Greedy Heuristics for TSP with Node Selection

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Problem Description

Given a set of nodes with (x, y) coordinates and costs, the goal is to:

1. **Select exactly 50% of nodes** (rounded up if odd number of nodes)
2. **Form a Hamiltonian cycle** through the selected nodes
3. **Minimize the objective function**: total path length + sum of selected node costs
4. **Distance calculation**: Euclidean distances rounded to nearest integer

Implemented Algorithms

1. Random Solution

Pseudocode:

```
1. Randomly select required number of nodes from all available nodes
2. Create random permutation of selected nodes as route
3. Return solution with selected nodes and route
```

2. Nearest Neighbor Construction Heuristic

Pseudocode:

```
1. Select (e.g. randomly) the starting vertex
2. Repeat:
   - Add to the solution the vertex (and the leading edge) closest to
     the last one added
   Until required number of vertices have been added
3. Add the edge from the last to the first vertex
```

3. Nearest Neighbor (Any Position)

Pseudocode:

```
1. Start with startNode in the route
2. While route size < required nodes:
   a. For each unselected node:
      - For each possible position in route:
        * Calculate objective change if inserted at this position
      - Keep best position for this node
   b. Select node and position with best objective change
   c. Insert selected node at best position
3. Return solution
```

4. Greedy Cycle Construction Heuristic

Pseudocode:

```
1. Select (e.g. randomly) the starting vertex
2. Choose the nearest vertex and create an incomplete cycle from these
   two vertices
3. Repeat:
   - Insert into the current cycle in the best possible place the vertex
     causing the smallest increase in cycle length
   Until required number of vertices have been added
```

Note: "Nearest" and "closest" consider the best change in objective function (distance + cost), not just geometric distance.

Computational Experiment Results

Experimental Results

Instance: TSPA

Algorithm	Runs	Min	Max	Average	Validated
Random Solution	200	238,849.00	288,140.00	265,165.54	YES
Greedy Cycle	200	71,488.00	74,410.00	72,635.98	YES
Nearest Neighbor Any	200	71,179.00	75,450.00	73,178.55	YES
Nearest Neighbor End	200	83,182.00	89,433.00	85,108.51	YES

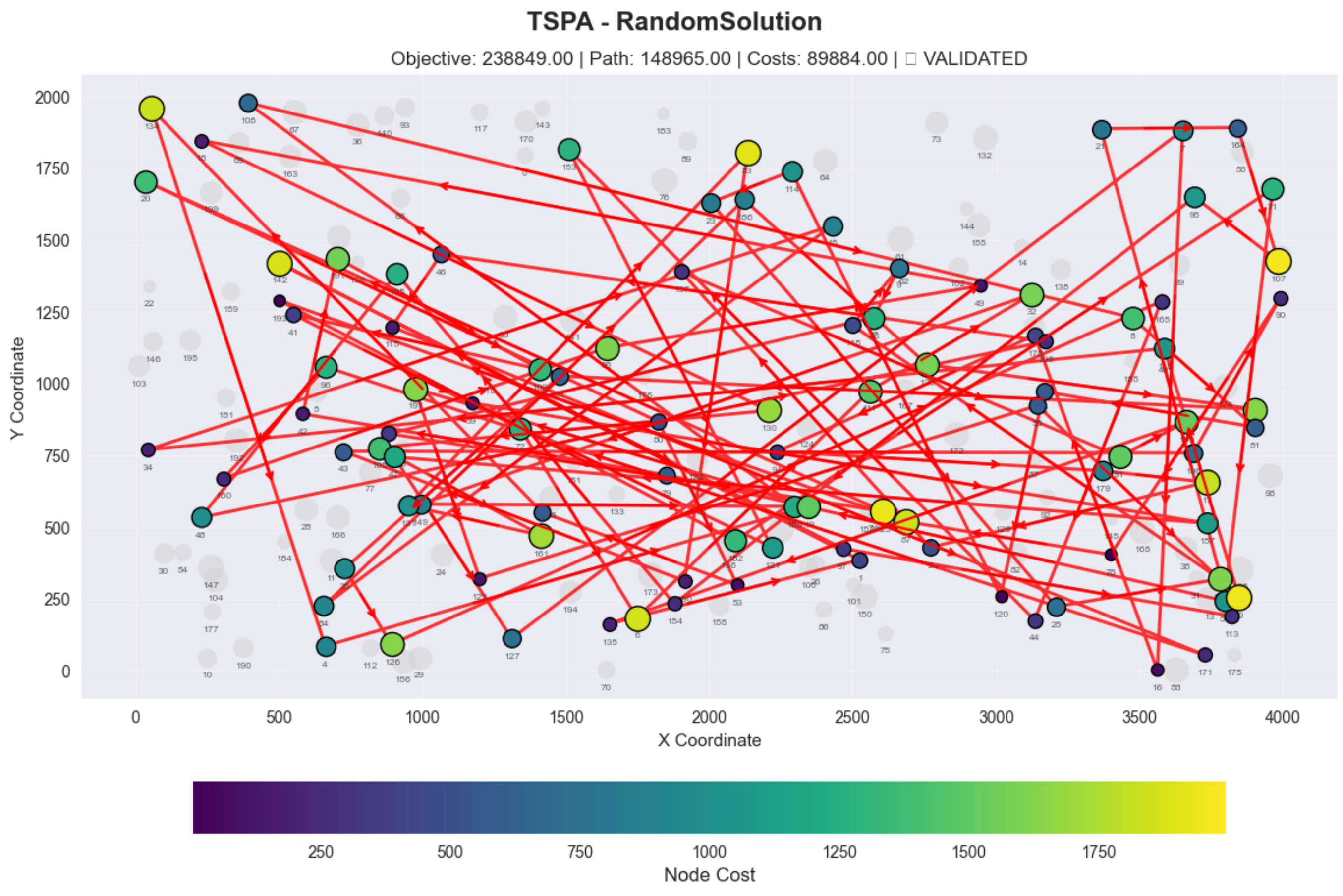
Instance: TSPB

Algorithm	Runs	Min	Max	Average	Validated
Random Solution	200	194,376.00	245,960.00	212,968.97	YES
Greedy Cycle	200	49,001.00	57,324.00	51,400.60	YES
Nearest Neighbor Any	200	44,417.00	53,438.00	45,870.25	YES
Nearest Neighbor End	200	52,319.00	59,030.00	54,390.43	YES

2D Visualization of Best Solution

Instance: TSPA

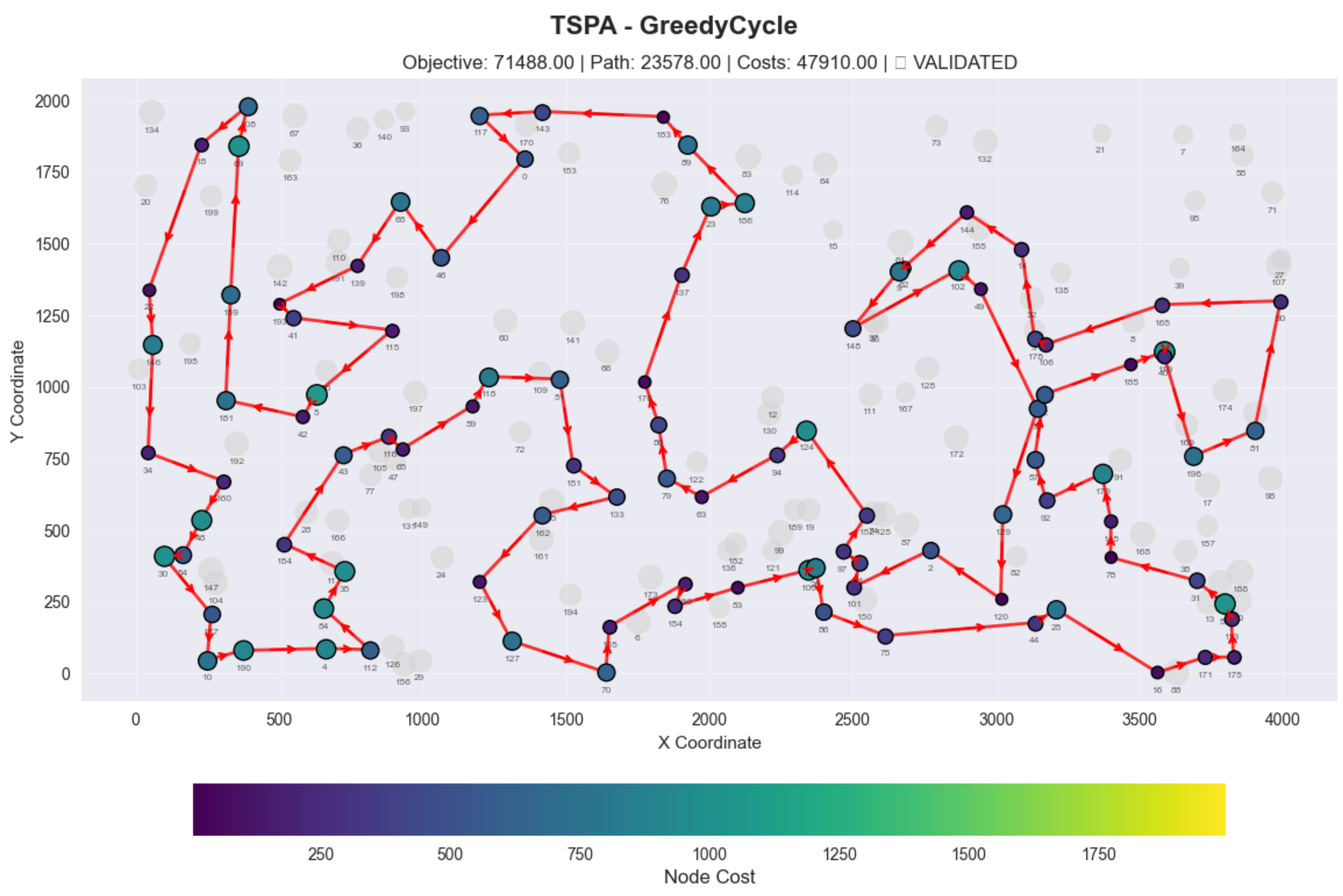
Random Solution



- Status: ✓ VALIDATED
- Objective Value: 238849.00
- Path Length: 148965.00
- Node Costs: 89884.00
- Selected Nodes: 100

Node Order (Route): 55, 50, 119, 34, 15, 84, 186, 128, 187, 51, 35, 126, 165, 44, 153, 121, 59, 157, 47, 127, 7, 16, 178, 94, 179, 17, 2, 137, 91, 169, 135, 1, 142, 97, 113, 21, 164, 107, 95, 154, 198, 48, 106, 46, 115, 171, 96, 160, 66, 49, 18, 130, 105, 161, 131, 83, 180, 43, 196, 90, 78, 87, 193, 182, 71, 56, 79, 42, 191, 109, 41, 72, 6, 111, 32, 149, 189, 108, 8, 81, 52, 120, 114, 23, 25, 85, 148, 9, 37, 116, 125, 20, 80, 53, 162, 134, 4, 19, 197, 123

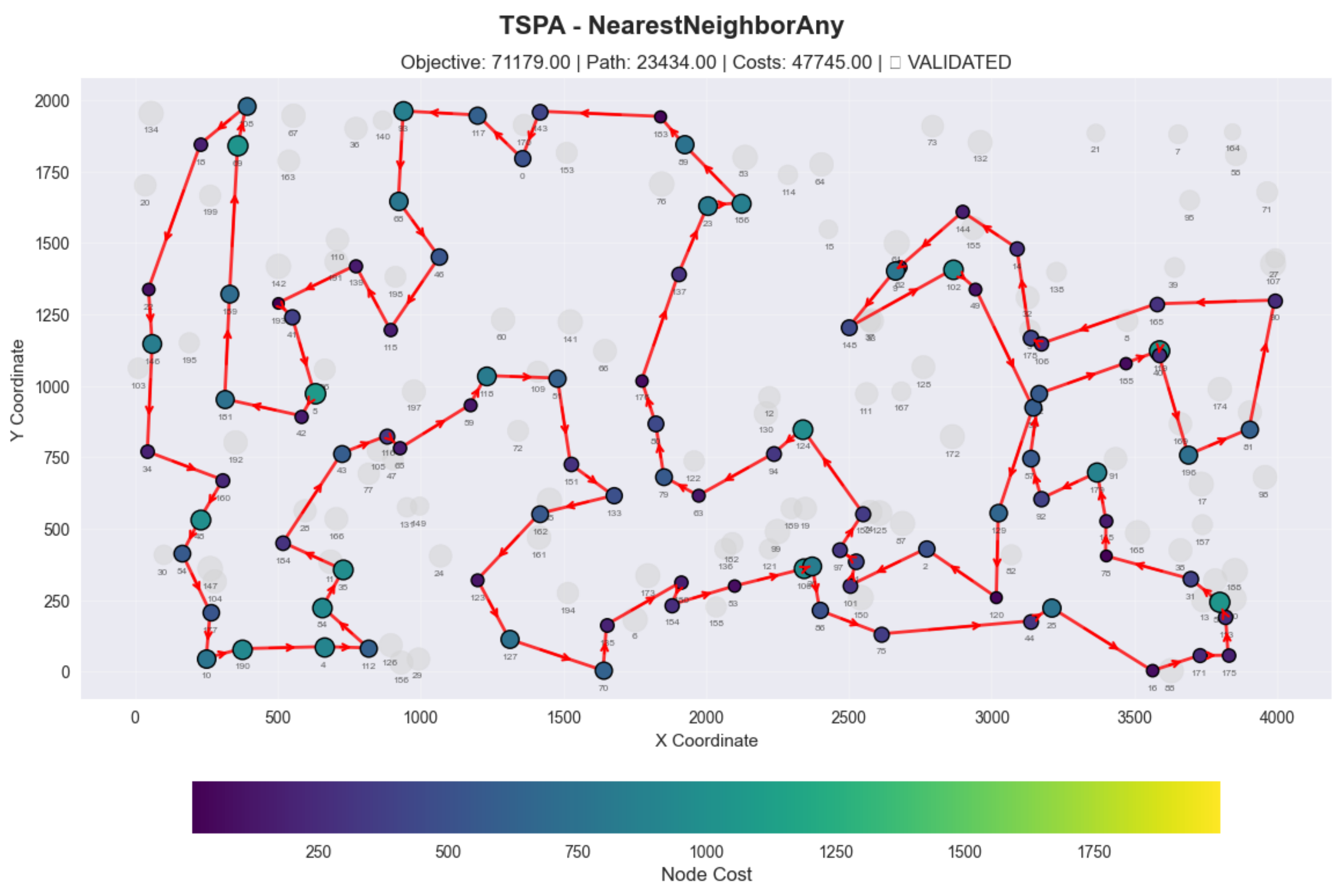
Greedy Cycle



- Status: ✓ VALIDATED
- Objective Value: 71488.00
- Path Length: 23578.00
- Node Costs: 47910.00
- Selected Nodes: 100

Node Order (Route): 0, 46, 68, 139, 193, 41, 115, 5, 42, 181, 159, 69, 108, 18, 22, 146, 34, 160, 48, 54, 30, 177, 10, 190, 4, 112, 84, 35, 184, 43, 116, 65, 59, 118, 51, 151, 133, 162, 123, 127, 70, 135, 180, 154, 53, 100, 26, 86, 75, 44, 25, 16, 171, 175, 113, 56, 31, 78, 145, 179, 92, 57, 52, 185, 119, 40, 196, 81, 90, 165, 106, 178, 14, 144, 62, 9, 148, 102, 49, 55, 129, 120, 2, 101, 1, 97, 152, 124, 94, 63, 79, 80, 176, 137, 23, 186, 89, 183, 143, 117

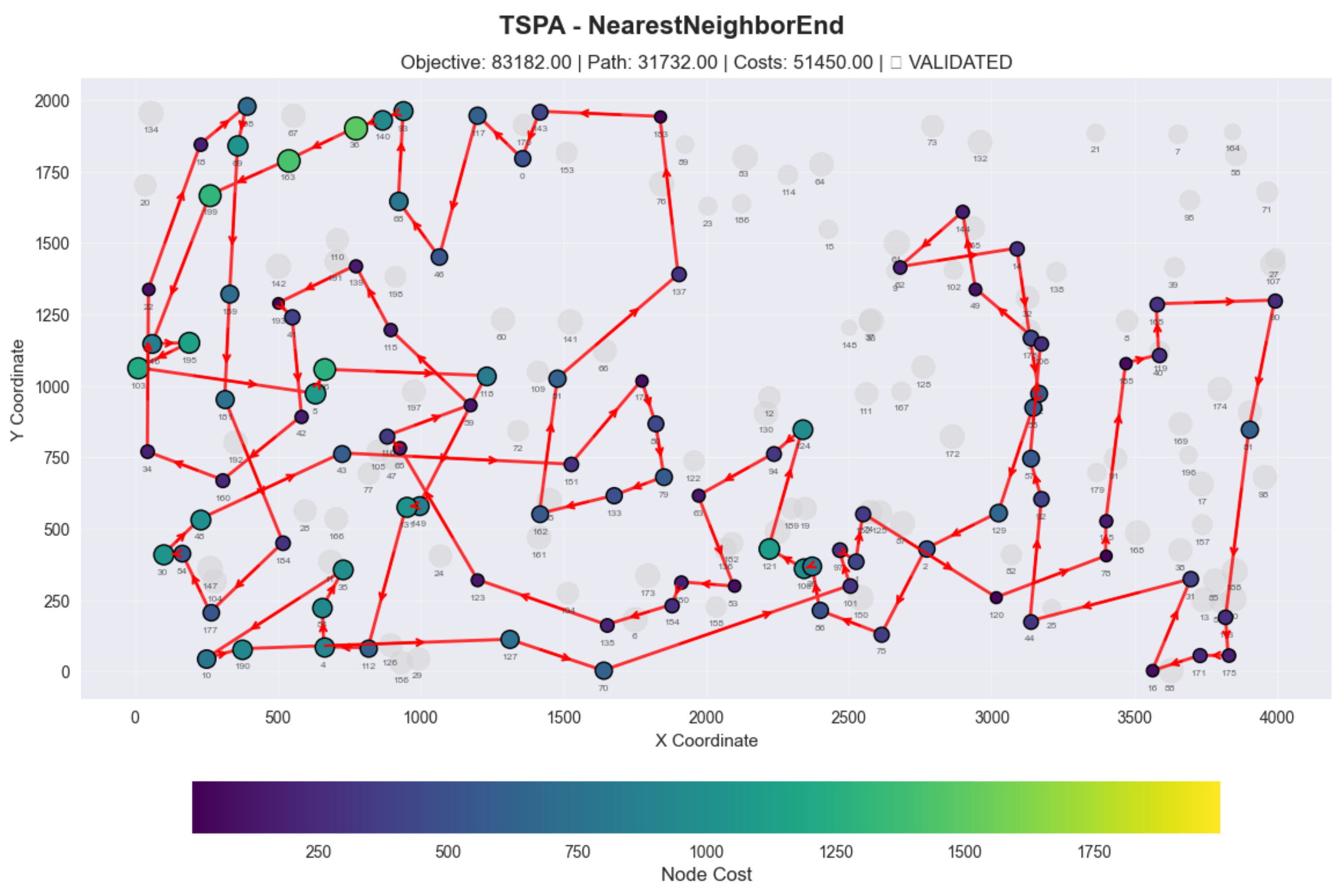
Nearest Neighbor Any



- Status: ✓ VALIDATED
- Objective Value: 71179.00
- Path Length: 23434.00
- Node Costs: 47745.00
- Selected Nodes: 100

Node Order (Route): 68, 46, 115, 139, 193, 41, 5, 42, 181, 159, 69, 108, 18, 22, 146, 34, 160, 48, 54, 177, 10, 190, 4, 112, 84, 35, 184, 43, 116, 65, 59, 118, 51, 151, 133, 162, 123, 127, 70, 135, 180, 154, 53, 100, 26, 86, 75, 44, 25, 16, 171, 175, 113, 56, 31, 78, 145, 179, 92, 57, 52, 185, 119, 40, 196, 81, 90, 165, 106, 178, 14, 144, 62, 9, 148, 102, 49, 55, 129, 120, 2, 101, 1, 97, 152, 124, 94, 63, 79, 80, 176, 137, 23, 186, 89, 183, 143, 0, 117, 93

Nearest Neighbor End

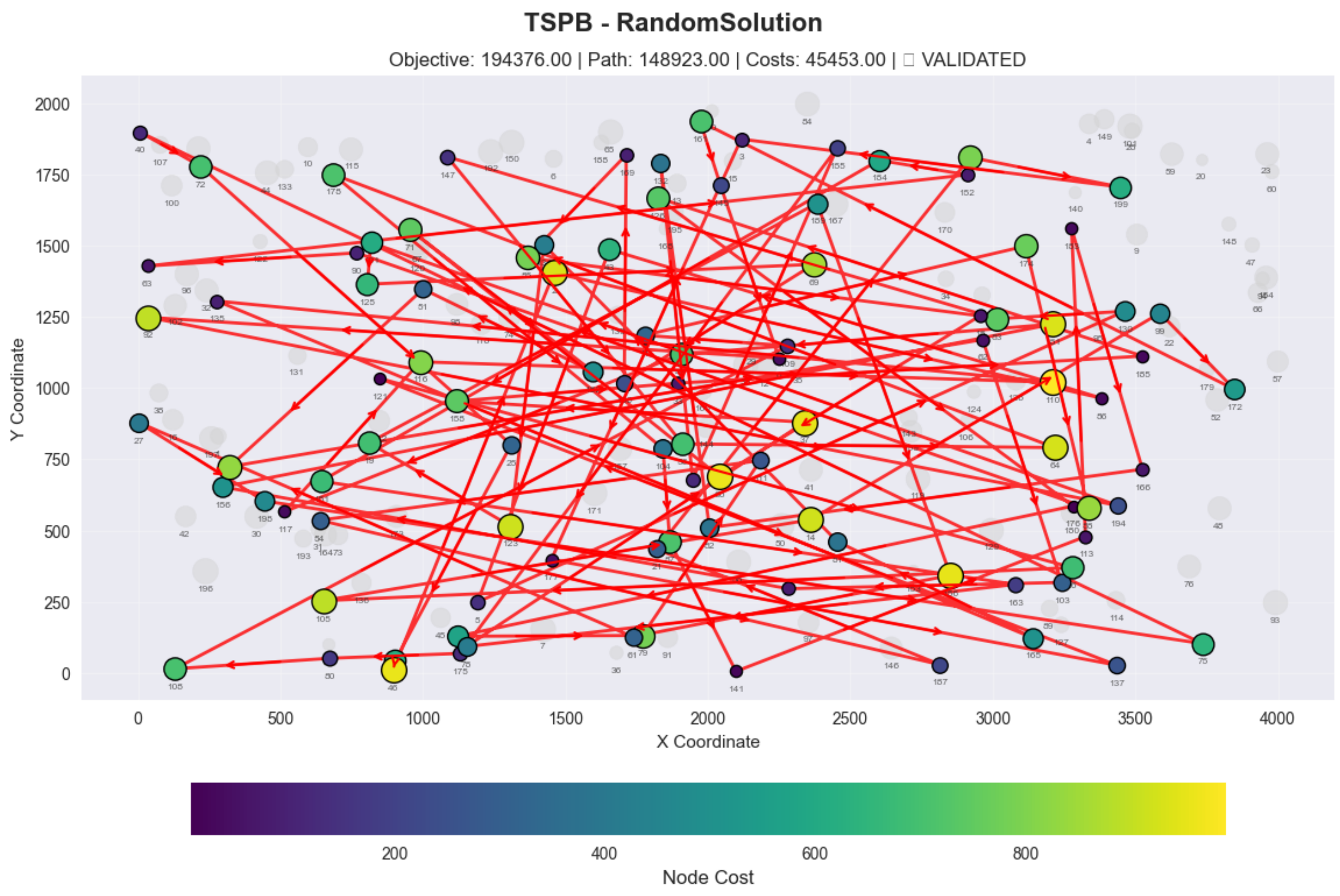


- Status: ✓ VALIDATED
- Objective Value: 83182.00
- Path Length: 31732.00
- Node Costs: 51450.00
- Selected Nodes: 100

Node Order (Route): 124, 94, 63, 53, 180, 154, 135, 123, 65, 116, 59, 115, 139, 193, 41, 42, 160, 34, 22, 18, 108, 69, 159, 181, 184, 177, 54, 30, 48, 43, 151, 176, 80, 79, 133, 162, 51, 137, 183, 143, 0, 117, 46, 68, 93, 140, 36, 163, 199, 146, 195, 103, 5, 96, 118, 149, 131, 112, 4, 84, 35, 10, 190, 127, 70, 101, 97, 1, 152, 120, 78, 145, 185, 40, 165, 90, 81, 113, 175, 171, 16, 31, 44, 92, 57, 106, 49, 144, 62, 14, 178, 52, 55, 129, 2, 75, 86, 26, 100, 121

TSPB

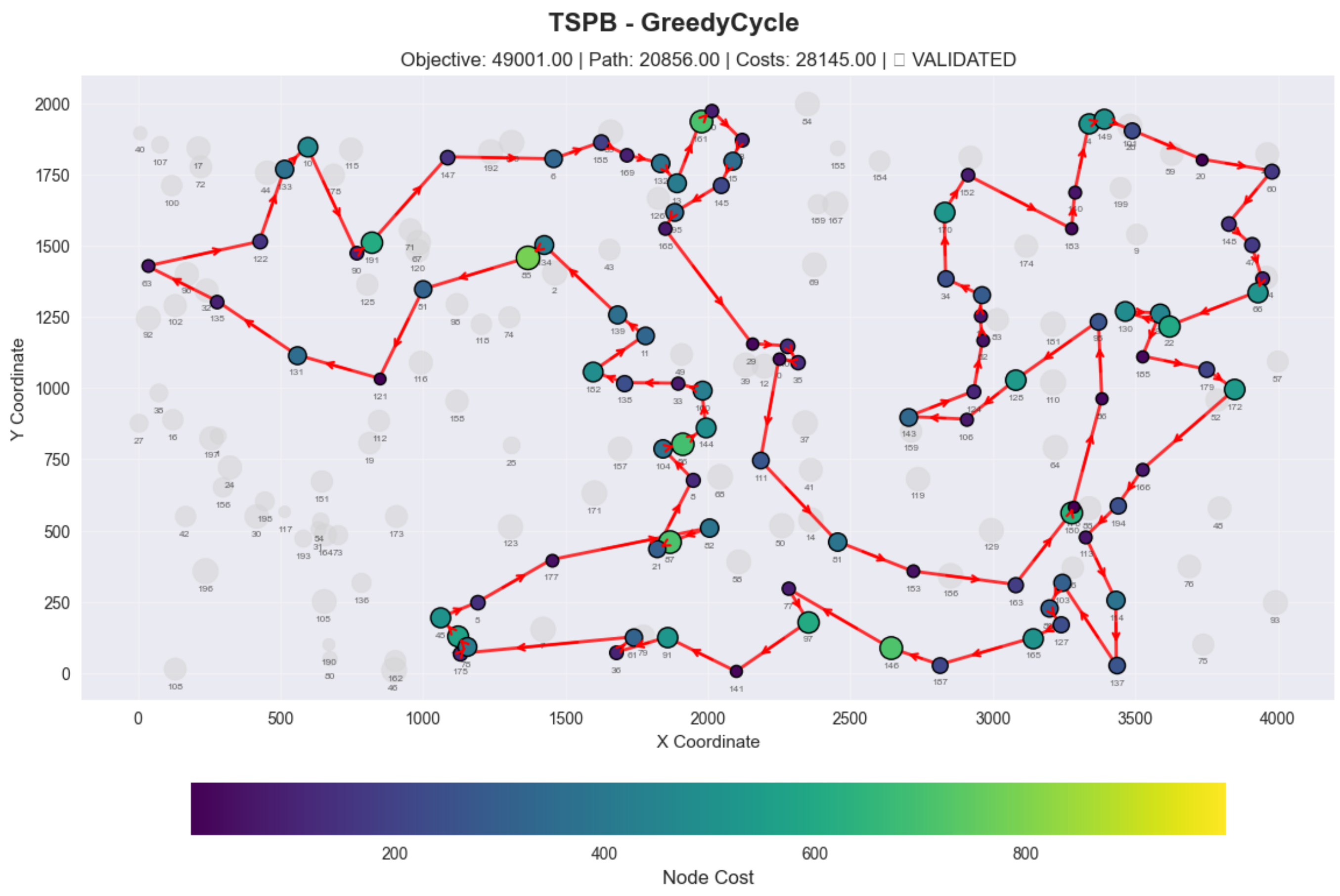
Random Solution



- Status: ✓ VALIDATED
- Objective Value: 194376.00
- Path Length: 148923.00
- Node Costs: 45453.00
- Selected Nodes: 100

Node Order (Route): 151, 163, 78, 37, 158, 33, 185, 126, 176, 142, 79, 111, 54, 187, 21, 53, 199, 3, 177, 137, 121, 26, 105, 14, 99, 172, 161, 145, 0, 92, 194, 191, 125, 69, 138, 169, 85, 18, 68, 71, 182, 51, 24, 62, 103, 77, 156, 181, 49, 117, 116, 110, 135, 165, 81, 134, 123, 19, 189, 186, 61, 27, 198, 75, 40, 72, 25, 162, 46, 2, 86, 43, 5, 130, 83, 147, 56, 64, 178, 104, 87, 141, 113, 183, 166, 82, 132, 8, 155, 175, 80, 108, 109, 11, 174, 88, 90, 63, 152, 184

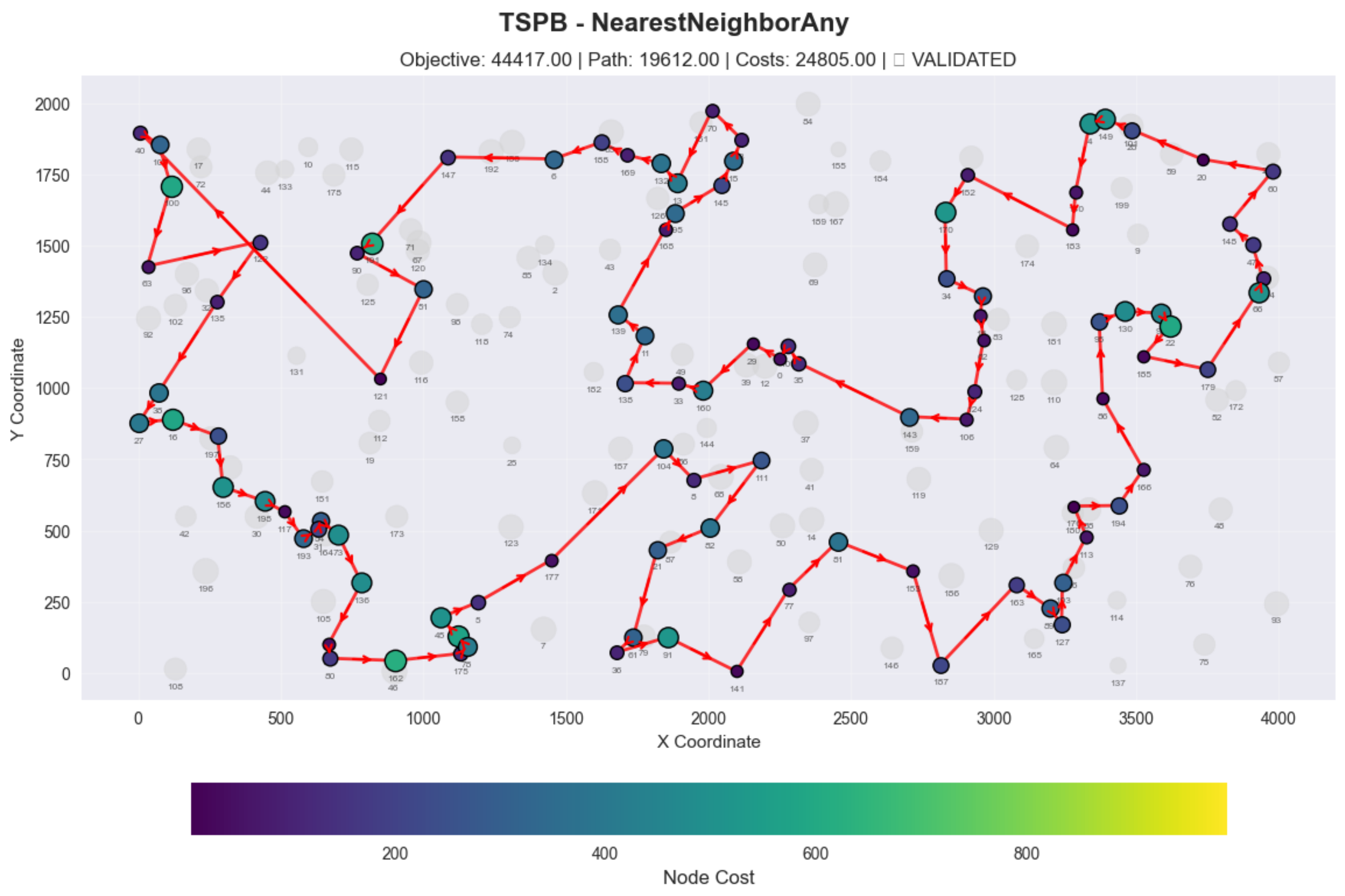
Greedy Cycle



- Status: ✓ VALIDATED
- Objective Value: 49001.00
- Path Length: 20856.00
- Node Costs: 28145.00
- Selected Nodes: 100

Node Order (Route): 85, 51, 121, 131, 135, 63, 122, 133, 10, 90, 191, 147, 6, 188, 169, 132, 13, 161, 70, 3, 15, 145, 195, 168, 29, 109, 35, 0, 111, 81, 153, 163, 180, 176, 86, 95, 128, 106, 143, 124, 62, 18, 55, 34, 170, 152, 183, 140, 4, 149, 28, 20, 60, 148, 47, 94, 66, 22, 130, 99, 185, 179, 172, 166, 194, 113, 114, 137, 103, 89, 127, 165, 187, 146, 77, 97, 141, 91, 36, 61, 175, 78, 142, 45, 5, 177, 82, 87, 21, 8, 104, 56, 144, 160, 33, 138, 182, 11, 139, 134

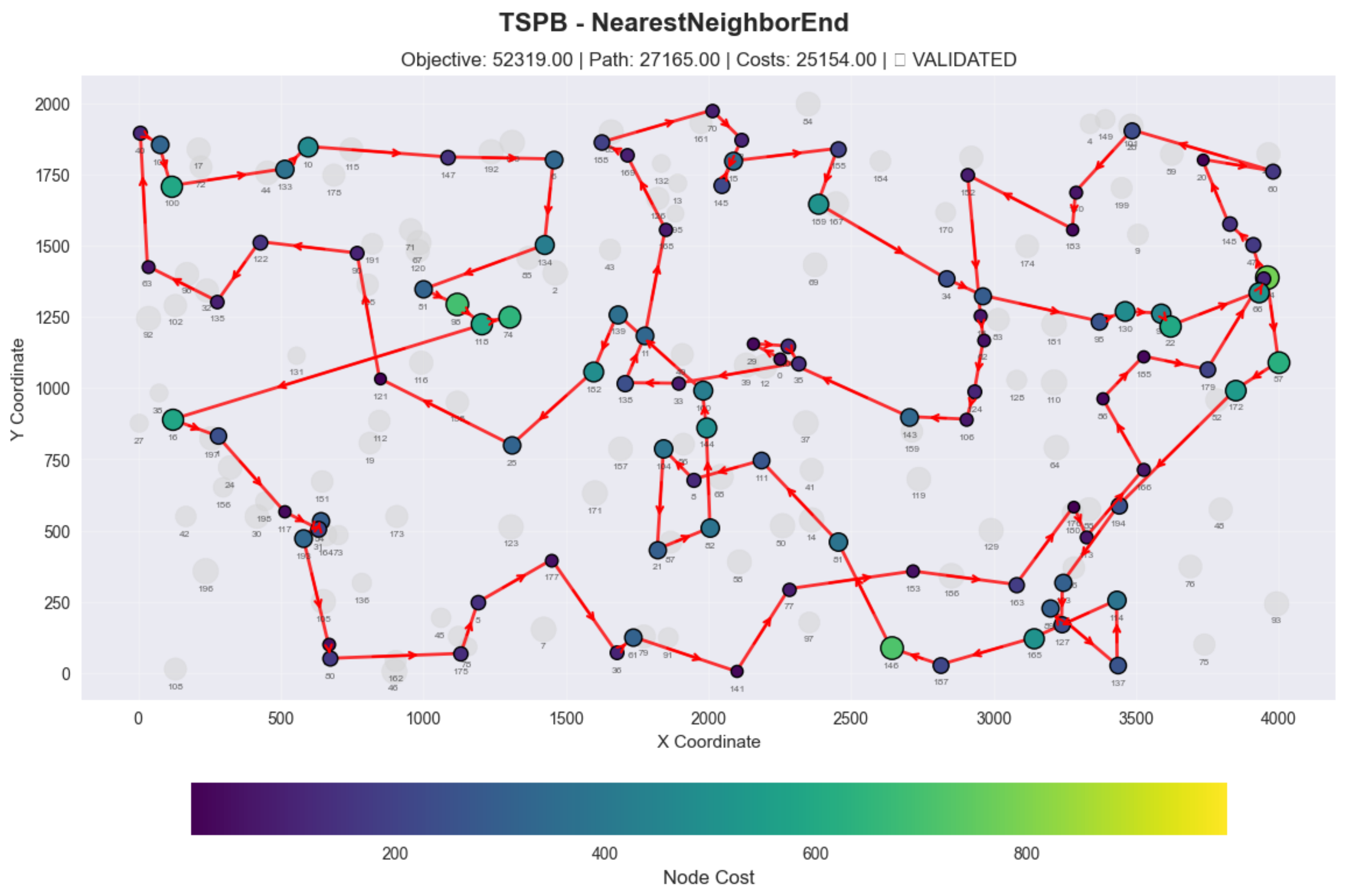
Nearest Neighbor Any



- Status: ✓ VALIDATED
- Objective Value: 44417.00
- Path Length: 19612.00
- Node Costs: 24805.00
- Selected Nodes: 100

Node Order (Route): 40, 107, 100, 63, 122, 135, 38, 27, 16, 1, 156, 198, 117, 193, 31, 54, 73, 136, 190, 80, 162, 175, 78, 142, 45, 5, 177, 104, 8, 111, 82, 21, 61, 36, 91, 141, 77, 81, 153, 187, 163, 89, 127, 103, 113, 176, 194, 166, 86, 95, 130, 99, 22, 185, 179, 66, 94, 47, 148, 60, 20, 28, 149, 4, 140, 183, 152, 170, 34, 55, 18, 62, 124, 106, 143, 35, 109, 0, 29, 160, 33, 138, 11, 139, 168, 195, 145, 15, 3, 70, 13, 132, 169, 188, 6, 147, 191, 90, 51, 121

Nearest Neighbor End



- Status: ✓ VALIDATED
- Objective Value: 52319.00
- Path Length: 27165.00
- Node Costs: 25154.00
- Selected Nodes: 100

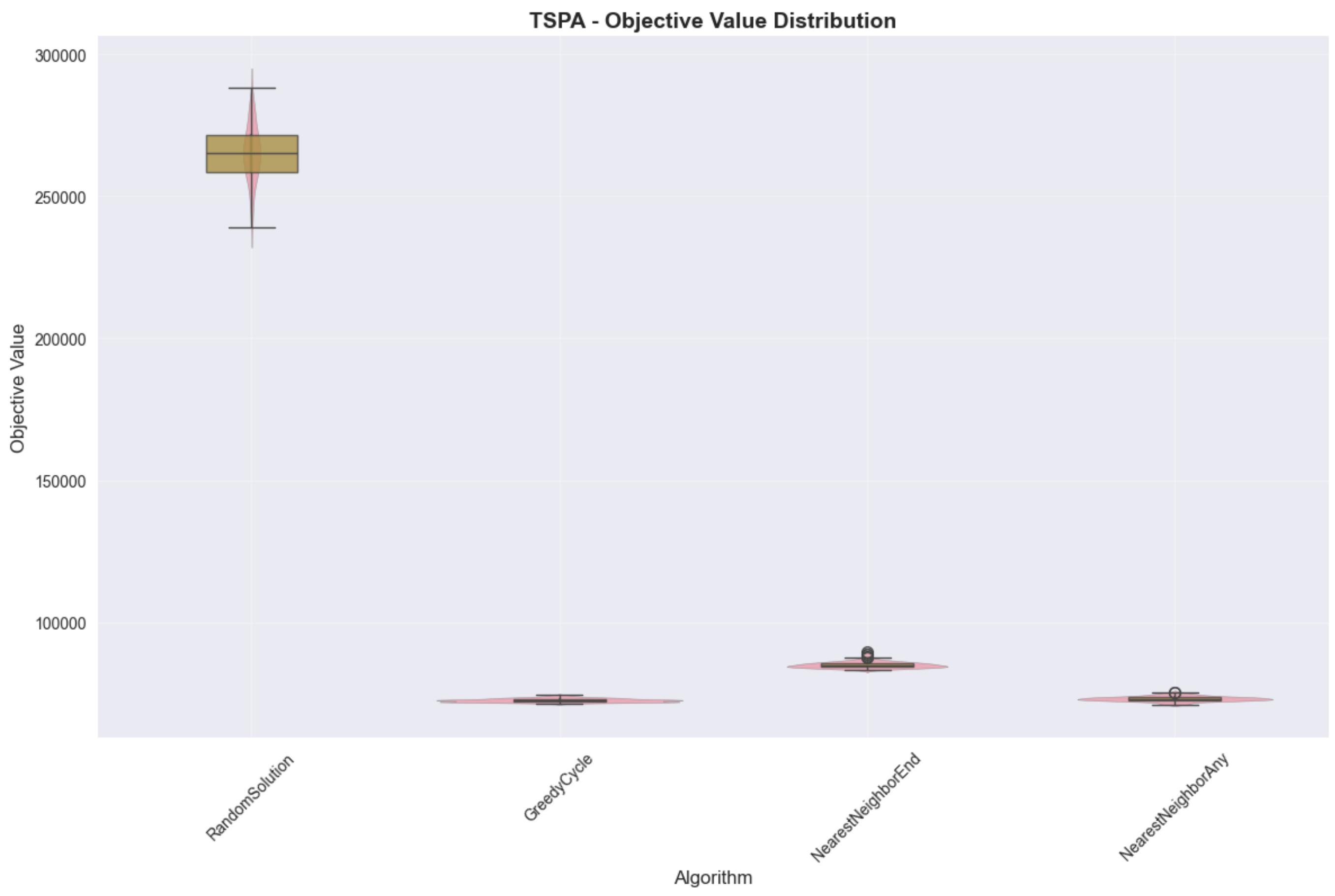
Node Order (Route): 16, 1, 117, 31, 54, 193, 190, 80, 175, 5, 177, 36, 61, 141, 77, 153, 163, 176, 113, 166, 86, 185, 179, 94, 47, 148, 20, 60, 28, 140, 183, 152, 18, 62, 124, 106, 143, 0, 29, 109, 35, 33, 138, 11, 168, 169, 188, 70, 3, 145, 15, 155, 189, 34, 55, 95, 130, 99, 22, 66, 154, 57, 172, 194, 103, 127, 89, 137, 114, 165, 187, 146, 81, 111, 8, 104, 21, 82, 144, 160, 139, 182, 25, 121, 90, 122, 135, 63, 40, 107, 100, 133, 10, 147, 6, 134, 51, 98, 118, 74

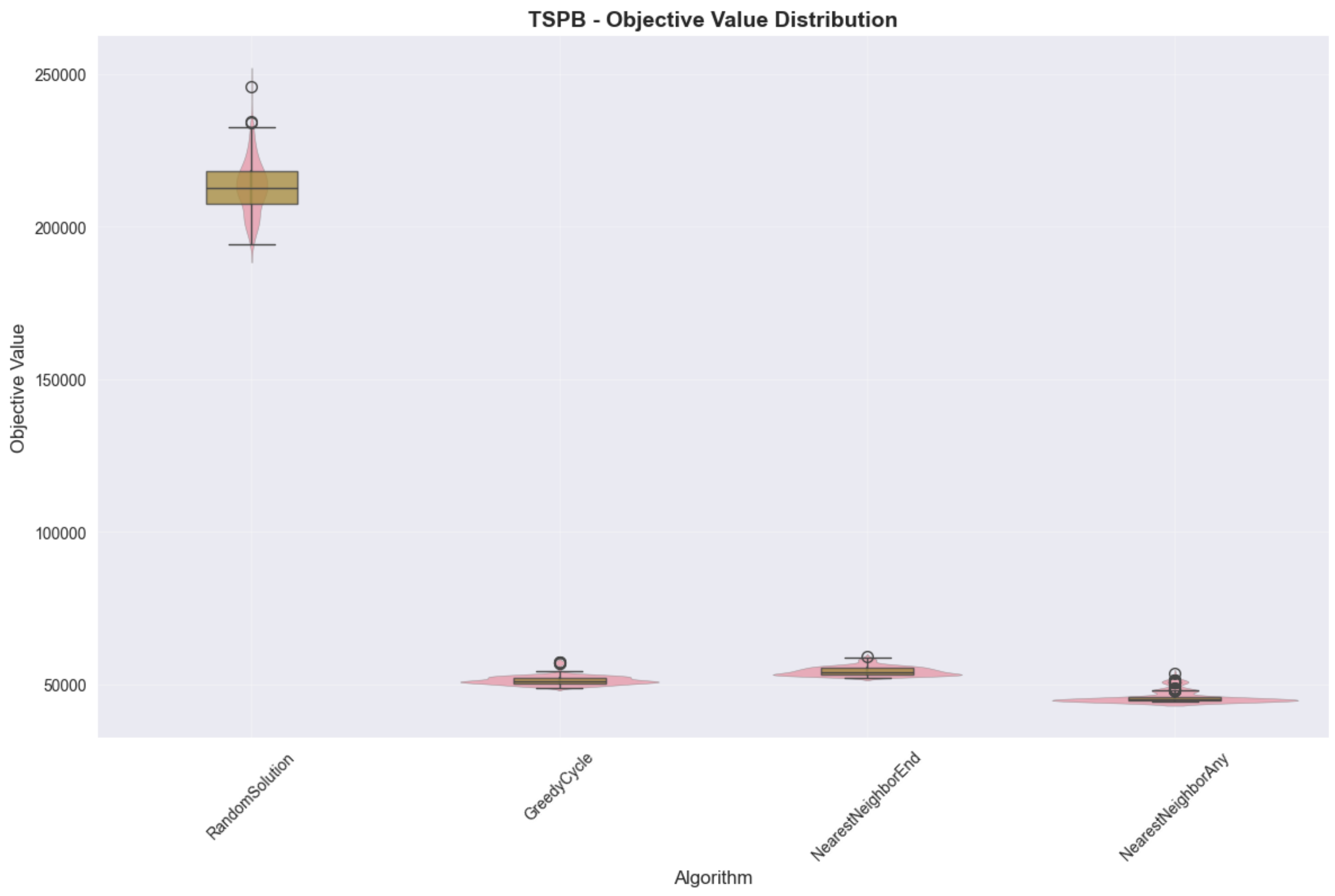
Best solution validation

In additional to the validator created by us, all of the 4 best solutions were checked manually by copying the nodes numbers to the solution checker excel.

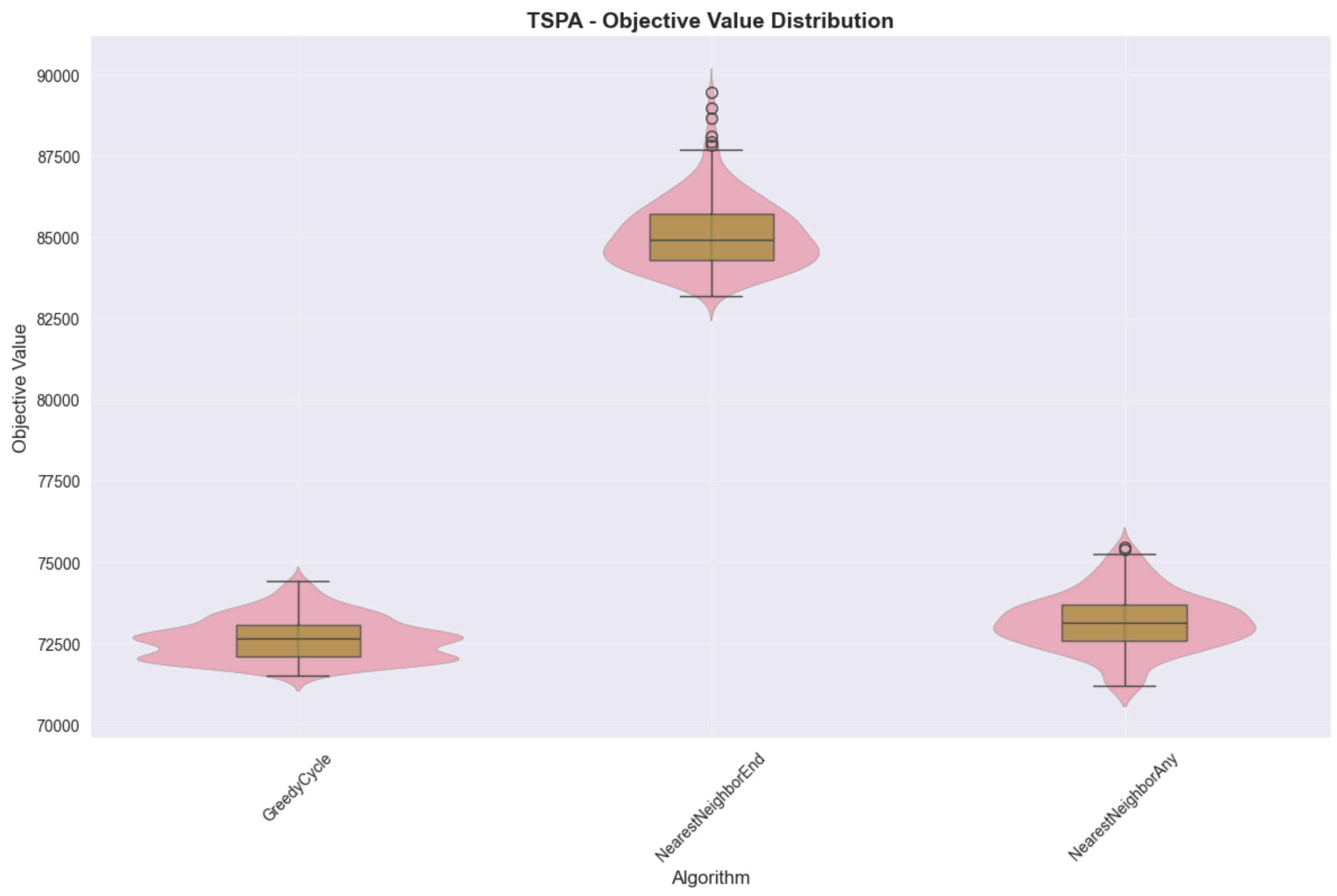
Algorithm Performance Comparison

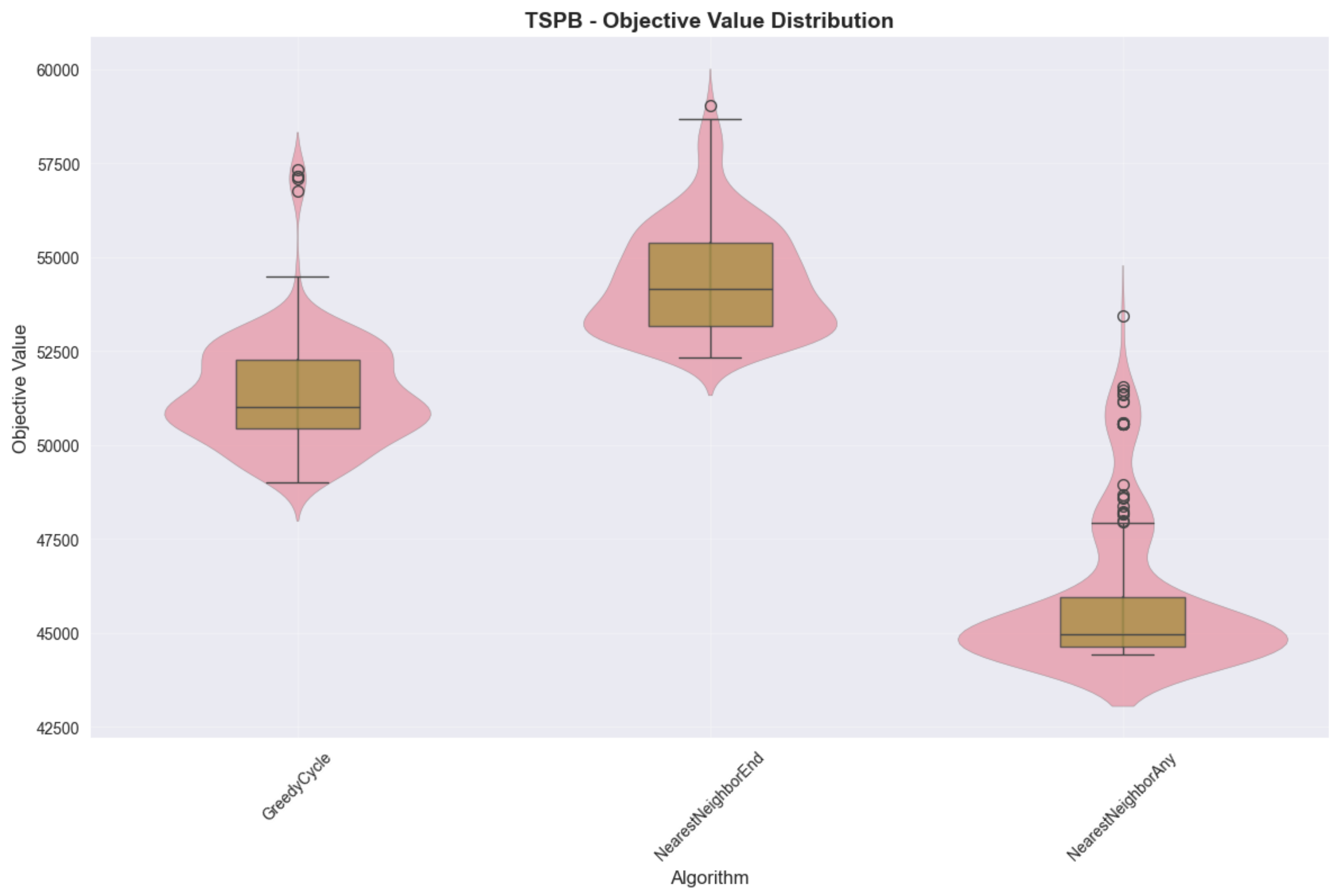
With Random Solutions





Without Random Solutions





Source Code

The complete implementation is available in the project repository:

- Github Link: https://github.com/Marcin59/evolutionary-computation

- Java source code: `src/main/java/tsp/algorithms/greedyAlgorithms/`
- This analysis notebook: `TSP_Greedy_Analysis.ipynb`

Conclusions

- The random solution is obviously the worst, however it has 1 benefit. It is the fastest
- Second worst is the nearest neighbor, which can only insert on the end. Again it is not surprising, however it has O(N) time complexity, which is much better than O(N^2) of the next two methods
- While nearest neighboar allowing all positions is similar to the greedy cycle, it performs slightly better, especially on the second test case. They both have the same time complexity. However, it is hard to say whether different examples would have different outcome.