Quantum Impact Collective: Optimization of Food Resources

In the U.S., fast food restaurants produce 22 to 33 billion pounds of food waste by annually.

Goal: To optimize vehicle routing from shelters to collect food resources in Boston.

Shapiroe, “Fast Food’s Contribution to Food Waste,” *Shapiro*, Mar. 08, 2024. https://shapiroe.com/blog/junk-food-waste/

Process

1. Find Homeless Shelters in Boston

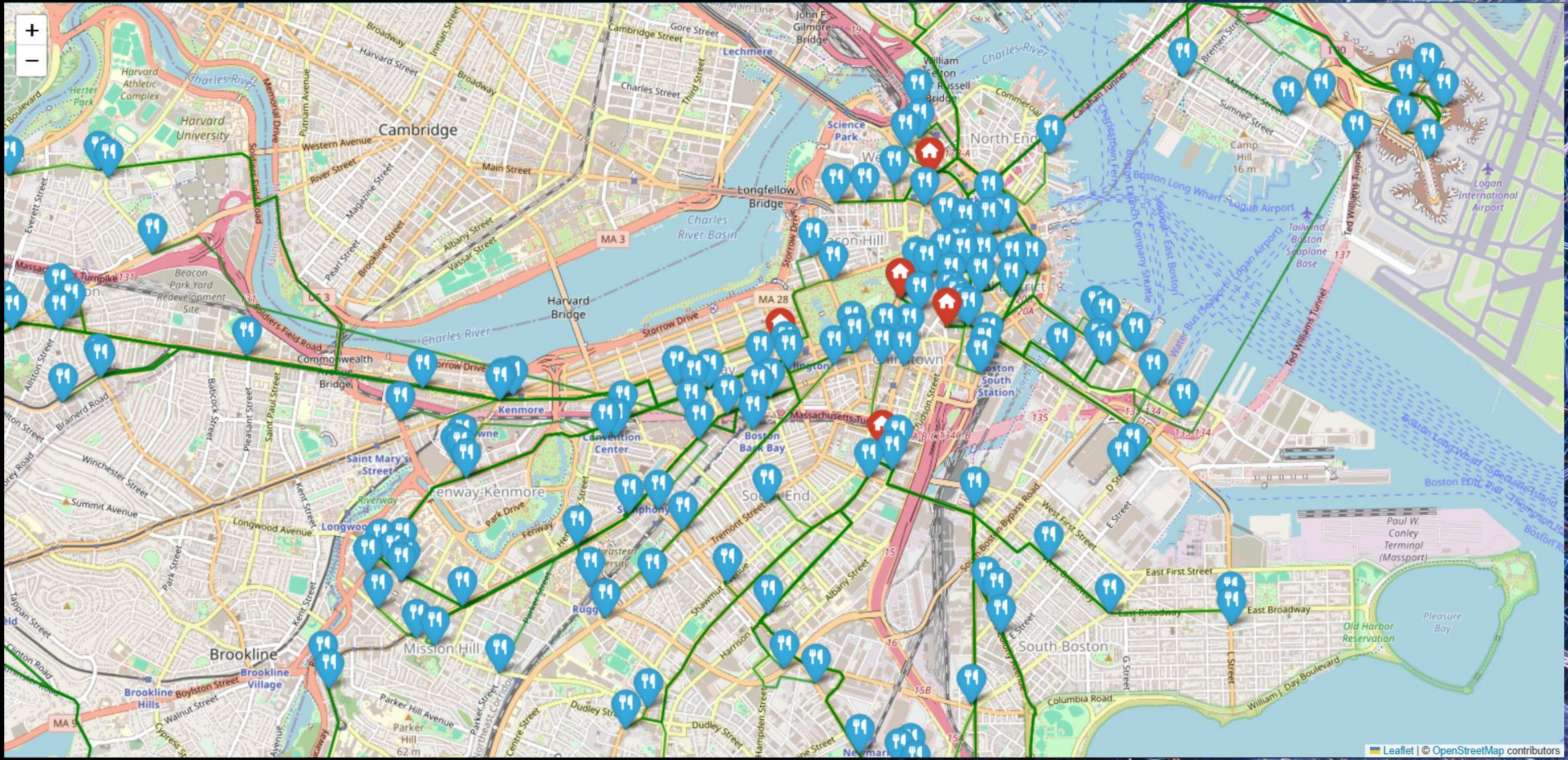
2. Determine fast food locations in Boston

3. Correlate locations between shelters and fast food locations
   a. Identify proximity based on longitude and latitude
   b. For simplicity purposes, we chose the closest 3 restaurants to each shelter

4. Establish a situation

1	Shelter	Latitude		Longitude
2	Family-Aid Boston	42.2981		-71.1166
3	Bridge Over Troubled Waters	42.35535		-71.063
4	Boston Rescue Mission	42.35375		-71.0595
5	Boston Night Center	42.36262		-71.06067
6	Pine Street Inn	42.3458		-71.06463

1	businessname	latitude	longitude
2	APPLEBEE'S NEIGHBORHOOD GRILL & BAR	42.32608686677121	-71.06361196234216
3	Auntie Anne's Pretzels/ Carvel	42.35195868500647	-71.05502724058353
4	Buffalo Wild Wings Go/Sp. AS2-A18	42.364539333151285	-71.02181778282163
5	Burger King	34.244386753001244	-73.6513909034731
6	Burger King	42.309265153704665	-71.05775317571394
7	Burger King	42.35631361369498	-71.06192094875507
8	Burger King	42.36883243461128	-71.03932826829823
9	Burger King	42.35301796551194	-71.13497876705965
10	Burger King	42.33921949208055	-71.05095898205067
11	Burger King	42.26820347573987	-71.09577982327994
12	Burger King	42.262078075396296	-71.1085691449198
13	Burger King	42.3861663166383	-71.00953086689843
14	Burger King # 3483	42.26588887601696	-71.16795211651815
15	Burger King # 3531	42.27597672024672	-71.13916232653567
16	CALIFORNIA PIZZA KITCHEN	42.34715955305909	-71.08251052626302
17	Cava	42.35312267843186	-71.05742343463301



+
−
Cambridge
Harvard University
Harvard Athletic Complex
Charles River
Lechmere
Science Park
North End
Longfellow Bridge
Charles River Basin
Beacon Hill
Harvard Bridge
Kenmore
Convention Center
Boston Back Bay
Boston South Station
Saint Mary's Street
Fenway-Kenmore
Symphony
South End
Longwood
Mission Hill
Brookline
Brookline Village
Brookline Hills
Parker Hill 62 m
Camp Hill 16 m
South Boston
Logan International Airport
Paul W. Conley Terminal (Massport)
Pleasure Bay
Old Harbor Reservation
Leaflet | © OpenStreetMap contributors

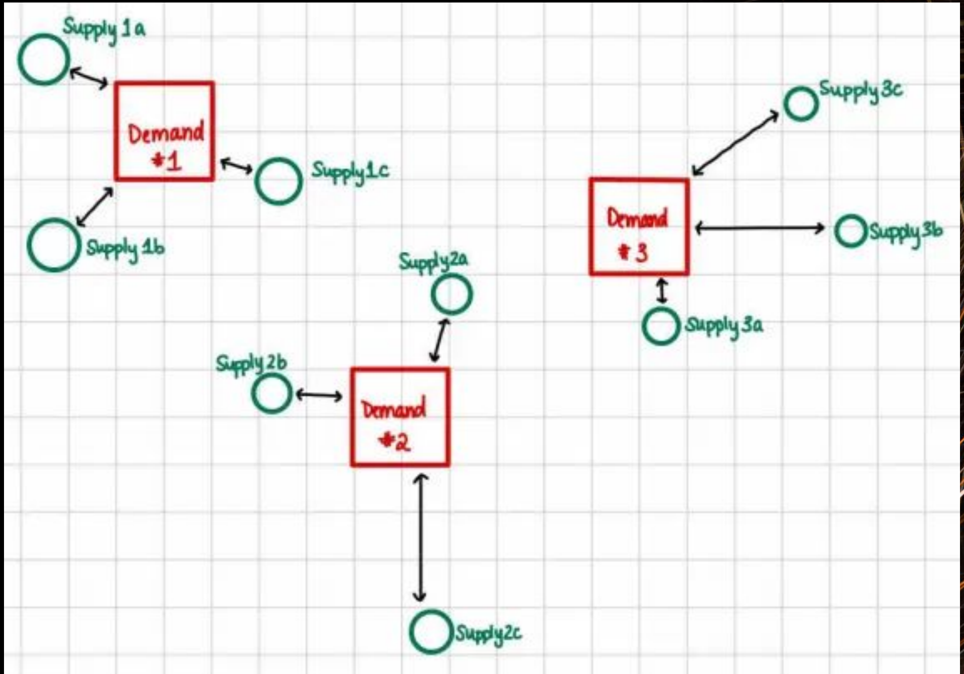
Establish a Situation

Consider the following situation for simplicity:

Suppose we have 3 **shelters** (Depos)
⟶ Each shelter has an **X** set demand

Based on distance, we have 3 **restaurants** for each shelter (Clients)
⟶ Each restaurant has a **Y** set supply
⟶ Restaurants are located at varying distances from each restaurant, but are the closest in terms of Euclidean distance.

How can be create an optimal route that not only takes the **shortest distance**, but also **completes the X demand** needed for the shelter?



Capacitated Vehicle Routing

Definition: An optimization that involves finding the best routes for a fleet of vehicles to deliver items to customers.

Characteristics:
→ Each vehicles has a maximum capacity
→ Each vehicles starts and ends at the depot (shelter)
→ Each client can only be served by 1 vehicles (restaurant)

Modifications to fit our problem:

1. Clients have supplies, depots have demand
2. Constraints include fulfilling demand (factor for optimization)

We attempted using a nonlinear model, a **quadratic model**, using the LeadHybridNSampler

Process of Application

1. Consider how to apply constraints to Quadratic Model → ConstrainedQuadraticModel
   a. PROBLEM : CVR uses a DiscreteQuadraticModel (DQM) – different methods
2. Enforce constraints on model using penalties → BinaryQuadraticModel
   a. PROBLEM: penalties added too much constraint
3. Utilize CVRP, but create separate depo + demand variables → 3 Arrays instead of 2
   a. PROBLEM: CVRP is defined in an interesting way
      i. The demand object MUST be an array, where the first element represents the demand of the depo which MUST be 0
      ii. The client array MUST have the first index represent the depo

* Using the current model of capacitated_vehicles_routing, we CANNOT define our situation.

** HOWEVER, we can present an alternative case, if we had editing access to CVR

Alternate Method

We attempted to treat the depo as its own variables and the depo's demand as an integer value.

Rather than populating an array to be [200, 0, 0 , 0], which is invalid according to the current CVR model, we can simply:

→ Take a route and track distance traveled and whether demand was met

→ After all routes are exhausted, compare values are run the optimization algorithm to determine the least costly route in terms of both distance and demand met.

```python
from dwave.optimization.generators import capacitated_vehicle_routing
from dwave.system import LeapHybridNLSampler

# Define the shelter and demand
depot = (0, 0)
depot_demand = 200  # Depot has demand

# Define the surrounding restaurants and their associated supply
restaurants = [(15, 38, 50), (23, -19, 100), (44, 62, 100)]

# Extract locations and supplies
locations_x = [x for x, y, s in restaurants]
locations_y = [y for x, y, s in restaurants]
supply = [s for x, y, s in restaurants]

# Initialize the demand list with depot demand and zero for restaurant demands
demand = [depot_demand] + [0] * len(supply)  # Depot has demand, restaurants have no demand

# Ensure depot is included in locations
locations_x = [depot[0]] + locations_x  # Add depot coordinates to the list
locations_y = [depot[1]] + locations_y  # Add depot coordinates to the list

# Create the CVRP model to fulfill demands + minimize distance
model = capacitated_vehicle_routing(
    demand=demand,  # Demand list where depot has non-zero demand, others are zero
    number_of_vehicles=3,  # Updated to 3 vehicles
    vehicle_capacity=200,
    locations_x=locations_x,
    locations_y=locations_y,
    depot_x_y=depot  # Explicitly provide depot_
)
```

```python
# Track the demand fulfillment
num_samples = model.states.size()  # This is important to determine how many samples were returned
for i in range(min(3, num_samples)):
    print(f"Objective value {int(model.objective.state(i))} for")

    # Initialize variables to track the supply usage
    demand_met = False
    remaining_demand = depot_demand  # Track remaining depot demand dynamically

    # Check the routes and calculate if the demand has been met
    for j, r in enumerate(routes):
        print(f"\t Route {j + 1}: {r.state(i)}")

        # Subtract the supply from the current demand based on the route
        for restaurant_idx, supply_value in enumerate(supply):
            if restaurant_idx == r.state(i):
                remaining_demand -= supply_value

        if remaining_demand <= 0:
            demand_met = True
            break  # Stop processing if demand is met

    # Check if the demand was met
    if demand_met:
        print(f"Demand successfully met after route {i + 1}.\n")
    else:
        print(f"Demand not fully met after route {i + 1}.\n")
```

Now Consider:
Grocery Stores→ Depo
Shelters → Clients

** Abides by the constraints set up by the CVR

Food Deserts

Food Deserts are defined as regions that don’t have access to “healthy” food. These areas often show signs of severe health issues, such as asthma and high obesity. We can provide options by involving grocery stores with healthy food.

We can apply this optimization problem by creating the following situation:

Grocery Stores → Depos

Communities/Regions → Clients

Results

```
  shelters.append((row[1],row[2]))
route:  <_cython_3_0_11.generator object at 0x16c86a8c0>
Objective value 331 for
         Route 1: [3. 1. 2.]     Route 2: [0. 4.]
         Feasible: True
Objective value 331 for
         Route 1: [3. 1. 2.]     Route 2: [4. 0.]
         Feasible: True
Objective value 331 for
         Route 1: [2. 1. 3.]     Route 2: [4. 0.]
         Feasible: True
(.venv) (base) druhibhargava@Druhis-MacBook-Pro quantum_hack %
```

Further Steps

→ Quadratic Assignment Problem (QAP)
→ Distribution of other resources
→ Mobile Food Markets
→ University food waste

QAP

Considering the previous problem, where:

Shelters $\longrightarrow$ Depos

Restaurants $\longrightarrow$ Clients

In a more realistic situation, we have trucks with larger capacities than the shelters; thus, they gain an excess of food. If that is the case, excess food at shelters is still considered “waste”. Thus, following the defined QAP protocol, we can transport this “waste” from shelter to shelter at certain times during the month. We can then consider additional costs of moving from shelter to shelter.

https://github.com/NandeeneeSingh/iQuHack_DWave