```python
import numpy as np
import random
import networkx as nx
import matplotlib.pyplot as plt

class Graph:
    def __init__(self, no_of_nodes, connectivity, increase,
tutorial_weight = [], seed = 1000):
        while(1):
            self.graph = nx.gnp_random_graph (no_of_nodes,
connectivity, seed )
            if(not nx.is_connected(self.graph)):
                connectivity += increase
                print("running again as we don't have conncted
graphs")
            else:
                break
        self.index = 0
        for u, v in self.graph.edges:
            if len(tutorial_weight) == 0:
                self.graph.add_edge(u, v, weight =
random.randint(1,9)/10)
            else:
                self.graph.add_edge(u, v, weight =
tutorial_weight[self.index])
                self.index += 1
        self.graph_edges = nx.get_edge_attributes(self.graph,
"weight")
        self.no_of_nodes = self.graph.number_of_nodes()
        # print(self.graph_edges)

    def getEdgeWeight(self, search_key):
        for key in self.graph_edges:
            if key == search_key:
                return self.graph_edges[key]

    def getNumberOfNodes(self):
        return self.no_of_nodes

    def plotGraph(self):
        links = [(u, v) for (u, v, d) in self.graph.edges(data=True)]
        pos = nx.nx_agraph.graphviz_layout(self.graph)
        nx.draw_networkx_nodes(self.graph, pos, node_size=1200,
node_color='lightblue', linewidths=0.25)
        nx.draw_networkx_edges(self.graph, pos, edgelist=links,
width=4)
        nx.draw_networkx_labels(self.graph, pos, font_size=20,
font_family="sans-serif")
        edge_labels = nx.get_edge_attributes(self.graph, "weight")
        nx.draw_networkx_edge_labels(self.graph, pos, edge_labels)
```

```python
        plt.show()

    def computeAStarPathLength(self, start, finish):
        return nx.astar_path_length(self.graph, start, finish)

    def computeAStarPath(self, start, finish):
        return nx.astar_path(self.graph, start, finish)

class Car:
    #all cars are at node0 at the start of the day
    def __init__(self):
        self.capacity = 0
        self.max_capacity = 5
        self.current_node = 0
        self.nodes_traversed = [0]
        self.current_service_path = []
        self.customer_wait_queue = []
        self.customer_picked_up_queue = []
        self.distance_travelled = 0.0
        self.current_serving_customer = -1
        self.no_of_trips = 0

    def moveCar(self, new_node, distance):
        self.distance_travelled = self.distance_travelled + distance
        self.current_node = new_node
        self.nodes_traversed.append(new_node)

    def isFull(self):
        return self.capacity == self.max_capacity

    def pickUpCustomerRequest(self, customer_index):
        self.capacity += 1
        self.customer_wait_queue.append(customer_index)

    def pickUpCustomer(self, customer_index):
        self.customer_wait_queue.remove(customer_index)
        self.customer_picked_up_queue.append(customer_index)

    def dropOffCustomer(self, customer_index):
        self.capacity -= 1
        if self.current_serving_customer != customer_index:
            self.customer_picked_up_queue.remove(customer_index)
        self.no_of_trips += 1
        self.current_serving_customer = -1

    # call this after pickup done only and remove on dropoff
    def updateCurrentlyServingCustomer(self):
        next_to_be_served_index = self.customer_picked_up_queue[0]
        self.customer_picked_up_queue.remove(next_to_be_served_index)
        self.current_serving_customer = next_to_be_served_index
```

```python
    def areAllJobsOver(self):
        is_wait_queue_empty = len(self.customer_wait_queue) == 0
        is_picked_up_queue_empty = len(self.customer_picked_up_queue)
== 0
        is_serving_customer_empty = self.current_serving_customer == -
1
        return is_wait_queue_empty and is_picked_up_queue_empty and
is_serving_customer_empty

class Customer:
    def __init__(self, pick_up_node, drop_off_node):
        self.pick_up_node = pick_up_node
        self.drop_off_node = drop_off_node

# Agent runs all the time
# Agent will have an instace of all cars and Customers generated

class Agent:
    def __init__(self, no_of_cars, no_of_nodes, connectivity,
increase, tutorial_edges = []):
        self.car_array = []
        # append no_of_cars objects to car_arrays
        for i in range(no_of_cars) :
            car_object = Car()
            self.car_array.append(car_object)
        self.graph = Graph(no_of_nodes, connectivity, increase,
tutorial_edges)
        self.no_of_nodes = self.graph.no_of_nodes
        self.customer_array = []

    def createCustomerObject(self):
        customer_index = len(self.customer_array)
        pick_up_node = random.randrange(self.no_of_nodes)
        drop_off_node = -1
        while 1:
            drop_off_node = random.randrange(self.no_of_nodes)
            if drop_off_node != pick_up_node:
                break
        customer = Customer(pick_up_node, drop_off_node)
        self.customer_array.append(customer)
        return customer_index

    def getFirstEmptyCar(self, eq_distant_array):
        for i in eq_distant_array:
            if self.car_array[i].capacity == 0:
                return i
        return -1

    def getCarForCustomer(self, customer_index):
```

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        # loop over all available car array
        # if equidistant cars then assign customer to the first non-
empty car from list of equidistant cars, else assign car to the lowest
index car.
        # if no car equidistant then assign customer to car with
smallest distance
        # if all car have 5 passengers print wait message
        pick_up_node =
self.customer_array[customer_index].pick_up_node
        smallest_distance = 10000000000
        eq_distant_array = []
        car_index = -1
        for i in range(len(self.car_array)):
            if self.car_array[i].isFull():
                print("Car ", i, "is full\n")
                continue
            distance = self.graph.computeAStarPathLength(pick_up_node,
self.car_array[i].current_node)
            if distance < smallest_distance:
                smallest_distance = distance
                eq_distant_array.clear()
                car_index = i
            if distance == smallest_distance:
                eq_distant_array.append(i)

        if len(eq_distant_array) != 0:
            first_non_empty_car_index =
self.getFirstEmptyCar(eq_distant_array)
            if first_non_empty_car_index != -1:
                return first_non_empty_car_index
            else:
                return eq_distant_array[0]
        else:
            return car_index

    def updateWaitQueue(self, car_index):
        car_object = self.car_array[car_index]
        car_current_node = car_object.current_node
        customers_in_wait_queue = car_object.customer_wait_queue
        #sort
        for i in range(len(customers_in_wait_queue)):
            for j in range(i, len(customers_in_wait_queue)):

                customer_index_i = customers_in_wait_queue[i]
                distance_i =
self.graph.computeAStarPathLength(car_current_node,
self.customer_array[customer_index_i].pick_up_node)

                customer_index_j = customers_in_wait_queue[j]
                distance_j =
```

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        self.graph.computeAStarPathLength(car_current_node,
        self.customer_array[customer_index_j].pick_up_node)

                    if distance_j < distance_i:
                        temp = customers_in_wait_queue[j]
                        customers_in_wait_queue[j] =
customers_in_wait_queue[i]
                        customers_in_wait_queue[i] = temp

        car_object.customer_wait_queue = customers_in_wait_queue
        print("\nthe service/wait queue is", customers_in_wait_queue)

    def moveCarObject(self, car_object, new_node):
        current_node = car_object.current_node
        search_key = ()
        if current_node < new_node:
            search_key = (current_node, new_node)
        else:
            search_key = (new_node, current_node)
        distance = self.graph.getEdgeWeight(search_key)
        if distance == None:
            distance = 0
        car_object.moveCar(new_node, distance)

    def checkPickUpOrDropOff(self, car_object):
        car_current_node = car_object.current_node

        current_servicing_customer_index =
car_object.current_serving_customer
        current_servicing_customer_drop_off_node = -1
        if current_servicing_customer_index != -1:
            current_servicing_customer_drop_off_node =
self.customer_array[current_servicing_customer_index].drop_off_node

        if car_current_node ==
current_servicing_customer_drop_off_node:

car_object.dropOffCustomer(current_servicing_customer_index)

        # need to check for same dropoff points iteratively
        for i in range(len(car_object.customer_picked_up_queue)):
            try:
                customer_index =
car_object.customer_picked_up_queue[i]
            except:
                break
            pickup_customer_drop_off_point =
self.customer_array[customer_index].drop_off_node
            if car_current_node == pickup_customer_drop_off_point:
                car_object.dropOffCustomer(customer_index)
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```python
        # need to check for same pickup points iteratively
        capacity = car_object.capacity
        index = 0
        next_in_queue_customer_index_length =
len(car_object.customer_wait_queue)
        while next_in_queue_customer_index_length != 0:
            next_in_queue_customer_index =
car_object.customer_wait_queue[index]
            next_in_queue_customer_pick_up_node =
self.customer_array[next_in_queue_customer_index].pick_up_node

            if car_current_node == next_in_queue_customer_pick_up_node
and capacity <=5:

car_object.pickUpCustomer(next_in_queue_customer_index)
                capacity += 1
                next_in_queue_customer_index_length -= 1
            else:
                break

    def checkAndUpdateCurrentServicePath(self, car_object):
        # service path is the path taken by the car to
        # goto pickup a customer
        # or goto dropoff a picked customer
        # customer are picked based on the service queue

        car_current_node = car_object.current_node
        current_service_path = car_object.current_service_path

        if len(current_service_path) == 0:
            if len(car_object.customer_wait_queue) != 0:
                customer_index = car_object.customer_wait_queue[0]
            else:
                customer_index =
car_object.customer_picked_up_queue[0]
            customer_pick_up_node =
self.customer_array[customer_index].pick_up_node
            new_service_path =
self.graph.computeAStarPath(car_current_node, customer_pick_up_node)

            if len(new_service_path) != 1:
                new_service_path.remove(car_current_node)
            car_object.current_service_path = new_service_path
            return new_service_path[0]
        else:
            car_object.current_service_path.remove(car_current_node)
            updated_service_path = car_object.current_service_path
            if len(updated_service_path) == 0:
```

```python
                    # either reached pick up or drop off point
                    # update accordingly
                    if len(car_object.customer_picked_up_queue) != 0:
                        # Just picked up or already picked customer need
to drop them off
                        first_queue_customer_index =
car_object.customer_picked_up_queue[0]
                        first_queue_customer_drop_off_node =
self.customer_array[first_queue_customer_index].drop_off_node
                        car_object.updateCurrentlyServingCustomer()
                        new_service_path =
self.graph.computeAStarPath(car_current_node,
first_queue_customer_drop_off_node)
                        new_service_path.remove(car_current_node)
                        car_object.current_service_path = new_service_path
                        return new_service_path[0]
                    else:
                        if len(car_object.customer_wait_queue) != 0:
                            # goto pickup first from wait queue/service
queue if present
                            first_wait_queue_customer_index =
car_object.customer_wait_queue[0]
                            fist_wait_queue_customer_pick_up_node =
self.customer_array[first_wait_queue_customer_index].pick_up_node
                            new_service_path =
self.graph.computeAStarPath(car_current_node,
fist_wait_queue_customer_pick_up_node)
                            new_service_path.remove(car_current_node)
                            car_object.current_service_path =
new_service_path
                            return new_service_path[0]
                else:
                    # continue movement along the service path
                    return updated_service_path[0]

    def processNewCustomerRequestSimulation(self, customer_objet,
customer_index):
        # get simulated customer object
        # compute ditance with the position of all cars, take capacity
into consderation, get the car index, else return wait 15 min message
        # assign customer to that car and update its service queue,
        # if no current service path find that else update current
service path
        self.customer_array.append(customer_objet)
        min_distance_car_index =
self.getCarForCustomer(customer_index)
        if min_distance_car_index == -1:
            print("All vans are full, please try again in 15 minutes")
        else:
```

```python
            print("\nCar ", min_distance_car_index, "allocated to
customer", customer_index)

self.car_array[min_distance_car_index].pickUpCustomerRequest(customer_
index)
            self.updateWaitQueue(min_distance_car_index)

    def processNewCustomerRequest(self):
        # create a new customer object and get it's index
        # compute ditance with the position of all cars, take capacity
into consderation, get the car index, else return wait 15 min message
        # assign customer to that car and update its service queue,
        # if no current service path find that else update current
service path
        customer_index = self.createCustomerObject()
        min_distance_car_index =
self.getCarForCustomer(customer_index)
        if min_distance_car_index == -1:
            # no car to take in customer
            print("All vans are full, please try again in 15 minutes")
        else:
            # print("Car ", min_distance_car_index, "allocated to
customer", customer_index)

self.car_array[min_distance_car_index].pickUpCustomerRequest(customer_
index)
            self.updateWaitQueue(min_distance_car_index)

    def moveAllCars(self):
        # check if either pickup or dropoff available
        # check and update current service path (need to do this to
get next node to move to)
        # take the current service path and update the path as well as
move the car
        car_array_objects = self.car_array
        for i in range(len(car_array_objects)):
            print("\nTraversed history for car", i, " is :",
self.car_array[i].nodes_traversed)
            if len(car_array_objects[i].customer_wait_queue) ==0 and
len(car_array_objects[i].customer_picked_up_queue) == 0 and
car_array_objects[i].current_serving_customer == -1:
                # this car has no customer so dont move
                # print("Car ", i, "has no customer so stays parked in
location", car_array_objects[i].current_node)
                continue
            else:
                self.checkPickUpOrDropOff(car_array_objects[i])
                next_node_to_move_to =
self.checkAndUpdateCurrentServicePath(car_array_objects[i])
```

```python
                print("\nCar ", i, " moves to new node ",
next_node_to_move_to)
                if next_node_to_move_to != None:
                    self.moveCarObject(car_array_objects[i],
next_node_to_move_to)

    def moveSpecificCar(self, i):
        car_array_objects = self.car_array
        if len(car_array_objects[i].customer_wait_queue) ==0 and
len(car_array_objects[i].customer_picked_up_queue) == 0 and
car_array_objects[i].current_serving_customer == -1:
            # this car has no customer so dont move
            print("\nCar ", i, "has no customer so stays parked in
location", car_array_objects[i].current_node)
        else:
            self.checkPickUpOrDropOff(car_array_objects[i])
            next_node_to_move_to =
self.checkAndUpdateCurrentServicePath(car_array_objects[i])
            print("\nCar ", i, " moves to new node ",
next_node_to_move_to)
            if next_node_to_move_to != None:
                self.moveCarObject(car_array_objects[i],
next_node_to_move_to)

    def areAllServicesComplete(self):
        remaining_car_index = []
        for i in range(len(self.car_array)):
            car_object = self.car_array[i]
            is_all_jobs_over = car_object.areAllJobsOver()
            if is_all_jobs_over != True:
                remaining_car_index.append(i)
        return remaining_car_index

    def areSpecificServicesComplete(self, service_array):
        remaining_car_index = []
        for i in range(len(service_array)):
            car_index = service_array[i]
            car_object = self.car_array[car_index]
            is_all_jobs_over = car_object.areAllJobsOver()
            if is_all_jobs_over != True:
                remaining_car_index.append(i)
        return remaining_car_index

    def calculateAverageDistanceTravelled(self):
        total_distance = 0
        for i in range(len(self.car_array)):
            car_object = self.car_array[i]
            total_distance += car_object.distance_travelled
        return total_distance/len(self.car_array)
```

```python
    def calculateAverageNoOfTrips(self):
        no_of_trips = 0
        for i in range(len(self.car_array)):
            car_object = self.car_array[i]
            no_of_trips += car_object.no_of_trips
        return no_of_trips/len(self.car_array)

print("-------------------------
DISCLOSURE----------------------------------------\n")
print("")
print("MY PROGRAM DOES NOT SHOW THE CURRENTLY SERVING CUSTOMER IN THE
WAIT QUEUE\n")
print("INSTEAD OF HAVING S1={(id1,p,8),(id1,d,9)} AS SERVICE QUEUE FOR
TICK 1\n")
print("THIS PROGRAM USES INDEX OF CUSTOMER(STARTING FROM 0) LIKE [0]
FOR SERVICE QUEUE IN TICK1\n")
print("THE SERVICE QUEUE IS ONLY UPDATED AND PRINTED AS LONG AS THERE
IS REQUEST FOR CUSTOMER\n")
print("BUT C1 IS ALREADY BEING SERVED SO IT IS NOT IN WAIT QUEUE SO MY
WAIT QUEUE IS [C2,C4,C5,C3](PROGRAM COUNTS CUSTOMER AND CAR FROM 0 NOT
1)\n")
print("CLOCK TICK STARTS IN 0 NOT 1\n")
print("-----------------------------------------------------------------
----------------\n")

# Run this for R2

if __name__ == "__main__":

    # FOR R2
    no_of_cars = 2
    no_of_nodes = 10
    connectivity = 0.3
    increase = 0.1
    # these are the edges of the nodes, since nodes are generated
randomly we need to generate node with these value to match tutorial 2
    tutorial_edges = [0.1, 0.8, 0.6, 1.0, 1.0, 0.7, 0.8, 0.5, 0.5,
0.4, 1.0, 0.8, 0.9, 0.7, 0.4]
    agent = Agent(no_of_cars, no_of_nodes, connectivity, increase,
tutorial_edges)
    # agent.graph.plotGraph()

    # Takes 20 clock ticks so
    c1 = Customer(8,9)
    c2 = Customer(3,6)
    c3 = Customer(4,7)
    c4 = Customer(2,4)
    c5 = Customer(1,7)
    c6 = Customer(1,9)
    index = 0
```

```python
    for i in range(20):
        print("CLOCK TICK ", i, "\n")
        if i == 0:
            # use first customer request
            agent.processNewCustomerRequestSimulation(c1, index)
            index += 1
            agent.processNewCustomerRequestSimulation(c2, index)
            index += 1
            agent.moveAllCars()
        elif i == 1:
            # use second customer request
            agent.processNewCustomerRequestSimulation(c3, index)
            index += 1
            agent.processNewCustomerRequestSimulation(c4, index)
            index += 1
            agent.moveAllCars()
        elif i == 2:
            # use second customer request
            agent.processNewCustomerRequestSimulation(c5, index)
            index += 1
            agent.processNewCustomerRequestSimulation(c6, index)
            index += 1
            agent.moveAllCars()
        #just move cars
        else:
            agent.moveAllCars()
        print("\nCLOCK TICK ENDS", i, "\n")
        print("-----------------------------------\n")


    # check if all service queue empty else do until empty
    # get the arrays of cars who's pickup queue, wait queue or current
serving is not emty
    # run an infinite loop over these cars until they are empty
    remaining_car_index = agent.areAllServicesComplete()
    index = 1
    if len(remaining_car_index) !=0:
        while(len(remaining_car_index) != 0):
            print("Additional clock tick", index)

            for i in range(len(remaining_car_index)):
                car_index = remaining_car_index[i]
                agent.moveSpecificCar(car_index)

            index += 1
            remaining_car_index =
agent.areSpecificServicesComplete(remaining_car_index)
            print("Additional tick ends", index, "\n")
        print("The job took an additional of", index - 1, " ticks to
complete")
```

```python
    del agent

# Run this for R3

if __name__ == "__main__":

    no_of_cars = 30
    no_of_nodes = 100
    connectivity = 0.03
    increase = 0.01
    agent = Agent(no_of_cars, no_of_nodes, connectivity, increase)
    # agent.graph.plotGraph()
    for i in range(200):
        print("CLOCK TICK ", i)
        # generating 10 reservation per minute i.e 600 request per
hour
        for j in range(3):
            agent.processNewCustomerRequest()
            agent.moveAllCars()

    remaining_car_index = agent.areAllServicesComplete()
    index = 1
    if len(remaining_car_index) !=0:
        while(len(remaining_car_index) != 0):
            print("Additional clock tick", index)

            for i in range(len(remaining_car_index)):
                car_index = remaining_car_index[i]
                agent.moveSpecificCar(car_index)

            index += 1
            remaining_car_index =
agent.areSpecificServicesComplete(remaining_car_index)
        print("The job took an additional of", index - 1, " ticks to
complete")

    print("Average distance covered = ",
agent.calculateAverageDistanceTravelled())
    print("Average no of trips = ", agent.calculateAverageNoOfTrips())
    del agent

# Run this for R4

if __name__ == "__main__":

    no_of_cars = 60
    no_of_nodes = 100
    connectivity = 0.03
    increase = 0.01
```

```python
    agent = Agent(no_of_cars, no_of_nodes, connectivity, increase)
    # agent.graph.plotGraph()
    for i in range(200):
        print("CLOCK TICK ", i)
        # generating 10 reservation per minute i.e 600 request per
hour
        for j in range(3):
            agent.processNewCustomerRequest()
            agent.moveAllCars()

    remaining_car_index = agent.areAllServicesComplete()
    index = 1
    if len(remaining_car_index) !=0:
        while(len(remaining_car_index) != 0):
            print("Additional clock tick", index)

            for i in range(len(remaining_car_index)):
                car_index = remaining_car_index[i]
                agent.moveSpecificCar(car_index)

            index += 1
            remaining_car_index =
agent.areSpecificServicesComplete(remaining_car_index)
        print("The job took an additional of", index - 1, " ticks to
complete")

    print("Average distance covered = ",
agent.calculateAverageDistanceTravelled())
    print("Average no of trips = ", agent.calculateAverageNoOfTrips())
    del agent


# Run this for R5

if __name__ == "__main__":

    no_of_cars = 60
    no_of_nodes = 100
    connectivity = 0.04
    increase = 0.01
    agent = Agent(no_of_cars, no_of_nodes, connectivity, increase)
    # agent.graph.plotGraph()
    for i in range(200):
        print("CLOCK TICK ", i)
        # generating 10 reservation per minute i.e 600 request per
hour
        for j in range(3):
            agent.processNewCustomerRequest()
            agent.moveAllCars()
```

```python
    remaining_car_index = agent.areAllServicesComplete()
    index = 1
    if len(remaining_car_index) !=0:
        while(len(remaining_car_index) != 0):
            print("Additional clock tick", index)

            for i in range(len(remaining_car_index)):
                car_index = remaining_car_index[i]
                agent.moveSpecificCar(car_index)

            index += 1
            remaining_car_index =
agent.areSpecificServicesComplete(remaining_car_index)
        print("The job took an additional of", index - 1, " ticks to
complete")

    print("Average distance covered = ",
agent.calculateAverageDistanceTravelled())
    print("Average no of trips = ", agent.calculateAverageNoOfTrips())
    del agent
```