

CS166 Final Project

Task: A simulation is built to evaluate the effects of different strategies taken within the simulation.

Topic: The scenario to model and simulate is waste removal between waste producing farms.

Main Goal: To use the model/simulation to evaluate different strategies in the scenario being modeled. The model and simulation incorporate some randomness. Most processes contain some uncertainty or inherent randomness. As part of the assignment, the Monte Carlo simulation of the random process outputs distribution over results that are then interpreted accordingly.

GitHub Link: <https://github.com/cesar-ca/cs166-modeling-and-analysis/tree/main/CS166%20Final%20Project>

Colab Link: <https://colab.research.google.com/drive/1v3L-Li1CJEmqswrRoDpS42kvlS4ZIIIVY?usp=sharing>

Feedback and Grading

The part of the work that I would like feedback on the most is on the assumptions and considerations taken in order to take a waste collection system and model it with networks.

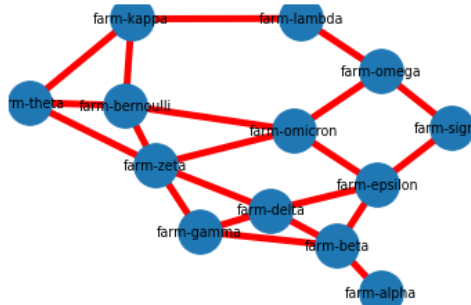
Project Outline

- Describe the scenario you are modeling.

The scenario being modeled is a waste removal company route, similar to the traveling salesman problem. The company has a few trucks that visit farms, collect waste, and drop it off at a few of the waste sites in the area. The road system is represented by a network that connects the farms, the waste removal company, and the waste drop-off sites.

In [4]:

```
plt.show()
```



Edge weights in the network represent the length of each road which means that in the network they will traverse the length of the road to travel between. Different farms have different average rates of waste production, but it is not fully deterministic so there will be more waste on some days than others. To determine a good collection schedule and route for the waste removal company given the uncertainty in the network we can look at the different parts of the network such as increasing drop-off sites or increasing trucks. There is a possibility that a farm might have no or very little waste.

Some of the given assumptions of the model

- Each truck has a finite capacity for carrying waste.
- Each truck has a finite fuel supply. When it is running low on fuel, it needs to return to the company headquarters to refuel.
- The waste removal company wants to optimize for time and profit by driving between farms as little as possible 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 company headquarters where it can refuel.

Simulation Capabilities

- What do you want your simulation to be able to do and what information do you want to be able to measure from it?

I want the simulation to be able to model as closely as possible the different interactions between different parts of the network such as trucks waste collection and drop-off sites, etc. The information that I want to be able to measure is the time it takes to travel in the network and to maximize that time.

Rules of the Simulation

- Describe the rules of the simulation and how they capture the scenario.

The rules set forth for the simulation allows for the drop-off sites to vary between runs of the model when the parameters are changed.

Modeling Assumptions

- Identify any modeling assumptions and explain under what circumstances these assumptions may or may not be valid.

The network is represented by nodes in an area that roughly represent the different interconnected sectors. The nodes themselves can contain within them drop-off sites, trucks waiting to go collect waste, and the farm themselves. The edges represent the different farm areas that are close to each other.

The different drop-off sites are contained within the nodes that rather than represent a single farm, represent an area where there exists a farm.

The edge weights represent the distance between the nodes so they are calculated through some assigned weight to each of the node that represent its size.

The rate at which the farms in the node require the waste to be collected is based on some assumed metric for the total annual waste of the area.

The network represents a mostly fictitious scenario with waste collection processes in place for the nodes and edges representing the distance between them. So, many of the initial values are assumed.

Model Parameters

- Describe the model parameters and how they affect the behavior of the simulation.

The model parameters include the network itself which in this scenario is a graph with nodes and edges where nodes represent some area that contain farms that need their waste collected and edges represent the distance between them.

The number of drop-off sites is the parameter that is being used for different strategies, so in one strategy the drop-off sites are randomized throughout the nodes in the network and for the other strategy the drop-off sites are strategically placed based on weights of the nodes.

- Some guiding factors to determine why there are drop-off sites at certain nodes include the length of the queue of the places that need their waste collected and the amount of waste at each node which can result in higher priority.

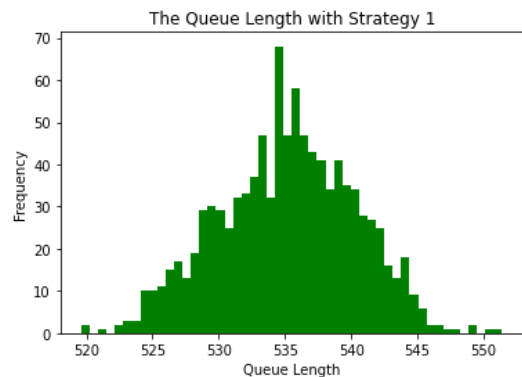
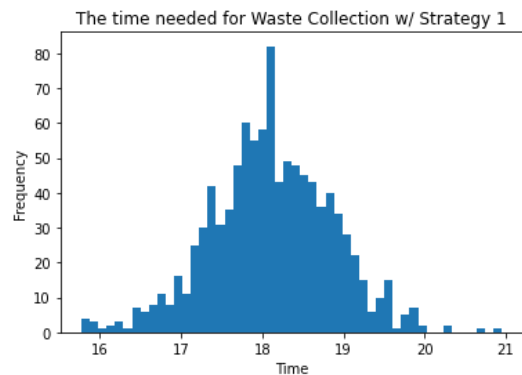
Model Output

- Describe the output/measurements of the simulation and how they relate to the scenario that is being modeled. What are the quantities of interest?

The output of the simulation include the drop-off sites available for specific waste collection event as well as the number of sites that need waste collected from.

In [10]:

```
# Randomized drop-off sites  
plt.show()
```



Average time needed for the average strategy: 18.11095171197446
Average time needed 95% confidence interval (18.064558225179493, 18.15734519876943)
Average queue length: 535.1788188257241
Average queue length 95% confidence interval (534.8606843644537, 535.4969532869944)

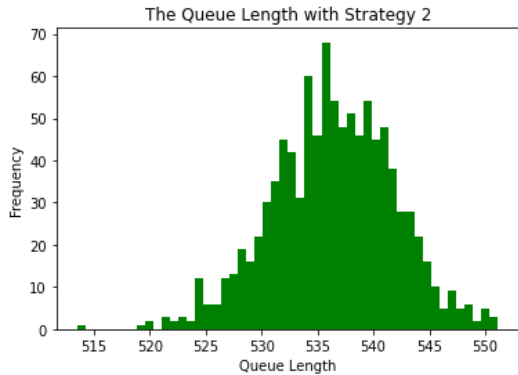
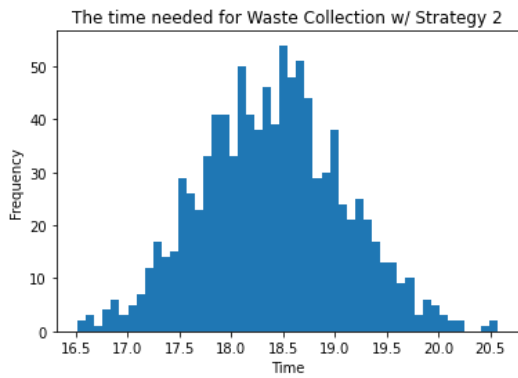
Distribution over the Outputs

- What is the distribution over the outputs of the simulation? Visualize, describe, and analyze results.

The initial strategy with randomized drop-off sites takes on average about 18.11 minutes for the waste collection process which includes traveling to and from the waste pickup and drop-off. There is a 95% confidence interval [18.06, 18.15] for this metric which demonstrates some uncertainty in the results. The simulation can be further improved and iterate more times to reduce the widths of the confidence interval.

In [13]:

```
plt.show()
```



Average time needed for the proposed strategy: 18.399693205735286
 Average time needed 95% confidence interval (18.356956220038434, 18.442430191432138)
 Average queue length: 536.3930840752898
 Average queue length 95% confidence interval (536.0535634117368, 536.7326047388428)

Distribution over the Outputs

- What is the distribution over the outputs of the simulation? Visualize, describe, and analyze results.

The second strategy with weighted drop-off sites takes on average about 18.39 minutes for the waste collection process which includes traveling to and from the waste pickup and drop-off. There is a 95% confidence interval [18.35, 18.44] for this metric which still show some uncertainty.

In this run of the simulation there is actually an increase in time in the strategy expected to perform better (have a decrease in time), but this could be attributed to perhaps other confounding variables in the model and the probabilistic randomness introduced in other places.

Analysis

- Describe and interpret the simulation results and provide advice on the best course of action to take or strategy to employ in the scenario.

The initial strategy introduces even more uncertain and probabilistic randomness to the model by including drop-off sites at random nodes in the network. The results of the metrics such as time and queue length demonstrate that there could be further improvement to this method. So, perhaps, given the explored strategies, the course of action would be to place the drop-off sites at places where they would be most useful such as where there is more waste production and in situations where the waste collection process takes less time to complete.

The empirical results show that for the waste collection process, there is some time to complete the assignments at different locations in the network. This involves the rate at which waste is produced in the different sites, the number of nodes connected to make paths shorter. The connectivity of the network would allow for faster times because the traveling distance between the different nodes will decrease.

If the waste collection company wishes to implement changes to their current operations, they can decide to place the different drop-off sites at the different nodes based on a given strategy and increase or decrease the number of drop-off sites.

The strategies herein contained are for exploratory purposes and more can be conducted to understand how to best solve the problem for optimizing waste collection processes. There is still randomness in these simulations which can explain the different results when running these simulations and here I show results for two of these possible strategies.

```
In [14]: from IPython.core.display import HTML
HTML("""
<style>

div.cell { /* Tunes the space between cells */
margin-top:1em;
margin-bottom:1em;
}

div.text_cell_render h1 { /* Main titles bigger, centered */
font-size: 2.2em;
line-height:1.4em;
text-align:center;
}

div.text_cell_render h2 { /* Parts names nearer from text */
margin-bottom: -0.4em;
```

```

text-align:center;
}

div.text_cell_render { /* Customize text cells */
font-family: 'Times New Roman';
font-size:1.35em;
line-height:1.4em;
padding-left:3em;
padding-right:3em;
}
</style>
"""

```

Out[14]:

In [8]:

```

#This cell is to test if the simulation working as expected or not
farm_sites = nx.Graph()

for edge in connected_farms:
    farm_sites.add_edge(edge[0], edge[1], weight = find_weights(edge[0], edge[1]))

dis = drop_off_sites(farm_sites, 6)

for node in farm_sites.nodes():
    farm_sites.nodes[node]['population'] = node_population[node]
    farm_sites.nodes[node]['area'] = farm_sites_dict[node]
    farm_sites.nodes[node]['waste_rate'] = waste_production_rate(node)
    farm_sites.nodes[node]['waste_truck'] = dis[node]

run_waste_simulation(farm_sites, run_until = 100, re_print = True)

```

Waste collection ordered at the farm-epsilon farm
Schedule() at time 6.203980363979583 with 14 events in the queue
Drop off site: ['farm-beta', 'farm-zeta', 'farm-bernoulli', 'farm-theta', 'farm-omega', 'farm-kappa']
Waste collection queue: []
Number of sites to collect waste: 0

Waste collection from truck at farm-bernoulli to collect at farm-epsilon
Schedule() at time 6.203980363979583 with 14 events in the queue
Drop off site: ['farm-beta', 'farm-zeta', 'farm-theta', 'farm-omega', 'farm-kappa']
Waste collection queue: []
Number of sites to collect waste: 1

Waste collection ordered at the farm-alpha farm
Schedule() at time 6.494918845169813 with 15 events in the queue
Drop off site: ['farm-beta', 'farm-zeta', 'farm-theta', 'farm-omega', 'farm-kappa']
Waste collection queue: []
Number of sites to collect waste: 1

Waste collection from truck at farm-beta to collect at farm-alpha
Schedule() at time 6.494918845169813 with 15 events in the queue
Drop off site: ['farm-zeta', 'farm-theta', 'farm-omega', 'farm-kappa']
Waste collection queue: []
Number of sites to collect waste: 2

Waste collection ordered at the farm-beta farm
Schedule() at time 6.909557818709806 with 16 events in the queue
Drop off site: ['farm-zeta', 'farm-theta', 'farm-omega', 'farm-kappa']
Waste collection queue: []
Number of sites to collect waste: 2

Waste collection from truck at farm-zeta to collect at farm-beta
Schedule() at time 6.909557818709806 with 16 events in the queue
Drop off site: ['farm-theta', 'farm-omega', 'farm-kappa']
Waste collection queue: []
Number of sites to collect waste: 3

Waste collection ordered at the farm-gamma farm
Schedule() at time 7.404721421872227 with 17 events in the queue
Drop off site: ['farm-theta', 'farm-omega', 'farm-kappa']
Waste collection queue: []
Number of sites to collect waste: 3

Waste collection from truck at farm-kappa to collect at farm-gamma
Schedule() at time 7.404721421872227 with 17 events in the queue
Drop off site: ['farm-theta', 'farm-omega']
Waste collection queue: []
Number of sites to collect waste: 4

Waste collection ordered at the farm-sigma farm
Schedule() at time 7.7271192867673 with 18 events in the queue
Drop off site: ['farm-theta', 'farm-omega']
Waste collection queue: []
Number of sites to collect waste: 4

Waste collection from truck at farm-omega to collect at farm-sigma
Schedule() at time 7.7271192867673 with 18 events in the queue

Drop off site: ['farm-theta']
Waste collection queue: []
Number of sites to collect waste: 5

Waste collection ordered at the farm-zeta farm
Schedule() at time 8.209158479903902 with 19 events in the queue
Drop off site: ['farm-theta']
Waste collection queue: []
Number of sites to collect waste: 5

Waste collection from truck at farm-theta to collect at farm-zeta
Schedule() at time 8.209158479903902 with 19 events in the queue
Drop off site: []
Waste collection queue: []
Number of sites to collect waste: 6

Waste collection ordered at the farm-lambda farm
Schedule() at time 8.962615437662425 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda']
Number of sites to collect waste: 6

Waste collection ordered at the farm-omega farm
Schedule() at time 9.218281924586448 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega']
Number of sites to collect waste: 6

Waste collection ordered at the farm-delta farm
Schedule() at time 9.472077965558256 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta']
Number of sites to collect waste: 6

Waste collection ordered at the farm-epsilon farm
Schedule() at time 9.9488197827628 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon']
Number of sites to collect waste: 6

Waste collection ordered at the farm-omicron farm
Schedule() at time 9.975501396193279 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron']
Number of sites to collect waste: 6

Waste collection ordered at the farm-theta farm
Schedule() at time 11.132515449094758 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta']
Number of sites to collect waste: 6

Waste collection ordered at the farm-alpha farm
Schedule() at time 12.396701379615331 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha']
Number of sites to collect waste: 6

Waste collection ordered at the farm-beta farm
Schedule() at time 13.68347653088624 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta']
Number of sites to collect waste: 6

Waste collection ordered at the farm-zeta farm
Schedule() at time 14.021918090800629 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta']
Number of sites to collect waste: 6

Waste collection ordered at the farm-sigma farm
Schedule() at time 14.171221741268191 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma']
Number of sites to collect waste: 6

Waste collection ordered at the farm-epsilon farm
Schedule() at time 14.561630638965624 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon']
Number of sites to collect waste: 6

Waste collection ordered at the farm-zeta farm


```
Waste collection ordered at the farm-theta farm
Schedule() at time 40.38304773946771 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-gamma', 'farm-epsilon', 'farm-sigma', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernoulli', 'farm-theta', 'farm-kappa', 'farm-beta', 'farm-omicron', 'farm-epsilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-beta', 'farm-theta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta', 'farm-theta']
Number of sites to collect waste: 6
```

```
Waste collection from truck at farm-bernoulli to collect at farm-theta
Schedule() at time 40.5567672491336 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-gamma', 'farm-epsilon', 'farm-sigma', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernoulli', 'farm-theta', 'farm-kappa', 'farm-beta', 'farm-omicron', 'farm-epsilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-beta', 'farm-theta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta']
Number of sites to collect waste: 7
```

```
Waste collection ordered at the farm-omega farm
Schedule() at time 41.21756633060321 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-gamma', 'farm-epsilon', 'farm-sigma', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernoulli', 'farm-theta', 'farm-kappa', 'farm-beta', 'farm-omicron', 'farm-epsilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-beta', 'farm-theta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-alpha']
Number of sites to collect waste: 7
```

```
Waste collection ordered at the farm-sigma farm
Schedule() at time 42.62966733297479 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-omicron', 'farm-alpha', 'farm-gamma', 'farm-epsilon', 'farm-sigma', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernoulli', 'farm-theta', 'farm-kappa', 'farm-beta', 'farm-omicron', 'farm-epsilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-beta', 'farm-theta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-alpha', 'farm-gamma', 'farm-sigma']
Number of sites to collect waste: 7
```

```
Waste collection ordered at the farm-zeta farm
Schedule() at time 42.789349320330956 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-gamma', 'farm-epsilon', 'farm-sigma', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernoulli', 'farm-theta', 'farm-kappa', 'farm-beta', 'farm-omicron', 'farm-epsilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-beta', 'farm-theta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta', 'farm-lambda', 'farm-omega', 'farm-gamma', 'farm-sigma', 'farm-zeta']
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rm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta', 'farm-lambda', 'farm-omeg
a', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-zeta', 'farm-zeta', 'farm-bernoulli', 'farm-beta', 'farm-alpha', 'farm
-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta', 'farm-theta', 'farm-omega', 'farm-gamma', 'farm-omicron', 'farm-alpha']
Number of sites to collect waste: 10

```
Waste collection ordered at the farm-zeta farm
Schedule() at time 55.883550756314094 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-gamma', 'farm-epsilon', 'farm-sigma', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernoulli', 'farm-theta', 'farm-kappa', 'farm-beta', 'farm-omicron', 'farm-epsilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-beta', 'farm-theta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta', 'farm-lambda', 'farm-omega', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-zeta', 'farm-zeta', 'farm-bernoulli', 'farm-beta', 'farm-alpha', 'farm-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta', 'farm-theta', 'farm-omega', 'farm-gamma', 'farm-omicron', 'farm-alpha', 'farm-delta', 'farm-zeta']
Number of sites to collect waste: 10
```

```
Waste collection ordered at the farm-beta farm
Schedule() at time 58.83209528774685 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-gamma', 'farm-epsilon', 'farm-sigma', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernoulli', 'farm-theta', 'farm-kappa', 'farm-beta', 'farm-omicron', 'farm-epsilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-beta', 'farm-theta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta', 'farm-lambda', 'farm-omega', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-zeta', 'farm-zeta', 'farm-bernoulli', 'farm-beta', 'farm-alpha', 'farm-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta', 'farm-theta', 'farm-omega', 'farm-gamma', 'farm-omicron', 'farm-alpha', 'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-beta']
Number of sites to collect waste: 10
```

```
Waste collection from truck at farm-kappa to collect at farm-beta
Schedule() at time 59.54199145453011 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-gamma', 'farm-epsilon', 'farm-sigma', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-kappa', 'farm-beta', 'farm-omicron', 'farm-epsilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-beta', 'farm-theta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta', 'farm-lambda', 'farm-omega', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-zeta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-zeta', 'farm-beta', 'farm-alpha', 'farm-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta', 'farm-theta', 'farm-omega', 'farm-gamma', 'farm-omicron', 'farm-alpha', 'farm-delta', 'farm-zeta', 'farm-epsilon']
Number of sites to collect waste: 11
```

```
'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-omicron']
Number of sites to collect waste: 11
```

```
Waste collection ordered at the farm-lambda farm
Schedule() at time 59.69372933257768 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta',
'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-
rnu-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-berno
ilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'f
rm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta
a', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'fa
-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta'
'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm
Number of sites to collect waste: 11
```

```
Waste collection ordered at the farm-zeta farm
Schedule() at time 60.184829164505146 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta',
'a', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-
rnu-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernou-
ilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-
rnu-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta',
'a', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-
epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta',
'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-
Number of sites to collect waste: 11
```

```
Waste collection ordered at the farm-epsilon farm
Schedule() at time 60.8813447169612 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta', 'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-epsilon']
Number of sites to collect waste: 11
```

```
Waste collection ordered at the farm-alpha farm
Schedule() at time 62.002756318371404 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta',
'a', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-
rm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernou-
ilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-
rm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta',
'a', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-
epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta',
'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-
Number of sites to collect waste: 11
```

```
Waste collection ordered at the farm-theta farm
Schedule() at time 63.10183049902891 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta',
'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-
rnu-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-berno
ilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'f
rm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta
a', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'fa
-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta'
'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm
```

```
Schedule() at time 63.32123439084881 with 19 events in the queue
Drop off site: ['farm-zeta']
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-bernoilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta', 'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-bernoilon']
Number of sites to collect waste: 11
```

```
Waste collection from truck at farm-zeta to collect at farm-theta
Schedule() at time 63.32123439084881 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta',
'a', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-
rm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernou-
ilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-
rm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta',
'a', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-
epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta',
'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-
Number of sites to collect waste: 12
```



```
Waste collection ordered at the farm-alpha farm
Schedule() at time 76.30734293942795 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-gamma', 'farm-epsilon', 'farm-sigma', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-bernoulli', 'farm-theta', 'farm-kappa', 'farm-beta', 'farm-omicron', 'farm-epsilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-beta', 'farm-theta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta', 'farm-lambda', 'farm-omega', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-zeta', 'farm-zeta', 'farm-bernoulli', 'farm-beta', 'farm-alpha', 'farm-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta', 'farm-theta', 'farm-omega', 'farm-gamma', 'farm-omicron', 'farm-alpha', 'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-lambda', 'farm-zeta', 'farm-epsilon', 'farm-alpha', 'farm-delta', 'farm-sigma', 'farm-gamma', 'farm-zeta', 'farm-omega', 'farm-epsilon', 'farm-bernoulli', 'farm-beta', 'farm-lambda', 'farm-alpha', 'farm-sigma', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-omega', 'farm-theta', 'farm-zeta', 'farm-alpha']
Number of sites to collect waste: 13
```



```
'farm-theta', 'farm-lambda']
Number of sites to collect waste: 14
```

```
Waste collection ordered at the farm-zeta farm
Schedule() at time 87.6067564304188 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-alpha', 'farm-beta', 'farm-gamma', 'farm-sigma', 'farm-epsilon', 'farm-omicron', 'farm-theta']
Number of sites to collect waste: 14
```

```
Waste collection ordered at the farm-omega farm
Schedule() at time 90.15470642709349 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta',
'a', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-
zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-berno-
ilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'f
rm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta',
'a', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'fa
rm-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta',
'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-
sigma', 'farm-gamma', 'farm-zeta', 'farm-omega', 'farm-epsilon',
'a', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-omega', 'm-
beta', 'farm-sigma', 'farm-gamma', 'farm-omega', 'farm-zeta',
'farm-theta', 'farm-lambda', 'farm-beta', 'farm-zeta', 'farm-eps
Number of sites to collect waste: 14
```

```
Waste collection ordered at the farm-alpha farm
Schedule() at time 90.39706278571568 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta',
'a', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-
ron-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-berno
ilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'f
```

```

m-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta', 'farm-lambda', 'farm-omeg
a', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-zeta', 'farm-zeta', 'farm-bernoulli', 'farm-beta', 'farm-alpha', 'farm
-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta', 'farm-theta', 'farm-omega', 'farm-gamma', 'farm-omicron', 'farm-alpha',
'farm-delta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-lambda', 'farm-zeta', 'farm-epsilon', 'farm-alpha', 'farm-delta', 'farm-
sigma', 'farm-gamma', 'farm-zeta', 'farm-omega', 'farm-epsilon', 'farm-bernoulli', 'farm-beta', 'farm-lambda', 'farm-alpha', 'farm-sigm
a', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-omega', 'farm-theta', 'farm-zeta', 'farm-alpha', 'farm-lambda', 'farm-delta', 'far
m-beta', 'farm-sigma', 'farm-gamma', 'farm-omega', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-epsilon', 'farm-delta', 'farm-sigma',
'farm-theta', 'farm-lambda', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-omega', 'farm-kappa', 'farm-alpha']
Number of sites to collect waste: 14

```

```
Waste collection from truck at farm-beta to collect at farm-alpha
Schedule() at time 91.82854586749744 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-gamma', 'farm-epsilon', 'farm-sigma', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-omicron', 'farm-theta', 'farm-kappa', 'farm-beta', 'farm-omicron', 'farm-epsilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-beta', 'farm-theta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-lambda', 'farm-omega', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-zeta', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-omega', 'farm-gamma', 'farm-omicron', 'farm-alpha', 'farm-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-omicron', 'farm-lambda', 'farm-zeta', 'farm-epsilon', 'farm-alpha', 'farm-delta', 'farm-sigma', 'farm-gamma', 'farm-zeta', 'farm-omega', 'farm-epsilon', 'farm-omicron', 'farm-epsilon', 'farm-beta', 'farm-lambda', 'farm-alpha', 'farm-sigma', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-omega', 'farm-theta', 'farm-zeta', 'farm-alpha', 'farm-lambda', 'farm-lambda', 'farm-delta', 'farm-beta', 'farm-sigma', 'farm-gamma', 'farm-omega', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-epsilon', 'farm-delta', 'farm-sigma', 'farm-theta', 'farm-lambda', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-omega', 'farm-kappa']
Number of sites to collect waste: 15
```

```
Waste collection ordered at the farm-beta farm
Schedule() at time 93.3512451865714 with 19 events in the queue
Drop off site: []
Waste collection queue: ['farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-alpha', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-gamma', 'farm-epsilon', 'farm-sigma', 'farm-zeta', 'farm-lambda', 'farm-omega', 'farm-delta', 'farm-epsilon', 'farm-omicron', 'farm-theta', 'farm-kappa', 'farm-beta', 'farm-omicron', 'farm-epsilon', 'farm-alpha', 'farm-zeta', 'farm-gamma', 'farm-delta', 'farm-beta', 'farm-beta', 'farm-theta', 'farm-theta', 'farm-lambda', 'farm-omega', 'farm-epsilon', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-sigma', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-delta', 'farm-lambda', 'farm-omega', 'farm-gamma', 'farm-sigma', 'farm-zeta', 'farm-omicron', 'farm-zeta', 'farm-zeta', 'farm-bernoulli', 'farm-beta', 'farm-alpha', 'farm-epsilon', 'farm-lambda', 'farm-beta', 'farm-sigma', 'farm-zeta', 'farm-sigma', 'farm-zeta', 'farm-sigma', 'farm-zeta', 'farm-theta', 'farm-omega', 'farm-gamma', 'farm-omicron', 'farm-alpha', 'farm-delta', 'farm-zeta', 'farm-gamma', 'farm-zeta', 'farm-omega', 'farm-epsilon', 'farm-bernoulli', 'farm-beta', 'farm-lambda', 'farm-alpha', 'farm-sigma', 'farm-zeta', 'farm-epsilon', 'farm-omicron', 'farm-omega', 'farm-theta', 'farm-zeta', 'farm-alpha', 'farm-lambda', 'farm-delta', 'farm-beta', 'farm-sigma', 'farm-gamma', 'farm-omega', 'farm-zeta', 'farm-omicron', 'farm-alpha', 'farm-epsilon', 'farm-delta', 'farm-sigma', 'farm-theta', 'farm-lambda', 'farm-beta', 'farm-zeta', 'farm-epsilon', 'farm-omega', 'farm-kappa', 'farm-zeta', 'farm-beta']
Number of sites to collect waste: 15
```