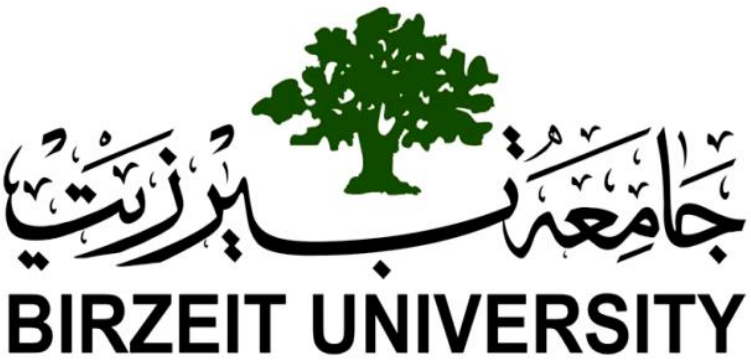

Faculty of Engineering & Technology

Electrical & Computer Engineering Department

Artificial Intelligence - ENCS3340

Project #1 Report

Optimization Strategies for Local Package Delivery Operations

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Prepared by:

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Section: 4.

Date: 3/05/2025.

Problem Formulation

➢ Project Objective

In this project, the problem is about planning how delivery vehicles should pick up and deliver packages. We have a list of packages, each with details like location, weight, and priority level, and a fleet of vehicles that can only carry a certain amount of weight. The goal is to assign packages to the right vehicles and find the best routes for them, so the vehicles travel the shortest distance possible, while also trying to deliver high-priority packages first, if possible. To solve this, we used two methods: Simulated Annealing (SA) and Genetic Algorithm (GA). Both methods look at different ways to solve the problem, improving the solutions step by step. They focus on factors like distance, priority penalties, and the weight limits of each vehicle, helping us find good solutions without checking every possible option.

Constraints:

1. Vehicle Capacity: Each vehicle has a maximum capacity limit, and it can only carry up to its specified capacity.
2. Delivery Priority: Higher-priority packages should be delivered earlier, but this is a soft constraint. It can be violated if prioritizing high-priority packages significantly increases the total cost.
3. No Package Duplication: Each package must be assigned to exactly one vehicle and delivered once. It cannot be duplicated across vehicles or missed.
4. Package Dropping: If a package cannot be assigned to any vehicle due to capacity or other constraints, it will be dropped, and the solver will continue solving the problem with the remaining packages.
5. Specific route: Each vehicle travels a specific route, visiting different locations (the package destinations), and the total distance traveled by all vehicles should be minimized.

Objective: The goal is to minimize the total delivery cost, including fuel costs, vehicle operating costs, and penalties associated with constraint violations.

How It Works

Initialization:

- The program starts by creating a random initial solution. Each package is randomly assigned to a vehicle, and a random route is generated for each vehicle. This is the starting point for both the SA and GA.

Simulated Annealing (SA):

- The algorithm randomly makes small changes to the solution (e.g., swapping packages between vehicles, changing routes).
- It accepts changes that improve the solution (lower cost) and sometimes accepts worse solutions (to explore more possibilities).
- The "temperature" in SA decreases over time, meaning the algorithm becomes more focused on finding better solutions and less likely to accept bad ones.

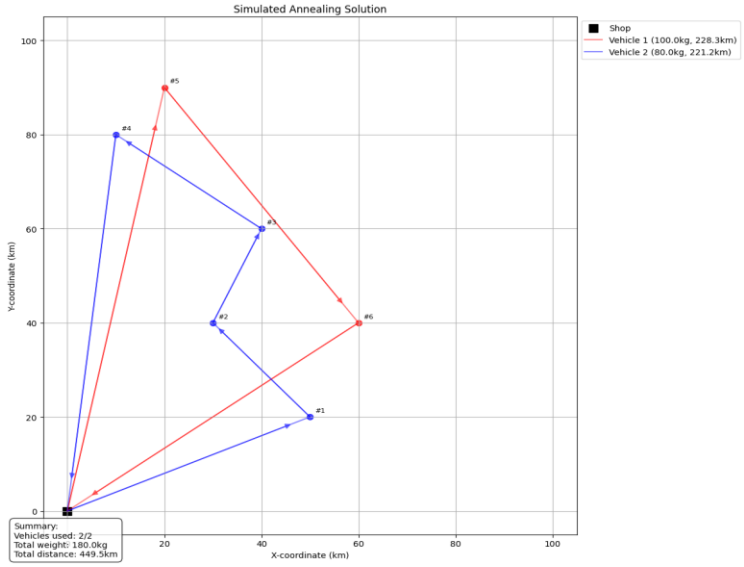
Genetic Algorithm (GA):

- **Selection**: It selects the best solutions from the current population based on their performance (how good their routes are).
- **Crossover**: It combines the best solutions (similar to reproduction) to create new solutions.
- **Mutation**: Small random changes are introduced to ensure the algorithm doesn't get stuck in a local minimum.
- This process repeats for many generations, gradually improving the solutions.

➢ Effects of parameters

Simulated Annealing:

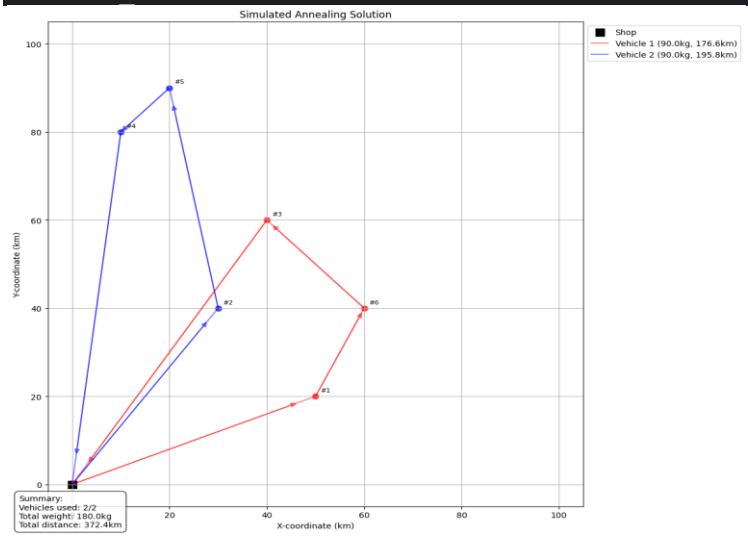
```
ITERATIONS_PER_TEMP = 100
```



If the starting temperature is high (1000), the algorithm is more open to trying bad moves at first. This helps it explore more and avoid getting stuck in a bad spot. But if the temperature starts low (100), it won't try many bad moves, so it might get stuck early and miss better solutions later.

Total distance for 100 iterations is 449.5km

```
INITIAL_TEMPERATURE = 1000
```



Total distance for 1000 iterations is 372.4km, which is less then the distance for the 100 iterations.

Genetic Algorithm:

If we change the population size in Genetic Algorithm (GA):

Increasing population → more genetic diversity, better chance of finding good solutions, but slower.

Decreasing population → faster, but might miss better solutions due to less exploration.

```
POPULATION_SIZE = 10
 Genetic Algorithm completed in 0.14 seconds.
```

```
POPULATION_SIZE = 75
 Genetic Algorithm completed in 1.04 seconds.
```

```
POPULATION_SIZE = 100
 Genetic Algorithm completed in 1.58 seconds.
```

```
POPULATION_SIZE = 200
 Genetic Algorithm completed in 3.72 seconds.
```

➢ Test cases

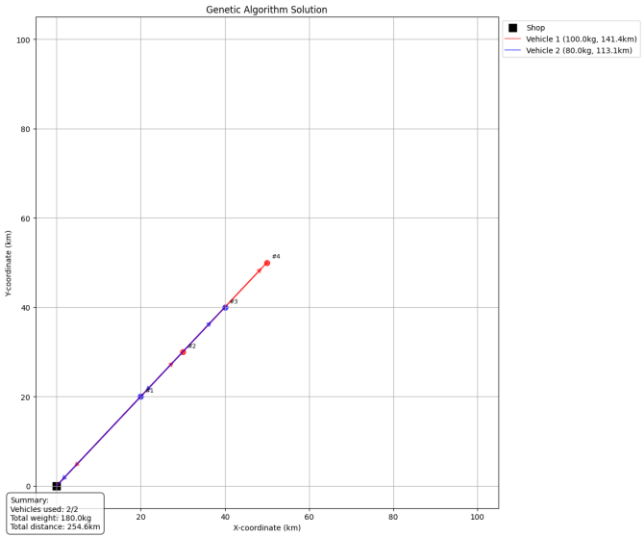
Test Case 1:

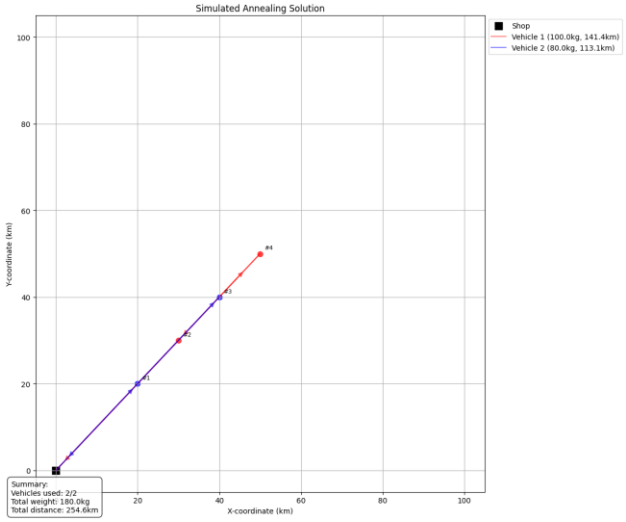
Packages are distributed among vehicles

such that no vehicle carries more than 100 kg.

All packages are assigned to vehicles.

```
# Vehicle capacity
Vehicle: 100.0
Vehicle: 100.0

# Package x y weight priority
Package: 20 20 30 1
Package: 30 30 40 2
Package: 40 40 50 1
Package: 50 50 60 2
```



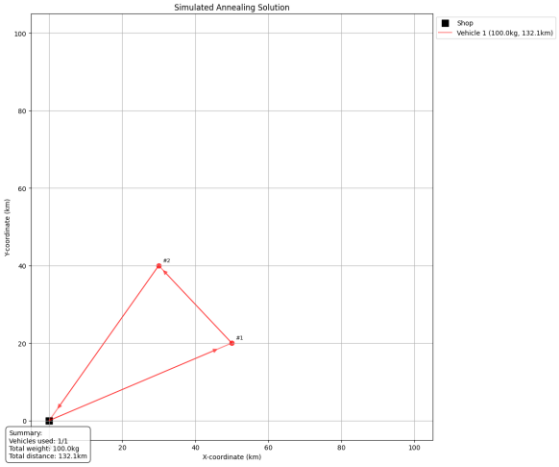


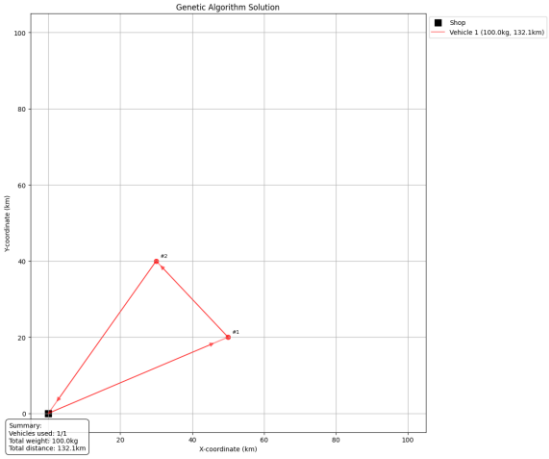
Test Case 2:

Packages 1 and 2 are selected for delivery due to higher priority.

Package 3 is dropped due to capacity constraints.

```
# Vehicle capacity
Vehicle: 100.0


# Package x y weight priority
Package: 50 20 50 1
Package: 30 40 50 2
Package: 40 60 50 3
```

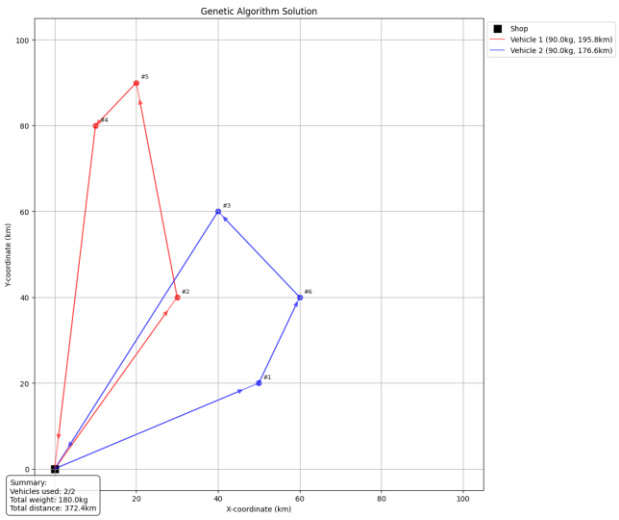


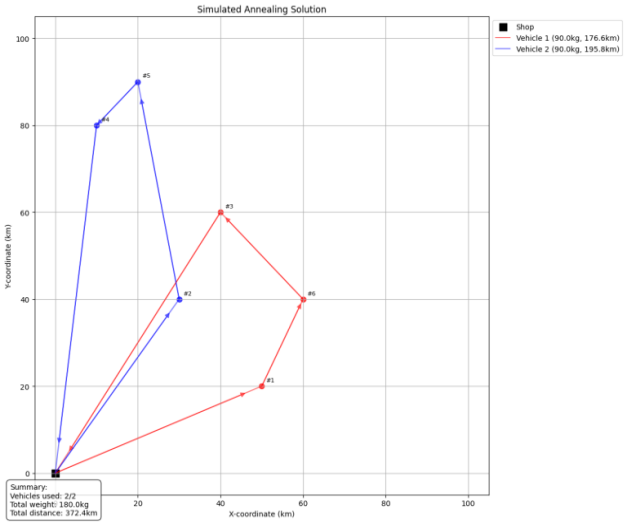


Test Case 3:

Packages are assigned and routed to minimize the combined distance travelled by both vehicles.

```
# Vehicle capacity
Vehicle: 100.0
Vehicle: 100.0

# Package x y weight priority
Package: 50 20 20 1
Package: 30 40 20 2
Package: 40 60 20 3
Package: 10 80 20 3
Package: 20 90 50 3
Package: 60 40 50 3
```





Test Case 4:

The system identifies that the package

cannot be delivered due to weight constraints.

Appropriate handling or notification is provided.

```
# Vehicle capacity
Vehicle: 100.0
Vehicle: 100.0

# Package x y weight priority
Package: 50 20 150 1
```

```
Running Simulated Annealing...
Simulated Annealing completed in 0.08 seconds.
Simulated Annealing assigned 0/1 packages.
Warning: 1 packages were not assigned.
```

```
Running Genetic Algorithm...
Genetic Algorithm completed in 0.37 seconds.
Genetic Algorithm assigned 0/1 packages.
Warning: 1 packages were not assigned.
```

Test Case 5:

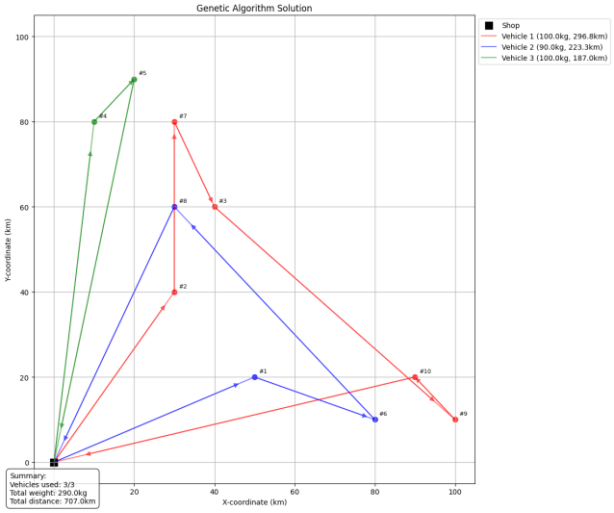
```
# Vehicle capacity
Vehicle: 100.0
Vehicle: 100.0
Vehicle: 100.0

# Package x y weight priority
Package: 50 20 20 1
Package: 30 40 20 2
Package: 40 60 10 3
Package: 10 80 40 4
Package: 20 90 60 5
Package: 80 10 20 1
Package: 30 80 40 2
Package: 30 60 50 3
Package: 100 10 15 4
Package: 90 20 15 5
```

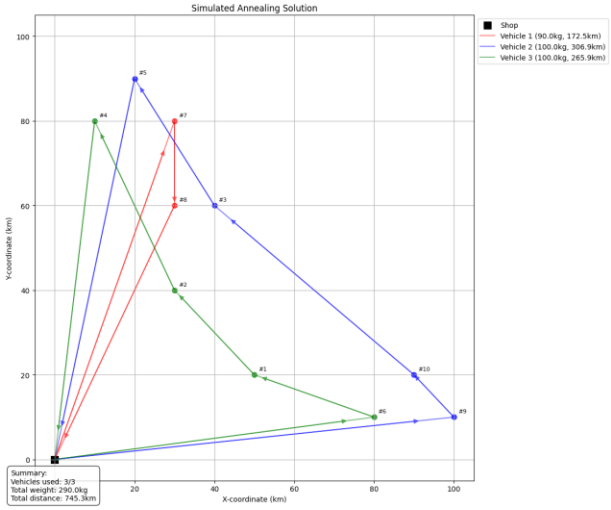
Both algorithms produce valid solutions.

Performance metrics (e.g., total distance, computation time) are recorded for comparison.

Solutions meet all constraints.

Comparative analysis highlights strengths and weaknesses of each algorithm.





Test Case 6:

We put in the input file 10 vehicles, each with a capacity of 100 kg, 100 packages with random weights and priorities.

System processes all packages efficiently, All constraints are satisfied.

It took a reasonable computation time,

However, GA takes more time because it checks many solutions at once in each round. SA is faster since it changes and checks only one solution at a time.

```
Comparison:
Simulated Annealing: 1000000.00 km in 0.08 seconds
Genetic Algorithm: 1000000.00 km in 24.53 seconds
```