# A STUDY ON VEHICLE ROUTING PROBLEM USING GENETIC ALGORITHM WITH LOCAL REFINEMENT

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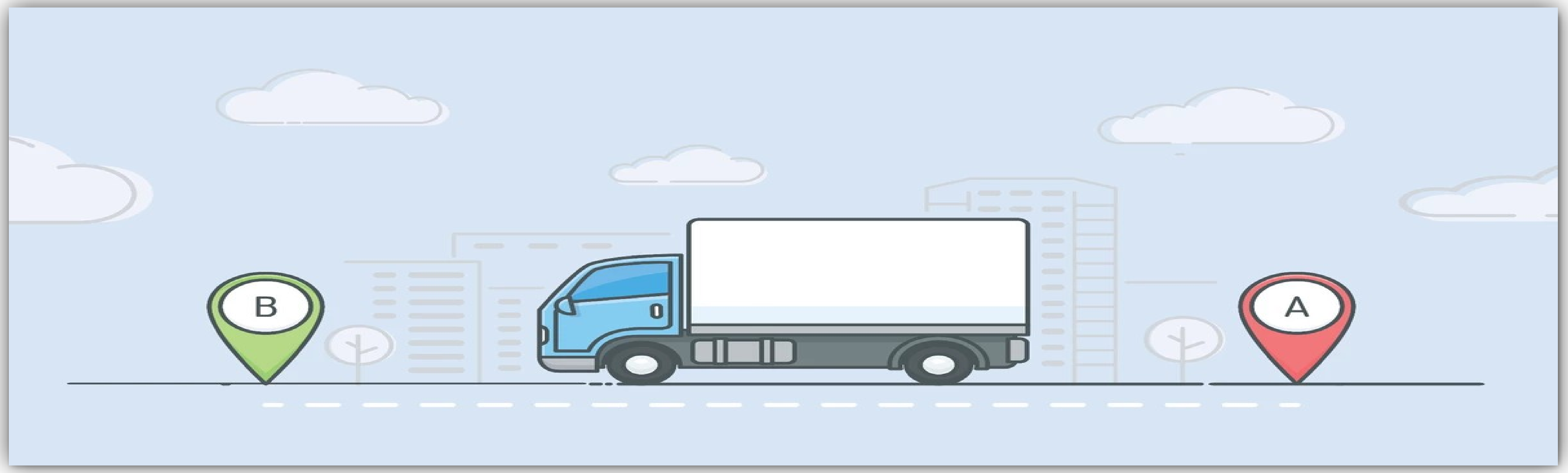


# INTRODUCTION

- The **Vehicle Routing Problem (VRP)** asks the following question: "*What is the optimal set of routes for a fleet of vehicles to traverse in order to deliver to a given set of customers?*"
- **Determine** a set of routes, S, (one route for each vehicle that must start and finish at its own depot) such that all *customers' requirements* and *operational constraints* are satisfied and the total transportation cost is **minimized**.
- The **road network** can be described using a graph where the *arcs* are roads and *vertices* are junctions between them. Arcs may be directed or undirected. Each arc has an associated cost which is generally its length or travel time.

# TYPES OF VEHICLE ROUTING PROBLEM

- **Capacitated Vehicle Routing Problem (CVRP).**
- Vehicle Routing Problem with Time Windows (VRPTW).
- Multi-Depot Vehicle Routing Problem (MDVRP).
- Open Vehicle Routing Problem (OVRP) and many more.

# PROBLEM INSTANCE

- vehicle1: Route1: D – 3 – 4 – 5 – D = 14+20+30+12 = 76.
- Vehicle2: Route2: D – 2 – 1 – 6 – D = 18+22+28+19 = 87.

  Hence total distance covered = 76+87 = 163 (*fitness value*).
- Could be feasible solution.

Our objective is to minimize this cost.

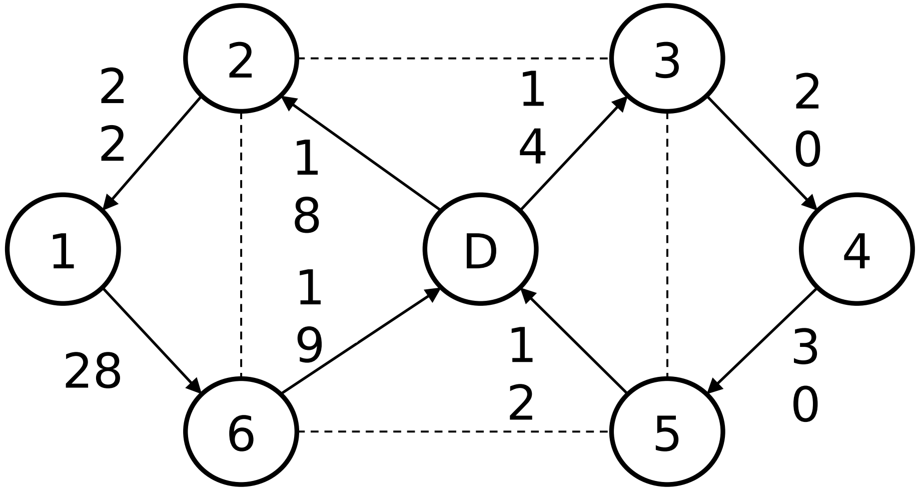



Fig. Road Network

# CONSTRAINTS

- **Capacity**: $q_o[4,6,3,2,3,2]$ i.e., i-th index: customer i and $q_o[i]$ = customer requirement.

  Q: 10 means the vehicle can carry up to maximum 10 units of product.

- **Constraint**: And from now whenever we try to obtain a feasible solution, we need to look if the allocation satisfy the *capacity constraints*.
- Route1 [D – 3 – 4 – 5 – D] total customer requirement is: 3+2+3 = 8.
- Route 2 [D – 2 – 1 – 6 – D] total customer requirement is: 4+6+2 = 12 > 10 (invalid).
- Hence the overall solution is not feasible now.

# MOTIVATION BEHIND GA

- In, Mathematical terms VRP can be classified as a **NP-Hard** Problem, meaning that the required solution time increases exorbitantly with size.
- The total time taken to solve the VRP for different numbers of nodes using this brute-force approach is given in Table [1] below.

| Problem Size | Solution Time |
|---|---|
| 10 | 3ms |
| 20 | 77 years |
| 25 | 490 million years |
| 35 | 8.4 * 10^15 years |
| 50 | 9.6 * 10^47 years |

# MOTIVATION BEHIND GA

- Due to the difficulty of solving to optimality large-scale instances of vehicle routing problems, a significant research effort has been dedicated to **metaheuristics** such as *Genetic algorithms(GA)*, *Tabu search(TA)*, *Simulated annealing(SA)*.
- These metaheuristics helps the problem solution to converge faster and reach an optimal or near optimal solution in much less amount of time than the brute force methods.

# IDEA BEHIND GENETIC ALGORITHM

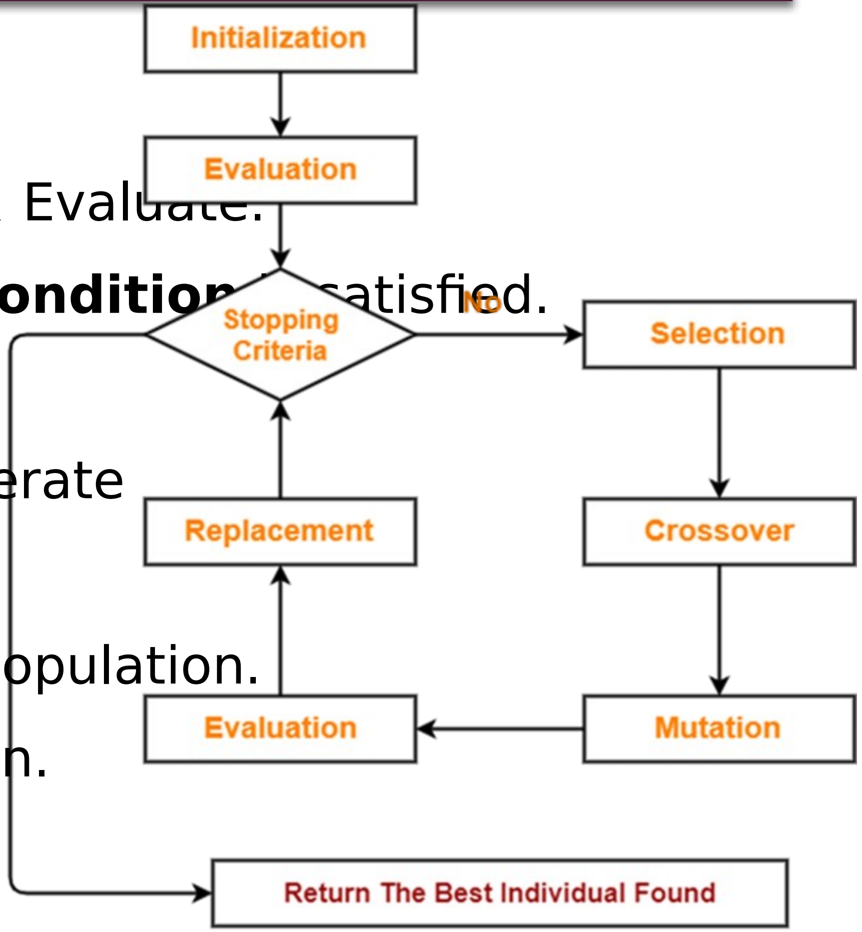
- Based on Darwin’s Principle of ***Natural Selection***.
- Darwin’s principle of Natural Selection is stated as “**Survival of the fittest**”.
- Genetic algorithms use techniques inspired by **evolutionary biology** such as *mutation, selection, crossover* and *inheritance*.
- The evolution process stops when some predefined **termination condition** is satisfied. At each intermediate stage, the old generation is replaced by the new generation.

# THE ALGORITHM

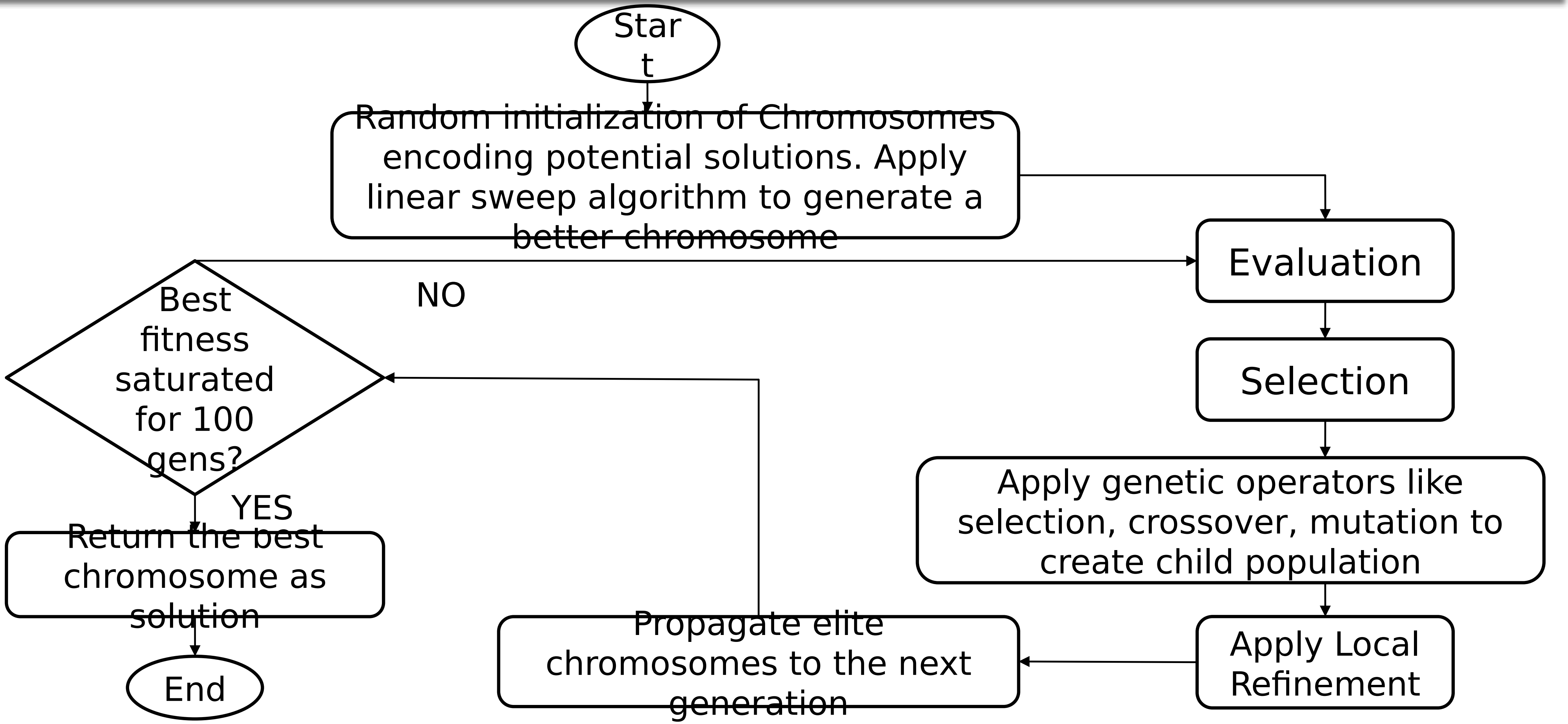
**Procedure GA [4]:**

- **Step 1.** Initialize the population: **current population &** Evaluate.
- **Step 2.** Repeat step 3 through step 5 till **termination condition** is satisfied.
- **Step 3.** Apply **selection** to obtain the mating pool.
- **Step 4.** **Crossover** and **Mutate** the mating pool to generate

  The new population.
- **Step 5.** **Propagate** the current population by the new population.
- **Step 6.** Return the best solution of the current population.



# PROPOSED GA WITH LOCAL REFINEMENT



# CHROMOSOME ENCODING

Route 1 Route 2 Route 3

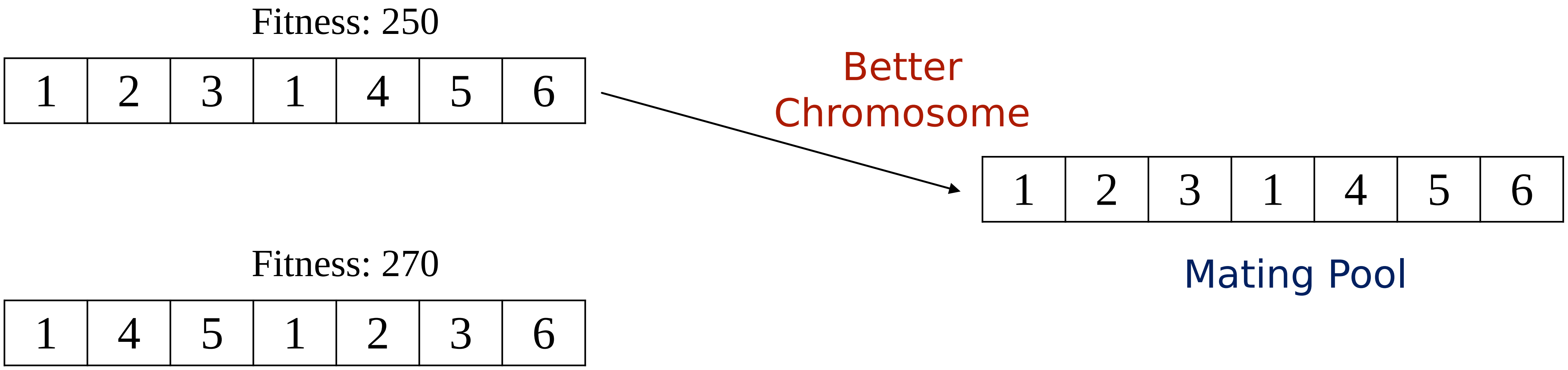
- One of the valid chromosome encoding will be : 1 – 2 – 3 – 4 – 1 – 5 – 6 – 7 – 1 – 8 – 9 – 10.
- Here digit 1 represents the depots.
- Invalid chromosomes:
  - Two ones occur simultaneously i.e., 1 – 2 – 3 – 4 – 1 – 1 – 5 – 6.
  - First digit is not one i.e., 2 – 3 – 1 – 4 – 1 – 5 – 6.
  - Last digit is one i.e., 1 – 2 – 3 – 4 – 1 – 5 – 6 – 7 – 1.
  - The above cases can occur simultaneously also.

# POPULATION INITIALIZATION

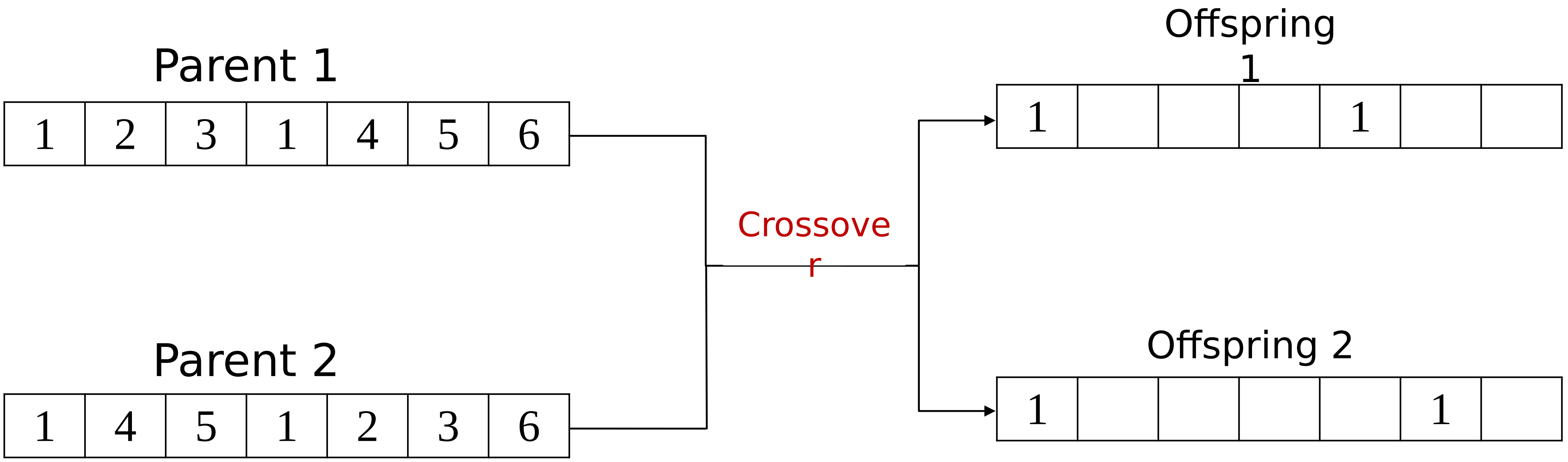
- Initial population is created randomly.
- If any chromosome is found invalid we make that chromosome valid using some user defined functions.
- **Linear Sweep Algorithm** [2] is used to generate a fitter chromosome.

# GENETIC OPERATORS: SELECTION

- **Binary Tournament Selection**.
- Selection based on fitness value of the chromosome.

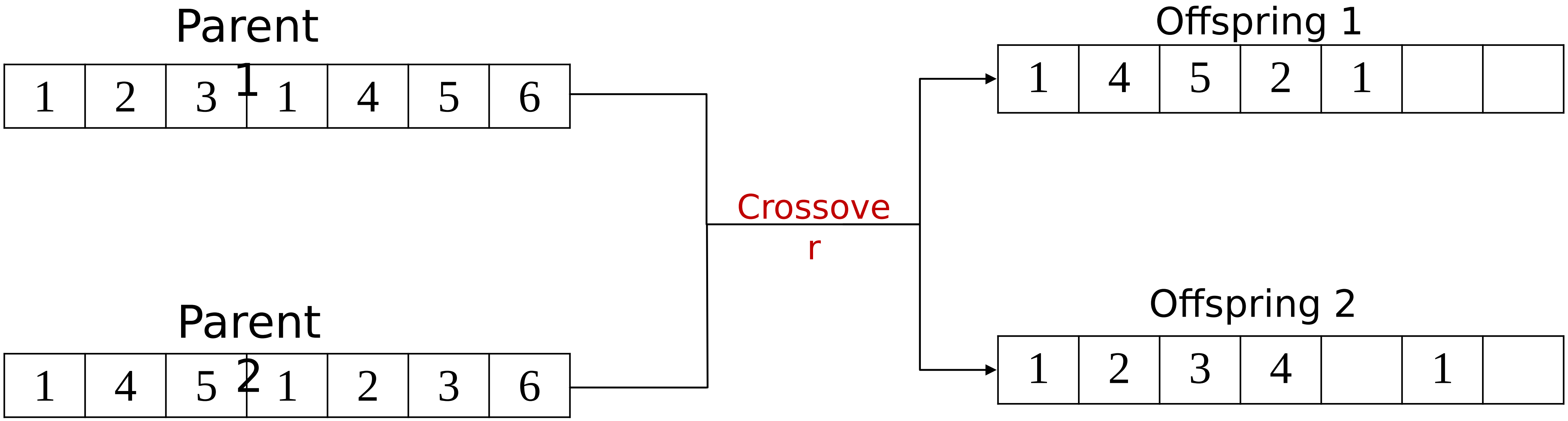


# CROSSOVER

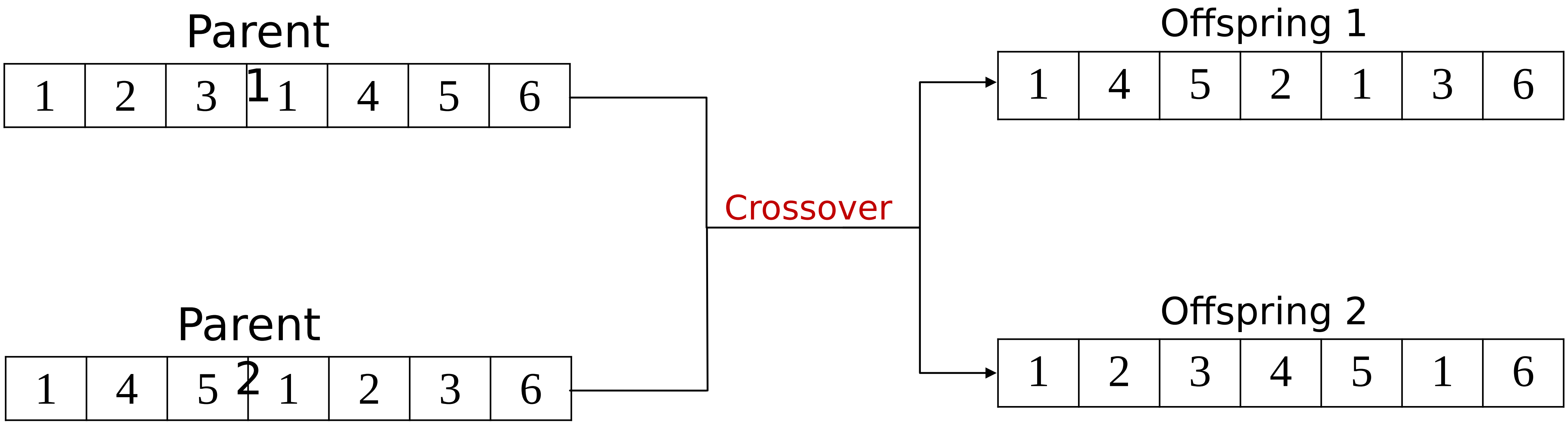


Parent 1
1 2 3 1 4 5 6
Parent 2
1 4 5 1 2 3 6
Crossove
r
Offspring
1
1 1
Offspring 2
1 1

# CROSSOVER


Parent 1
1 2 3 1 4 5 6
Parent 2
1 4 5 1 2 3 6
Crossover
Offspring 1
1 4 5 2 1
Offspring 2
1 2 3 4 1

# CROSSOVER


Parent 1
1 2 3 1 4 5 6
Parent 2
1 4 5 1 2 3 6
Crossover
Offspring 1
1 4 5 2 1 3 6
Offspring 2
1 2 3 4 5 1 6

# MUTATION

- Randomly selecting any two cities (except one) and swap them.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 1 | 4 | 5 | 6 |

$\xrightarrow{\text{Mutation}}$

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 5 | 3 | 1 | 4 | 2 | 6 |

# LOCAL REFINEMENT

Apply TSP

Apply TSP

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 1 | 6 | 7 | 8 | 9 |

Local
Refinement

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 4 | 2 | 5 | 1 | 8 | 6 | 7 | 9 |

Optimized
Offspring

# ELITISM

- prevent the loss of high-quality solutions.
- Combine Current Population and Mating Pool, Choose the best $\alpha$ solutions to propagate in next generations.
- guarantees the retention of the best chromosome obtained thus far.

# TERMINATING CONDITION

- Genetic operators are repeated over multiple generations.
- This loop continues until the best fitness value remains unchanged for the last 100 generations.
- Return  the best chromosome among the current population.

# RESULTS

- The above-mentioned solution of the VRP is implemented using MATLAB programming language in MATLAB 2021a with the system configuration: Intel(R) Pentium(R) CPU G4400 @ 3.30GHz, 3300 MHz, 2 Core(s), 2 Logical Processor(s), Windows 10 Operating System and 4 GB RAM.
- The input instances are taken from the standard VRP libraries: (Augerat, 1995) (Christofides and Eilon, 1969) (Christofides and Eilon, 1969) [3].
- The optimal solutions are also given in the above aforementioned libraries

- The *Crossover Probability* is in range [0.8 – 0.9].
- The *Mutation Probability* is in range [0.1 – 0.3].
- The *population size* is in range [1000 – 5000].

- Error Rate =

# RESULTS

| Instances | Mean Solution* | Mean Solution | Optimal Solution | Error(%) |
|---|---|---|---|---|
| E-n13-k4 | 247 | 247 | 247 | 0 |
| P-n16-k8 | 450 | 450 | 450 | 0 |
| P-n20-k2 | 218.24 | 218 | 218 | 0 |
| E-n23-k3 | 538.23 | 534 | 534 | 0 |
| A-n30-k3 | 582.47 | 562.87 | 534 | 0.18 |
| A-n32-k5 | 855.12 | 833.34 | 784 | 0.19 |
| A-n38-k5 | 812.36 | 794.49 | 730 | 0.23 |
| A-n45-k6 | 1113.68 | 1056.67 | 944 | 0.26 |
| E-n51-k5 | 696.62 | 652.72 | 521 | 0.49 |
| A-n61-k9 | 1512.23 | 1423.47 | 1034 | 0.61 |
| A-n80-k10 | 2912.45 | 2753.34 | 1763 | 0.70 |

* Solution without local refinement.

# DISCUSSION

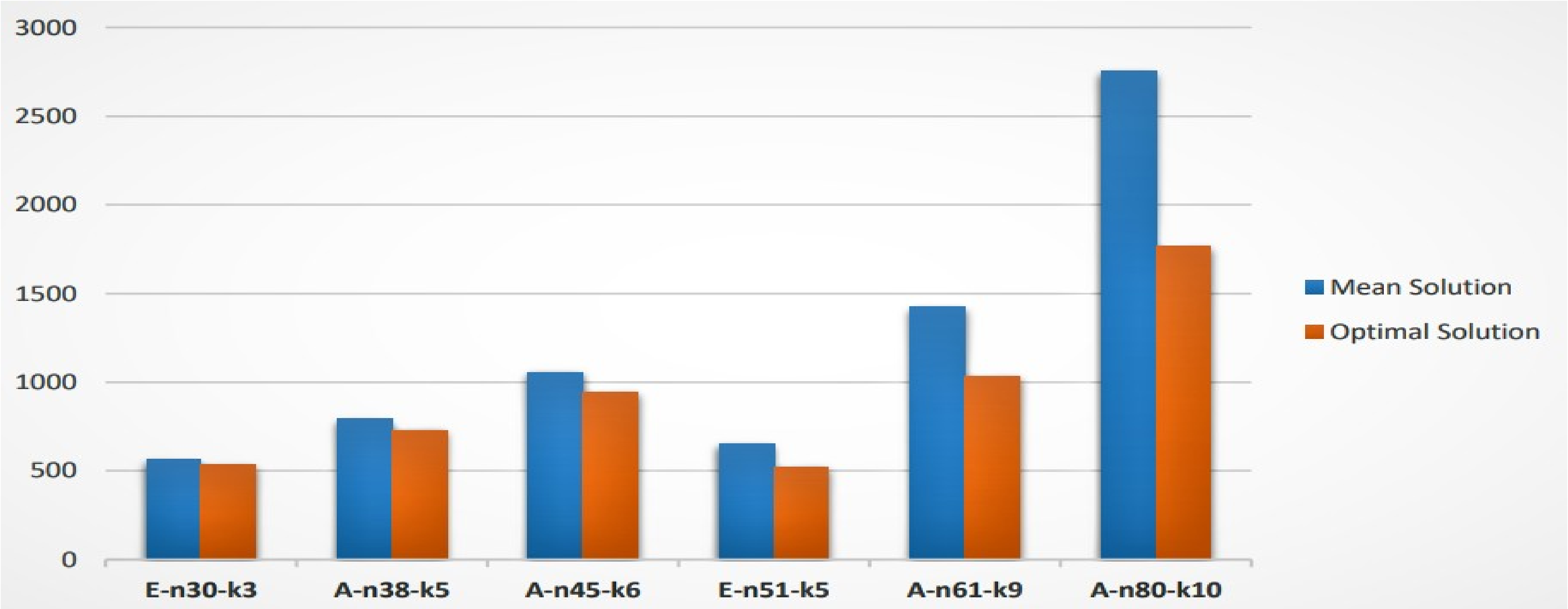



**Figure** : Bar chart for showing performance Comparison for the obtained solutions.

**X-axis**: Problem instance **Y-axis**: Total distance

# DISCUSSION

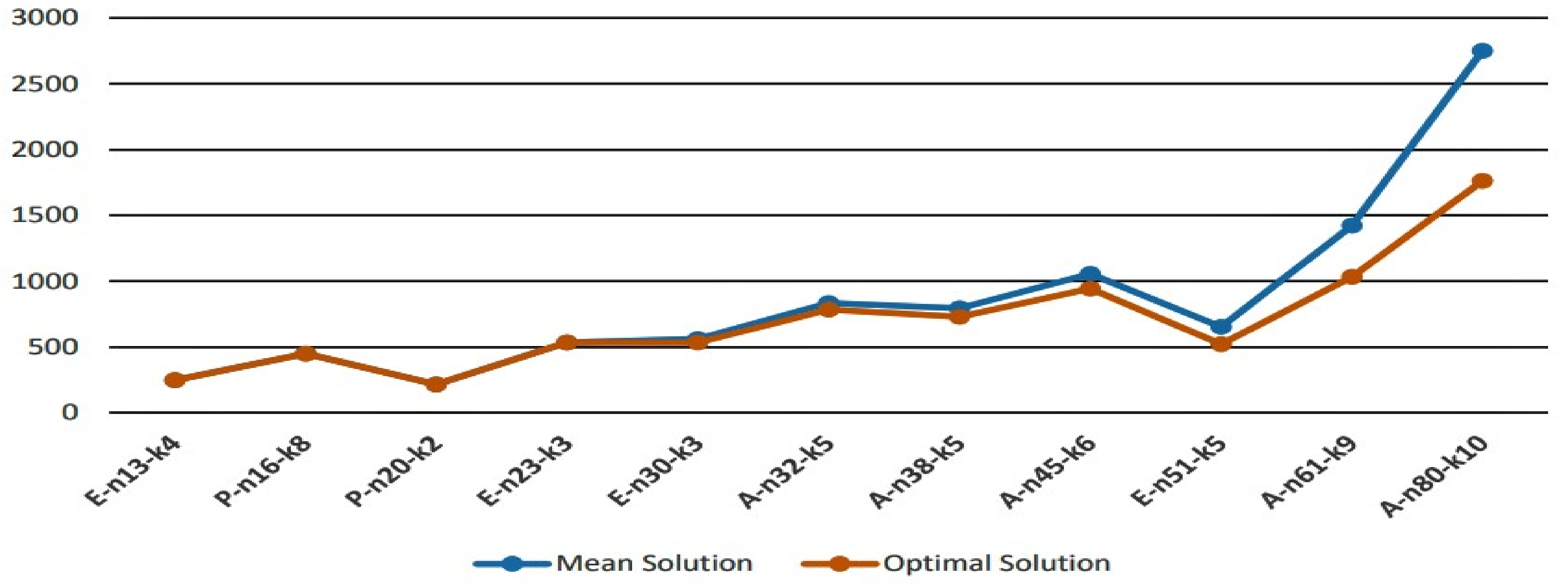



**Figure** : Line chart for showing difference in the result with increasing the size of the problem.

**X-axis**: Problem instance **Y-axis**: Total distance

# CONCLUSION

- In this article, we have introduced a genetic algorithm (GA) approach for addressing the vehicle routing problem (VRP). The GA-based approach we propose incorporates a local refinement strategy at the end of the genetic operators. By incorporating this local refinement strategy, the overall convergence rate of the approach is improved. Our future aim with this study is to develop a more efficient method for solving VRP using GA. Additionally, we seek to minimize the error rate for larger city instances.

# ACKNOWLEDGEMENT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# REFERENCES


- [1] Vehicle Routing Problems 101. by Anand Seshadri | by Opex Analytics | The Opex Analytical Blog | Medium
- [2] Kumar, VV Senthil, and R. Jayachitra. ”Linear sweep algorithm for vehicle routing problem with simultaneous pickup and delivery between two depots with several nodes.” Global Journal of Pure and Applied Mathematics 12.1 (2016): 897-908.
- [3] CVRPLIB - All Instances (puc-rio.br).
- [4] Introduction to soft computing: neuro-fuzzy and genetic algorithms.

# THANK YOU