belonging to the right area, along with their average, minimum, and maximum daily waste production. The truck should visit all farms every 14,000/1,863.2 ≈ 7.51 days if the farms produce an average amount of waste and every 14,000/3,726.4 ≈ 3.76 days if the farms produce a maximum amount of waste. Again, the latter value is chosen, and thus, the trash collection day for the right area is every 3 days.

We can see that the collection cycle greatly differs between the left and right areas because the right area contains some of the biggest farms in London, including Farm 7 (Mudchute City Farm) and Farm 9 (Woodlands Farm Trust).

	Farm name	Average daily waste	Minimum daily waste	Maximum daily waste
5	Stepney City Farm	41.1	0	82.2
6	Surrey Docks Farm	27.4	0	54.8
7	Mudchute City Farm	438.4	0	876.8
8	Newham City Farm	137	0	274
9	Woodlands Farm Trust	1,219.3	0	2,438.6

	Total	**1,863.2**	**0**	**3,726.4**

Figure 8. The list of farms in the right area and their average, minimum, and maximum waste production.

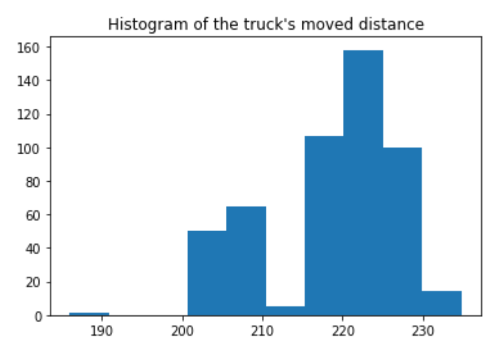
Strategy 1 Implementation: Truck Refuel Threshold

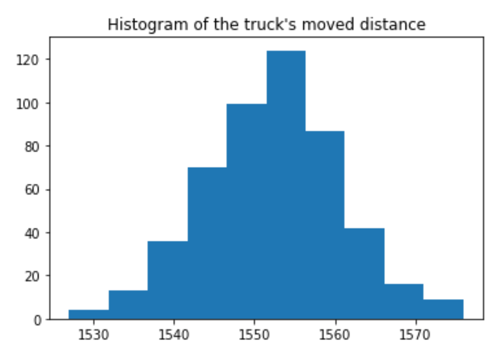
To determine the critical amount of fuel that requires the truck to refuel, we consider the nodes furthest from the headquarters in each area. For the left area, the furthest node from the headquarters is Farm 11, which is 5.66 away in coordinate distance units (≈8.43 miles away). Since we assumed that a truck can go 5.5 miles per gallon, the truck needs at least 8.43/5.5 ≈ 1.53 gallons to move from the furthest node to the headquarters for refueling. Rounding this up to be risk-averse, we assume the truck operating in the left area always needs 2 gallons for safety.

For the right area, the furthest node from the headquarters is Farm 9, which is 4.12 away in coordinate distance units (≈6.13 miles away). Thus, the truck needs at least 6.13/5.5 ≈ 1.115 gallons to move from the furthest node to the headquarters for refueling. Rounding this up, we assume the truck operating in the right area always needs 1.5 gallons for safety. When the trucks in each area have less than their refuel threshold, they move to the headquarters to refuel.

Strategy 1 Results

Figure 9 below shows the results of the implementation of Strategy 1 when the simulation has been run over a 1-year time period 500 times in total. The distribution of the outcomes is shown as a histogram, along with the average and 95% confidence intervals of the 500 trials rounded to one decimal place.

<table>
<tr><th></th><th>Strategy 1: Left area</th><th>Strategy 1: Right area</th></tr>
<tr><td><u>Outcome 1:</u>
Distance moved by the truck (yearly)</td><td>


Average: 219.5 miles
95% CI: [218.8, 220.2]</td><td>


Average: 1,552.3 miles
95% CI: [1,551.5, 1,553.0]</td></tr>
</table>

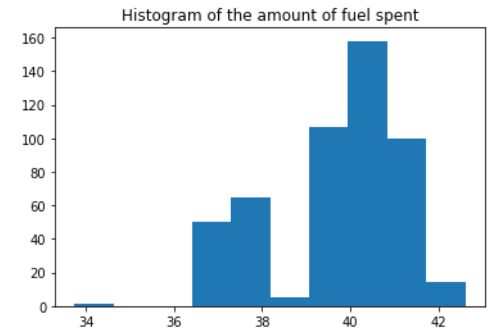
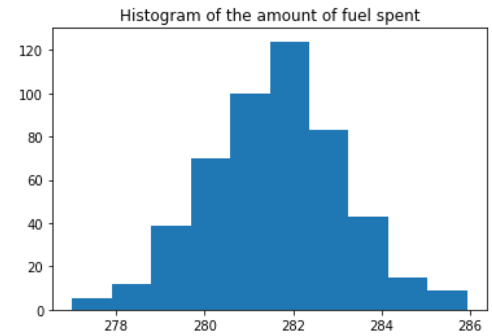
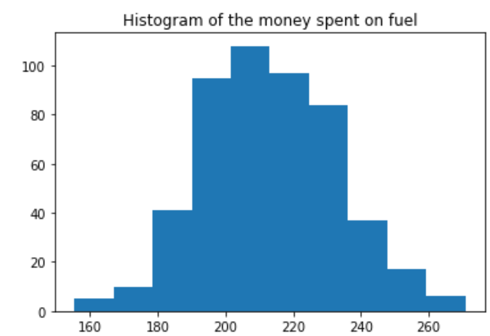
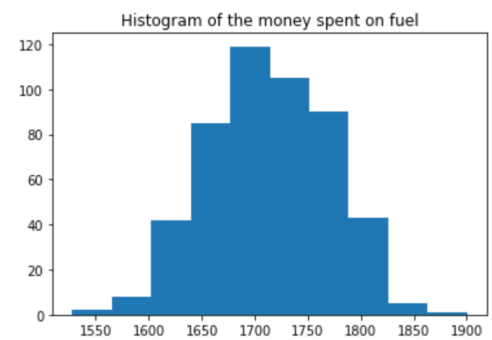
<u>Outcome 2:</u> Amount of fuel moved by the truck (yearly)	 Average: 39.8 gallons 95% CI: [39.7, 40.0]	 Average: 281.6 gallons 95% CI: [281.5, 281.7]
<u>Outcome 3:</u> Amount of money spent on fuel (yearly)	 Average: 213.3 GBP 95% CI: [211.6, 215.1]	 Average: 1,713.8 GBP 95% CI: [1,708.8, 1,718.8]

Figure 9. The key outcomes of the implementation of Strategy 1.

Strategy 2: Allocation based on Waste Production

Overview of Strategy 2

Unlike the first strategy that divided the area of London and grouped farms based on geographical proximity without considering each farm's individual waste production rate, the second strategy prioritizes considering each farm's waste production rate. The sum of the average waste production of the three biggest farms (Farm 7, 8, and 9) takes up approximately 86.3% of the total average waste production of the 11 farms. There will be one truck and one drop-off site for Strategy 2, and such company resources will be allocated prioritizing these three "big farms."

Again, we will treat the area where the farms are located as a coordinate plane and represent the relative position of each farm as coordinates, shown on the right in Figure 10. The company headquarters will be located in the center of the three "big farms," which can be found by computing the centroid of Farm 7, 8, and 9's coordinates. This is because—as will be explained below—the waste collection cycle of Strategy 2 requires the truck to visit these three farms much more frequently than the remaining farms.

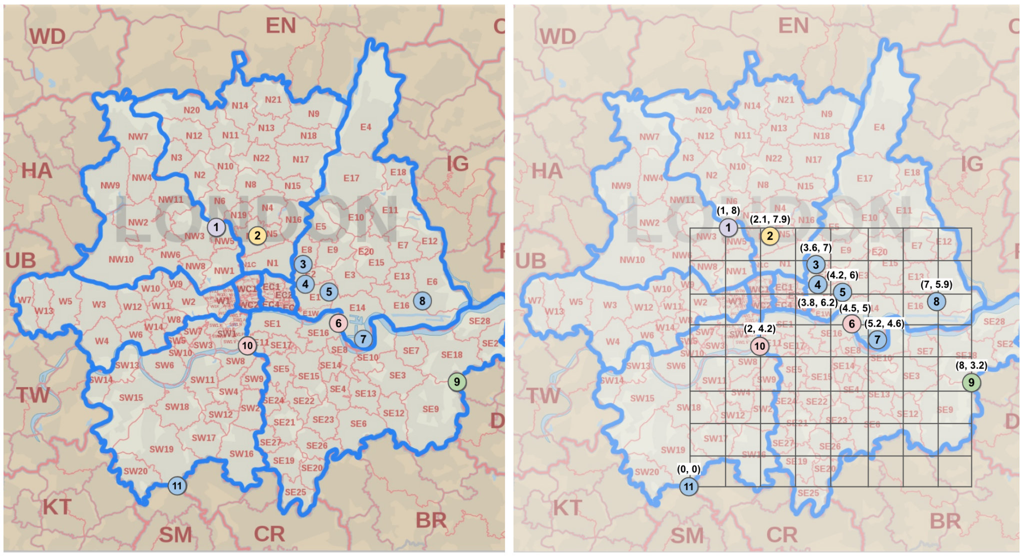


Figure 10. The original map (left) and coordinate-marked map (right).

While the company headquarters prioritize only the three "big farms," the drop-off site is allocated between the centroid of the "big farms" and the centroid of the remaining eight farms for a more balanced location. The centroid of the "big farms" is in coordinate (6.73, 4.57) (which is, thus, the location of the headquarters), and the centroid of the remaining small farms is in coordinate (2.65, 5.54). Hence, the drop-off site is located at the middle point of these two coordinates: (4.69, 5.05). Figure 11 shows the final version of the allocations of Strategy 2, where the headquarters is shown as a red heart icon and the drop-off site as a cloud icon.

In conclusion, Strategy 2 places one waste drop-off site at a location in between the three "big farms" and the remaining eight farms while the headquarters is at the center of the "big farms." One truck operates across the entire area, but like Strategy 1, there are specific "waste collection days" in which the trucks visit all scheduled farms rather than trucks visiting only some farms every day or skipping farms. In other words, the truck visits *all* three farms on days visiting the "big farms" and visits *all* eleven farms on days visiting the entire area.

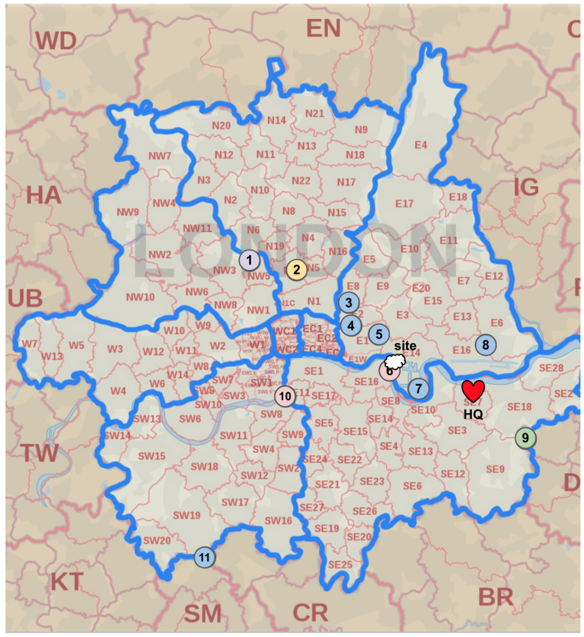


Figure 11. The final version of the allocations of Strategy 2.

Strategy 2 Implementation: Waste Collection Route

The same logic used in Strategy 1 is applied to find the shortest route that visits all scheduled farms. We first assume that all nodes (farms, drop-off site, and headquarters) are fully connected to each other and find the shortest route by summing the distances between the nodes.

When visiting only the "big farms," (Headquarters → Farm 7 → Farm 8 → Farm 9) is the shortest route. When visiting all eleven farms, (Headquarters → Farm 9 → Farm 8 → Farm 7 → Farm 6 → Farm 5 → Farm 4 → Farm 3 → Farm 2 → Farm 1 → Farm 10 → Farm 11) is the shortest route.

We use this shortest route to remove some of the edges of the graph so that all farms are connected to the drop-off site and headquarters but only connected to neighboring farms. Figure 12 shows the final network for Strategy 2. We can see that the relative positions of the nodes in the network roughly align with the actual positions on the map.

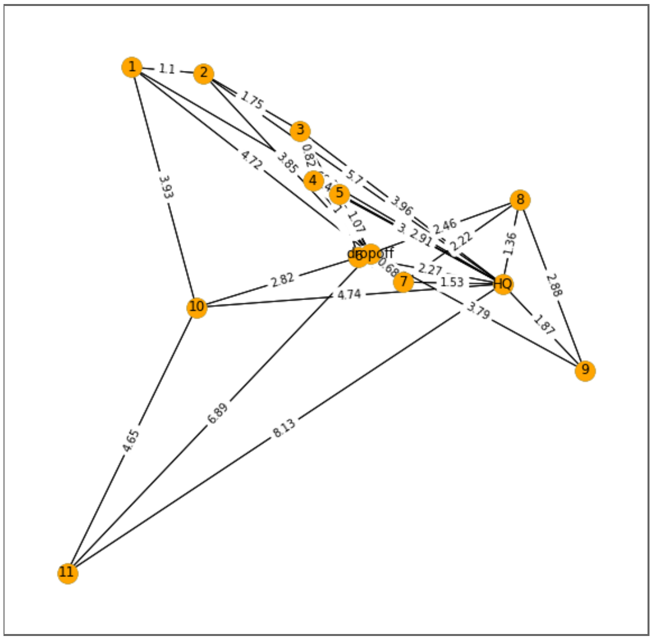


Figure 12. The final network of the London city farms for Strategy 2.

Strategy 2 Implementation: Waste Collection Schedule

Each farm's average, minimum, and maximum daily waste production (shown in Figure 5) is summed in groups and shown in Figure 13. This shows that the three "big farms" produce an average of 1,794.7 pounds and a maximum of 3,589.4 pounds of waste every day, whereas the remaining eight farms produce only an average of 285 pounds and a maximum of 569.9 pounds of waste every day.

Since we assumed that the truck's capacity is 14,000 pounds, the truck should visit the three "big farms" every 14,000/1,794.7 ≈ 7.8 days if the farms produce an average amount of waste and every 14,000/3,589.4 ≈ 3.9 days if the farms produce a maximum amount of waste. Likewise, the truck should visit the remaining eight farms every 14,000/285 ≈ 49.1 days for average waste production and 14,000/569.9 ≈ 24.6 days for maximum waste production.

Farm groups	Average daily waste	Minimum daily waste	Maximum daily waste
The three "big farms"	1,794.7	0	3,589.4
The remaining eight farms	285	0	569.9
Total	**2,079.7**	**0**	**4,159.3**

Figure 13. The average, minimum, and maximum waste production for each farm group.

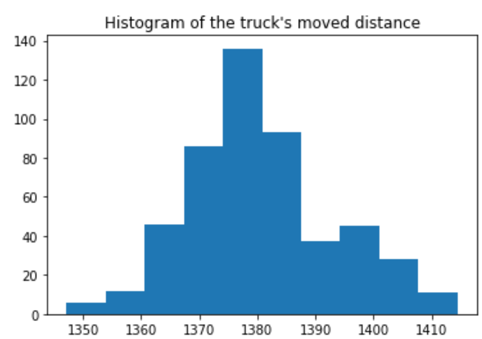
Using the latter maximum values, Strategy 2 determines that the truck should visit the three "big farms" every 3 days and all eleven farms every 24 days. Since the smaller eight farms do not produce much waste, the truck visits all eleven farms instead of just these eight farms every 24 days.

Strategy 2 Implementation: Truck Refuel Threshold

Within the network built for Strategy 2, the furthest node from the headquarters is Farm 11, which is 8.13 away in coordinate distance units (≈12.1 miles away). Since we assumed that a truck can go 5.5 miles per gallon, the truck needs at least 12.1/5.5 ≈ 2.2 gallons to move from the furthest node to the headquarters to refuel. Rounding this up to be risk-averse, we assume the truck always needs 2.5 gallons for safety.

Strategy 2 Results

Figure 14 below shows the results of the implementation of Strategy 2 when the simulation has been run over a 1-year time period 500 times in total. The distribution of the outcomes is shown as a histogram, along with the average and 95% confidence intervals of the 500 trials rounded to one decimal place.

	Strategy 2
<u>Outcome 1:</u> Distance moved by the truck (yearly)	 Average: 1,380.6 miles 95% CI: [1,379.5, 1,381.7]

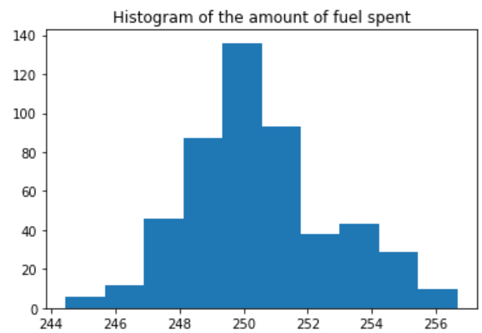
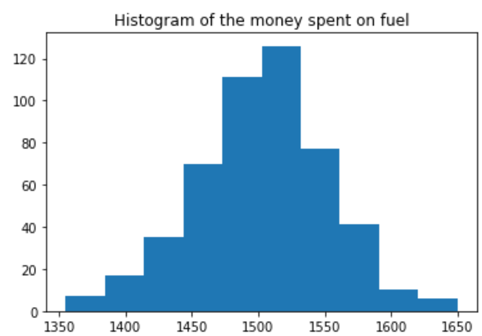
<u>Outcome 2:</u> Amount of fuel moved by the truck (yearly)	 Average: 250.5 gallons 95% CI: [250.3, 250.7]
<u>Outcome 3:</u> Amount of money spent on fuel (yearly)	 Average: 1,503.1 GBP 95% CI: [1,498.7, 1,507.5]

Figure 14. The key outcomes of the implementation of Strategy 2.

Strategy Comparison: Simulation Results

Figure 15 summarizes the distribution, average, and 95% confidence interval of the three outcomes when running each strategy simulation over a 1-year time period 500 times. The results for Strategy 1 are the results of simultaneously running the simulation for the left area and right area.

As can be seen, all three outcomes of Strategy 1 are higher than those of Strategy 2. Only comparing the average values, the truck(s) moves 1.14 times more, uses 1.14 more fuel, and spends 1.13 times more money on fuel per year for Strategy 1. Hence, Strategy 2 is a better strategy than Strategy 1 for a company that aims to optimize time and profit.

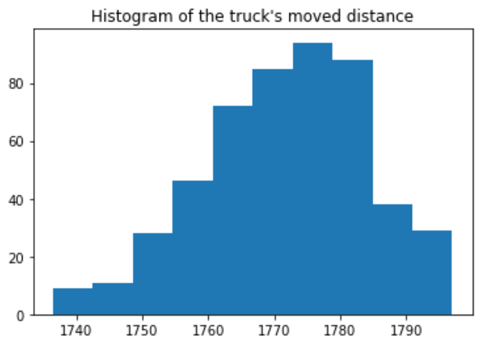
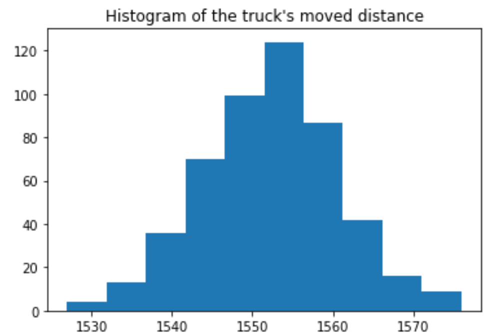
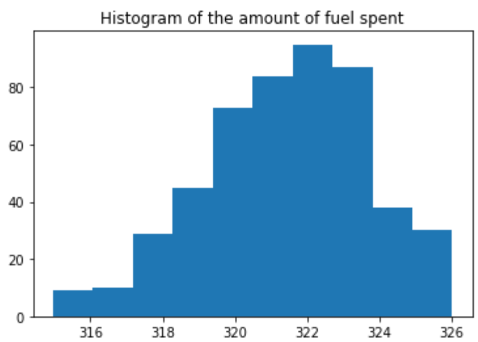
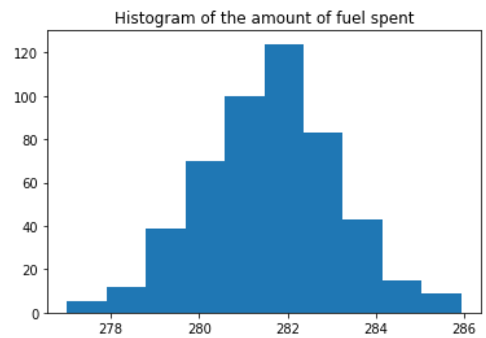
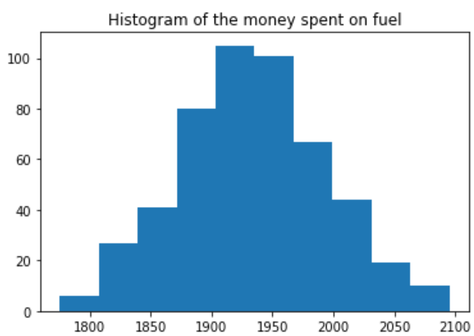
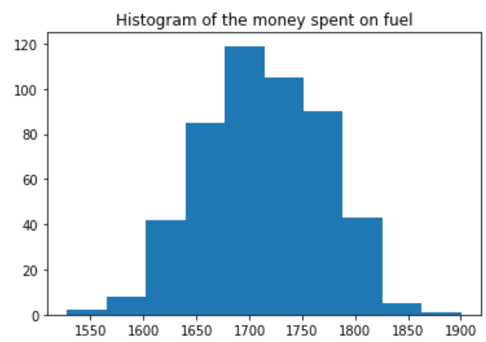
	Strategy 1	Strategy 2
<u>Outcome 1:</u> Distance moved by the truck (yearly)	 Average: 1,771.7 miles 95% CI: [1,770.7, 1,772.8]	 Average: 1,552.3 miles 95% CI: [1,551.5, 1,553.0]
<u>Outcome 2:</u> Amount of fuel moved by the truck (yearly)	 Average: 321.4 gallons 95% CI: [321.2, 321.6]	 Average: 281.6 gallons 95% CI: [281.5, 281.7]
<u>Outcome 3:</u> Amount of money spent on fuel (yearly)	 Average: 1,933.1 GBP 95% CI: [1,927.9, 1,938.4]	 Average: 1,713.8 GBP 95% CI: [1,708.8, 1,718.8]

Figure 15. The key outcomes of the implementation of Strategy 1 versus Strategy 2.

The 95% confidence intervals are quite narrow for both strategies, especially the first two outcomes that are less than ±1 mile and 0.2 gallons from the average value, respectively. The third outcome, the amount of money spent on fuel, has the widest confidence interval, about ±5.1 GBP from the average value. This is likely due to the model's fuel price distribution parameter that assumes the fuel price fluctuates daily. A more realistic way to model the fuel price could be to have a changing trend over a set of days rather than daily fluctuations.

Theoretically, since the uncertainty of Monte Carlo simulations reduces as $\frac{1}{\sqrt{n}}$ where n is the number of simulations, we can expect this to apply to our model as well. In other words, increasing the simulation runs from 500 to 1,000 or more could decrease the uncertainty. However, the empirical results showing that the first two outcomes have sufficiently narrow confidence intervals and that the third outcome's relatively wide confidence interval is likely due to the assumed fuel price distribution of the model indicate that it is not highly necessary to increase the number of runs.

Conclusion: Strategy Recommendation

As all three key outcomes of Strategy 2 are preferable to Strategy 1, Strategy 2 is a better strategy than Strategy 1 in optimizing time and profit. The company can move fewer distances and save more fuel money by consuming less fuel when pursuing Strategy 2.

The same conclusion still holds even when considering the maintenance costs of the company resources. Strategy 1 operates two trucks and two drop-off sites, whereas Strategy 2 operates only one each. Thus, we can expect lower maintenance costs and variable costs (e.g., truck driver labor cost) for Strategy 2 as well.

These results are reasonable considering how the two strategies were designed. Strategy 1 uses geographic proximity to group the farms, aiming to streamline the physical moving distance and, thus, time. However, this disregards the waste production rate of each farm, resulting in a highly unbalanced waste production and waste collection schedule between the left and right areas.

On the other hand, Strategy 2 uses waste production rates to extract farms that require more frequent visits than others, aiming to streamline the waste collection route. However, it is also important to note that Strategy 2 was lucky that the biggest farms with the highest waste production (Farms 7, 8, and 9) are geographically close to each other. If not, the result may have been drastically different as the truck would have to make frequent visits to farms far away from each other, thus risking both time and profit.

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