

Large Neighborhood Search (LNS) Algorithm for TSP Problem

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Implemented Algorithms

Large Neighborhood Search (LNS)

Pseudocode:

```
Algorithm LNS(instance, destructionRate, timeLimitMs,
              useLocalSearchAfterRepair):
    current_solution ← GenerateRandomSolution(instance)
    current_solution ← SteepestLocalSearch(current_solution)
    bestSolution ← current_solution
    startTime ← CurrentTime()

    // Main LNS loop - continue until time limit
    while (CurrentTime() - startTime) < timeLimitMs do:

        partialTour ← copy of current_solution.route
        nodesToRemove ← [|partialTour| × destructionRate]

        DestroyRandom(partialTour, nodesToRemove)

        repaired_solution ← RepairWith2Regret(partialTour,
                                              instance.requiredNodes)

        // Optional local search improvement
        if useLocalSearchAfterRepair then:
            repaired_solution ← SteepestLocalSearch(repaired_solution)

        // Accept if improvement found (greedy acceptance)
        if repaired_solution.objective < bestSolution.objective then:
            current_solution ← repaired_solution
            bestSolution ← repaired_solution

    return bestSolution

DestroyRandom(tour, nodesToRemove):
    // Remove randomly selected nodes from the tour
    randomNodes ← SelectRandom(tour, nodesToRemove)
    Remove randomNodes from tour
```

Experiment Results

Objective function

Algorithm	TSPA	TSPB
NearestNeighborAny2Regret_w1_1	72401.24 (70010.00 - 75452.00)	47664.46 (44891.00 - 55247.00)
STEEPESTLS_EDGES_RANDOM	73842.79 (71576.00 - 78846.00)	48374.04 (46064.00 - 52759.00)
MSLS_STEEPEST_TWO_OPT	71357.85 (70897.00 - 71801.00)	45641.30 (44699.00 - 46076.00)
ILS_STEEPEST_TWO_OPT_pert15_ext1	69990.80 (69287.00 - 70452.00)	44551.25 (44334.00 - 44912.00)
ILS_STEEPEST_TWO_OPT_pert15_ext3	70212.05 (69905.00 - 70466.00)	44514.45 (44012.00 - 44820.00)
LNS_d-0.20_RANDOM_REMOVAL_ls-Off_hood-TWO_OPT	69874.00 (69374.00 - 70503.00)	44412.50 (43602.00 - 45730.00)
LNS_d-0.20_RANDOM_REMOVAL_ls-On_hood-TWO_OPT	69784.30 (69255.00 - 70547.00)	44260.95 (43565.00 - 44932.00)
LNS_d-0.30_RANDOM_REMOVAL_ls-Off_hood-TWO_OPT	69850.40 (69537.00 - 70174.00)	44270.90 (43671.00 - 45118.00)
LNS_d-0.30_RANDOM_REMOVAL_ls-On_hood-TWO_OPT	69612.30 (69214.00 - 70184.00)	44292.90 (43484.00 - 45362.00)
LNS_d-0.40_RANDOM_REMOVAL_ls-Off_hood-TWO_OPT	69737.15 (69255.00 - 70554.00)	44199.95 (43602.00 - 44832.00)
LNS_d-0.40_RANDOM_REMOVAL_ls-On_hood-TWO_OPT	69605.65 (69185.00 - 70200.00)	44026.40 (43509.00 - 44623.00)

Computation Times (ms)

Algorithm	TSPA	TSPB
STEEPESTLS_EDGES_RANDOM	59.24 (51 - 80)	56.47 (42 - 65)
MSLS_STEEPEST_TWO_OPT	5850.60 (5756 - 6041)	5838.85 (5769 - 5930)

Iterations

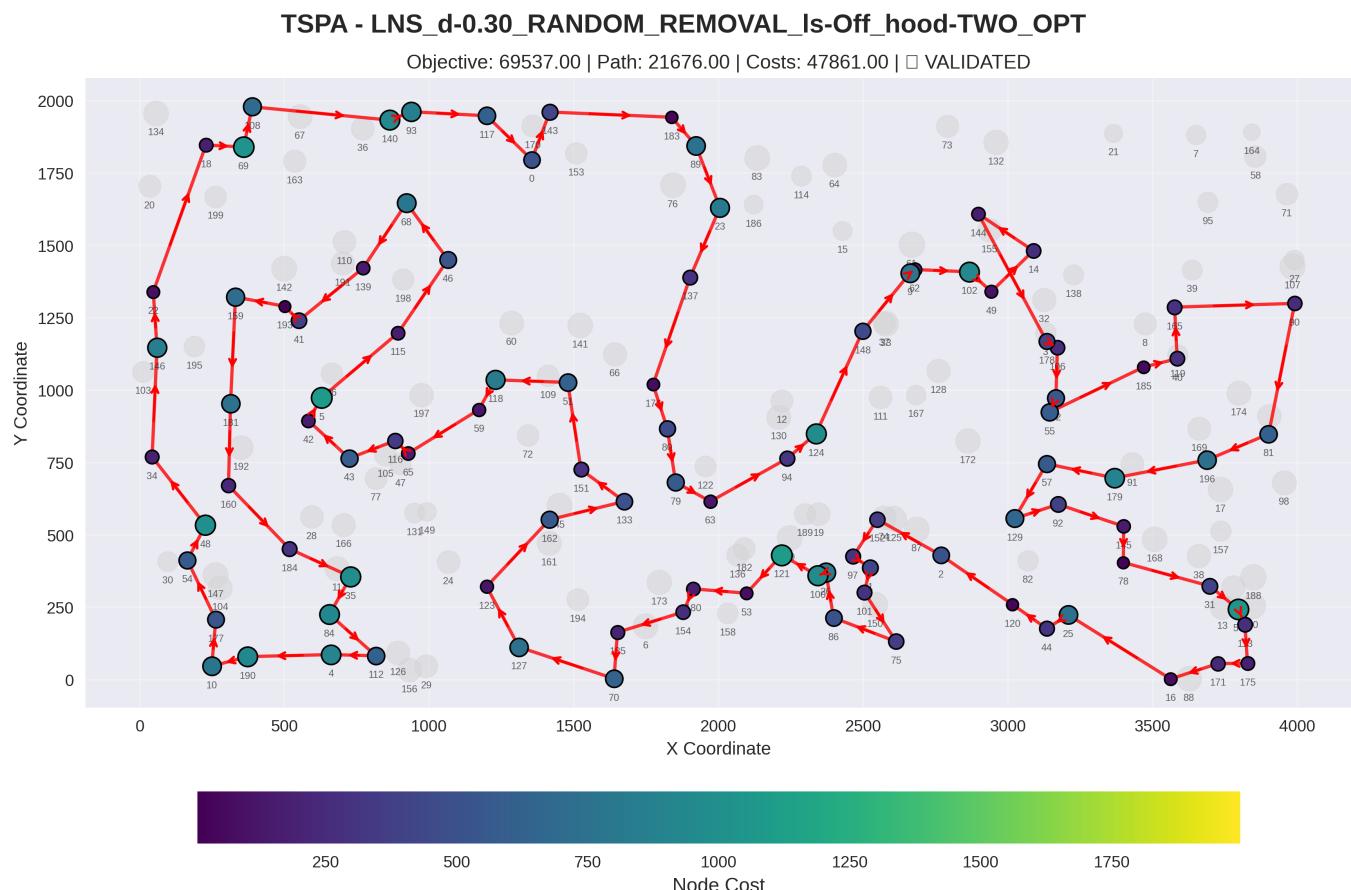
Algorithm	TSPA	TSPB
ILS_STEEPEST_TWO_OPT_pert15_ext1	1049.15 (1023 - 1079)	1041.85 (1023 - 1064)

Algorithm	TSPA	TSPB
ILS_STEEPEST_TWO_OPT_pert15_ext3	916.65 (907 - 932)	905.15 (889 - 920)
LNS_d-0.20_RANDOM_REMOVAL_ls-Off_hood-TWO_OPT	11177.45 (10979 - 11347)	11378.25 (11169 - 11565)
LNS_d-0.20_RANDOM_REMOVAL_ls-On_hood-TWO_OPT	6740.95 (5891 - 7517)	6586.00 (5215 - 7734)
LNS_d-0.30_RANDOM_REMOVAL_ls-Off_hood-TWO_OPT	7552.75 (7462 - 7631)	7708.45 (7591 - 7838)
LNS_d-0.30_RANDOM_REMOVAL_ls-On_hood-TWO_OPT	5108.50 (4188 - 5591)	4550.55 (3687 - 4960)
LNS_d-0.40_RANDOM_REMOVAL_ls-Off_hood-TWO_OPT	5782.30 (5704 - 5876)	5920.50 (5823 - 6006)
LNS_d-0.40_RANDOM_REMOVAL_ls-On_hood-TWO_OPT	3993.10 (3522 - 4428)	3530.70 (2935 - 3879)

2D Visualization of Best Solution

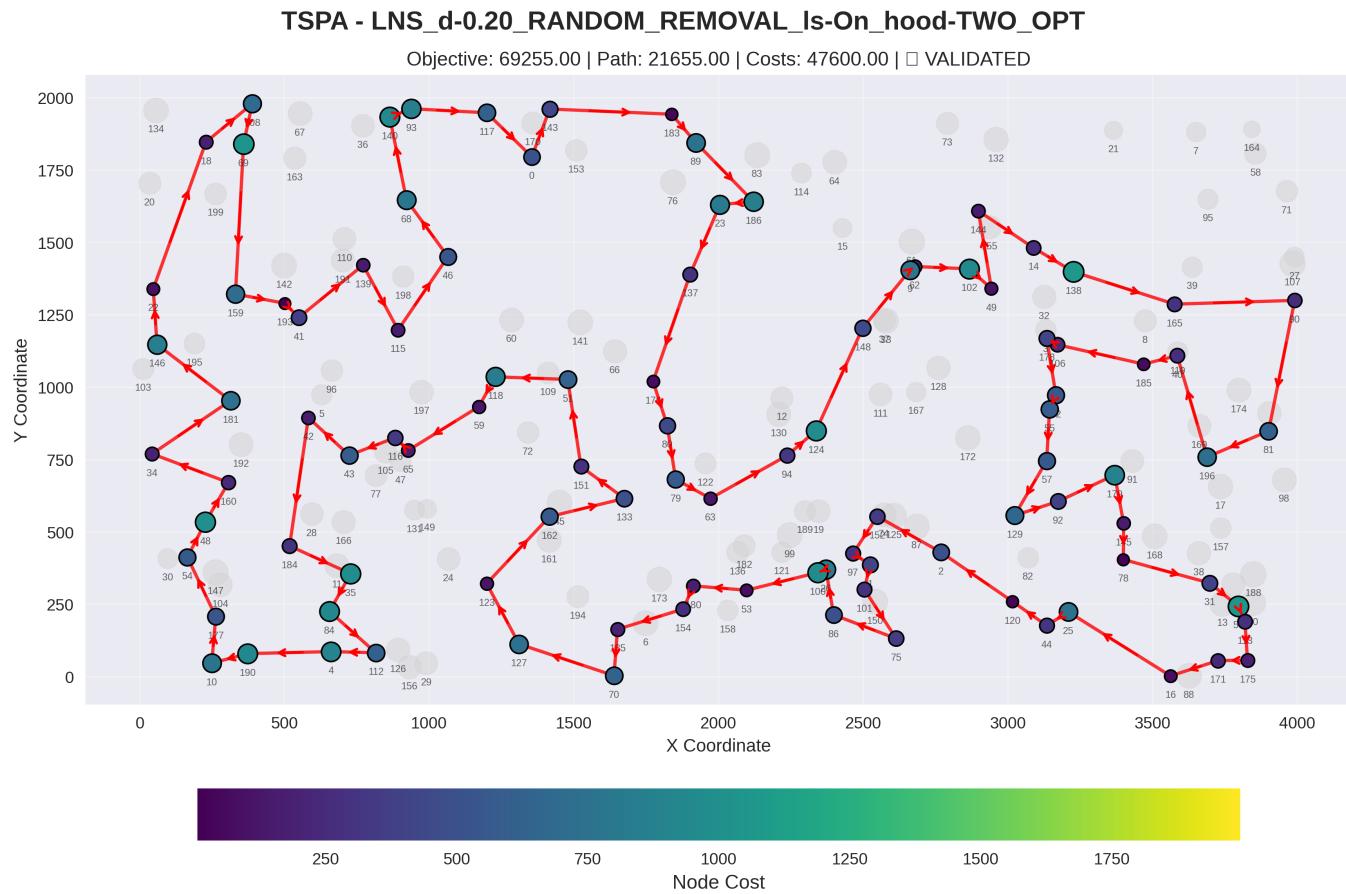
Instance: TSPA

LNS_d-0.30_RANDOM_REMOVAL_ls-Off_hood-TWO_OPT



Node Order (Route): 178, 106, 52, 55, 185, 40, 165, 90, 81, 196, 179, 57, 129, 92, 145, 78, 31, 56, 113, 175, 171, 16, 25, 44, 120, 2, 152, 97, 1, 101, 75, 86, 26, 100, 121, 53, 180, 154, 135, 70, 127, 123, 162, 133, 151, 51, 118, 59, 65, 116, 43, 42, 5, 115, 46, 68, 139, 41, 193, 159, 181, 160, 184, 35, 84, 112, 4, 190, 10, 177, 54, 48, 34, 146, 22, 18, 69, 108, 140, 93, 117, 0, 143, 183, 89, 23, 137, 176, 80, 79, 63, 94, 124, 148, 9, 62, 102, 49, 14, 144

LNS_d-0.20_RANDOM_REMOVAL_ls-On_hood-TWO_OPT

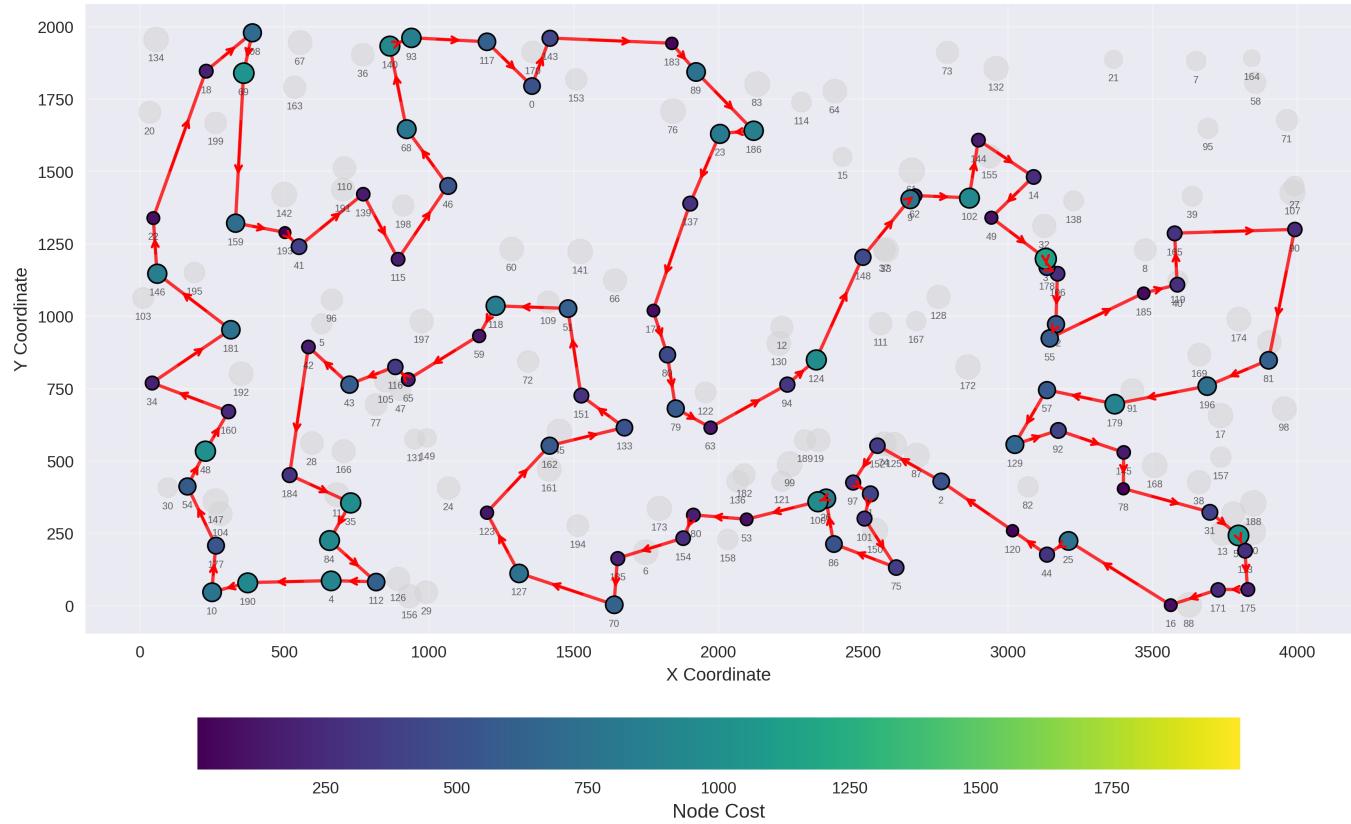


Node Order (Route): 2, 152, 97, 1, 101, 75, 86, 26, 100, 53, 180, 154, 135, 70, 127, 123, 162, 133, 151, 51, 118, 59, 65, 116, 43, 42, 184, 35, 84, 112, 4, 190, 10, 177, 54, 48, 160, 34, 181, 146, 22, 18, 108, 69, 159, 193, 41, 139, 115, 46, 68, 140, 93, 117, 0, 143, 183, 89, 186, 23, 137, 176, 80, 79, 63, 94, 124, 148, 9, 62, 102, 49, 144, 14, 138, 165, 90, 81, 196, 40, 185, 106, 178, 52, 55, 57, 129, 92, 179, 145, 78, 31, 56, 113, 175, 171, 16, 25, 44, 120

LNS_d-0.40_RANDOM_REMOVAL_ls-On_hood-TWO_OPT

TSPA - LNS_d-0.40_RANDOM_REMOVAL_Is-On_hood-TWO_OPT

Objective: 69185.00 | Path: 21507.00 | Costs: 47678.00 | VALIDATED

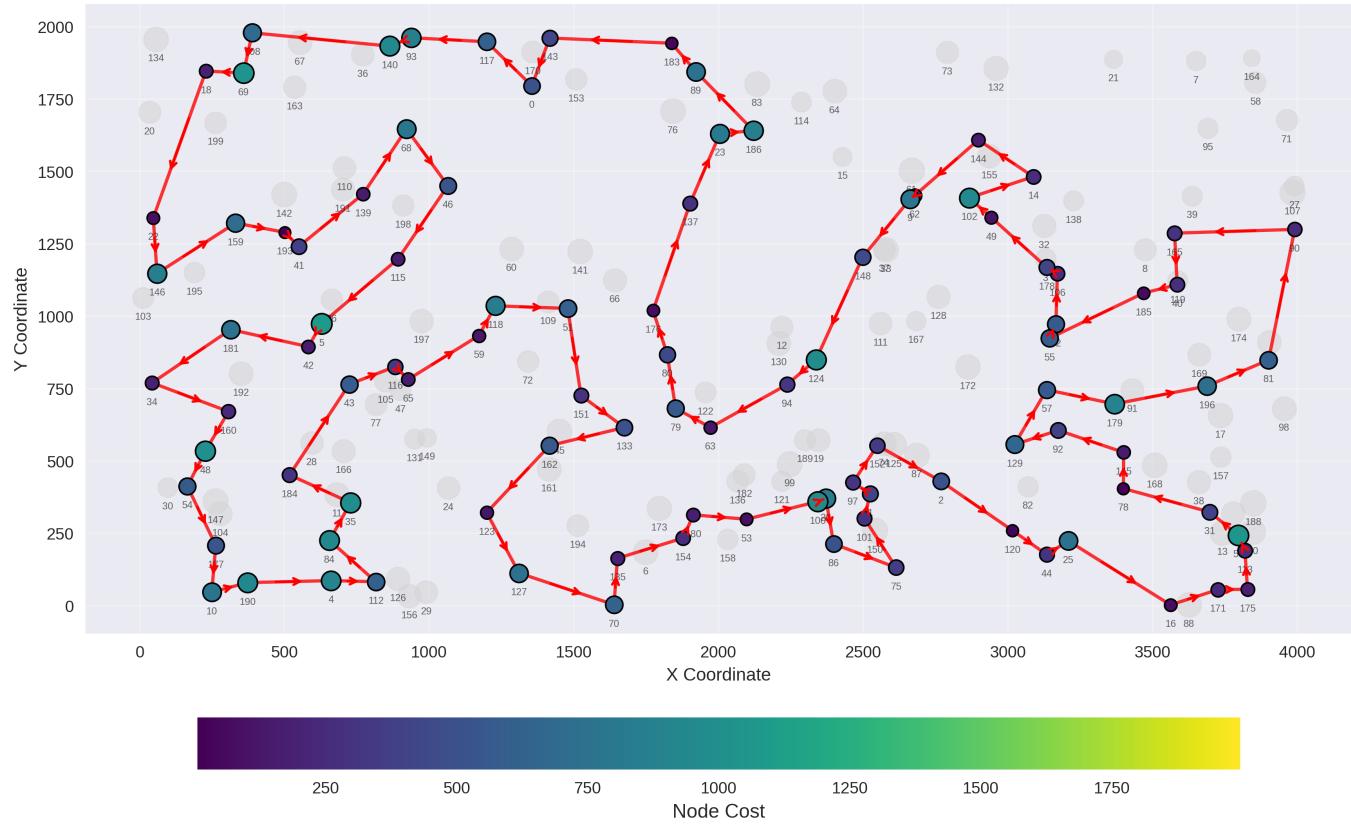


Node Order (Route): 51, 118, 59, 65, 116, 43, 42, 184, 35, 84, 112, 4, 190, 10, 177, 54, 48, 160, 34, 181, 146, 22, 18, 108, 69, 159, 193, 41, 139, 115, 46, 68, 140, 93, 117, 0, 143, 183, 89, 186, 23, 137, 176, 80, 79, 63, 94, 124, 148, 9, 62, 102, 144, 14, 49, 3, 178, 106, 52, 55, 185, 40, 165, 90, 81, 196, 179, 57, 129, 92, 145, 78, 31, 56, 113, 175, 171, 16, 25, 44, 120, 2, 152, 97, 1, 101, 75, 86, 26, 100, 53, 180, 154, 135, 70, 127, 123, 162, 133, 151

LNS_d-0.30_RANDOM_REMOVAL_Is-On_hood-TWO_OPT

TSPA - LNS_d-0.30_RANDOM_REMOVAL_Is-On_hood-TWO_OPT

Objective: 69214.00 | Path: 21588.00 | Costs: 47626.00 | VALIDATED

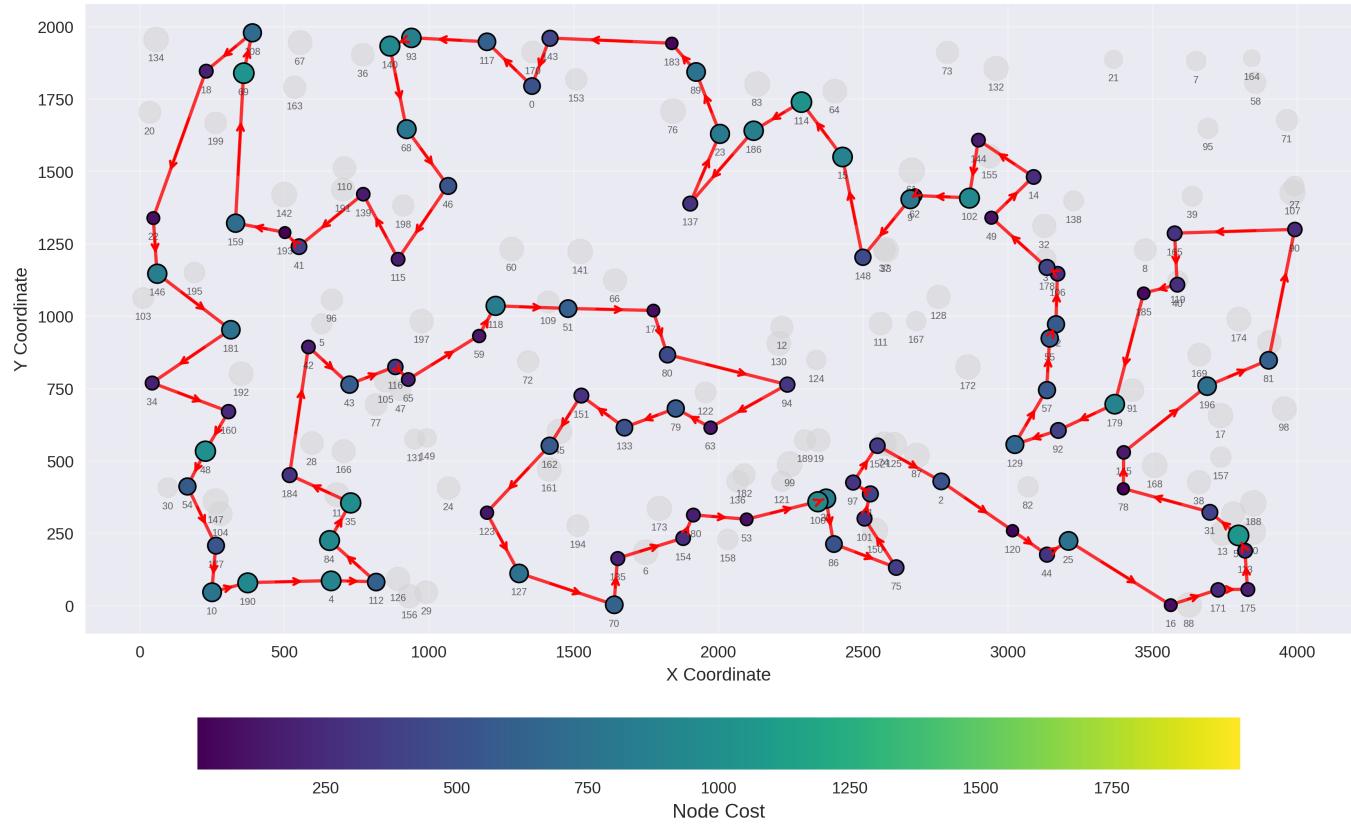


Node Order (Route): 78, 145, 92, 129, 57, 179, 196, 81, 90, 165, 40, 185, 55, 52, 106, 178, 49, 102, 14, 144, 62, 9, 148, 124, 94, 63, 79, 80, 176, 137, 23, 186, 89, 183, 143, 0, 117, 93, 140, 108, 69, 18, 22, 146, 159, 193, 41, 139, 68, 46, 115, 5, 42, 181, 34, 160, 48, 54, 177, 10, 190, 4, 112, 84, 35, 184, 43, 116, 65, 59, 118, 51, 151, 133, 162, 123, 127, 70, 135, 154, 180, 53, 100, 26, 86, 75, 101, 1, 97, 152, 2, 120, 44, 25, 16, 171, 175, 113, 56, 31

LNS_d-0.20_RANDOM_REMOVAL_Is-Off_hood-TWO_OPT

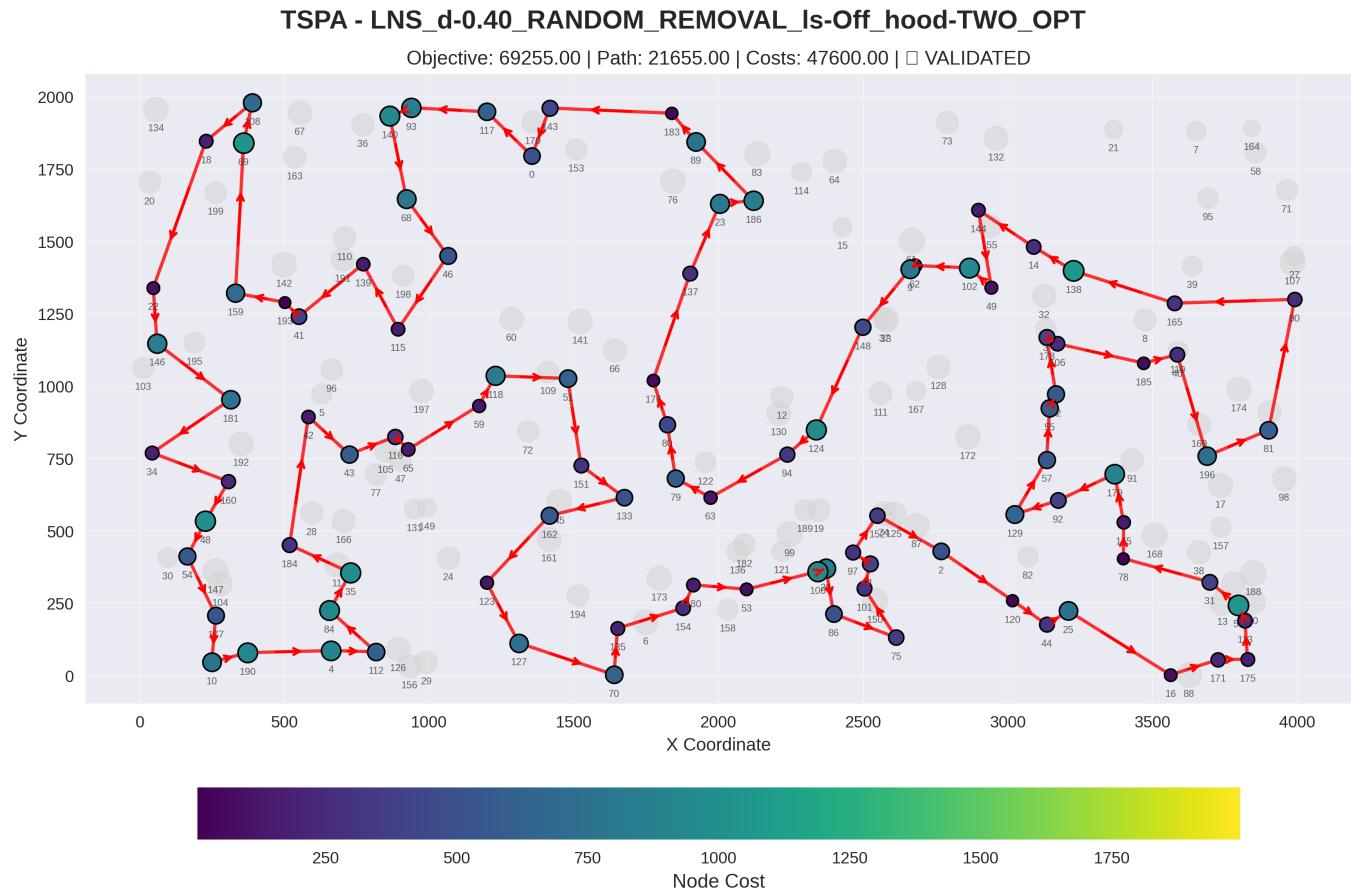
TSPA - LNS_d-0.20_RANDOM_REMOVAL_Is-Off_hood-TWO_OPT

Objective: 69374.00 | Path: 21878.00 | Costs: 47496.00 | VALIDATED



Node Order (Route): 179, 92, 129, 57, 55, 52, 106, 178, 49, 14, 144, 102, 62, 9, 148, 15, 114, 186, 137, 23, 89, 183, 143, 0, 117, 93, 140, 68, 46, 115, 139, 41, 193, 159, 69, 108, 18, 22, 146, 181, 34, 160, 48, 54, 177, 10, 190, 4, 112, 84, 35, 184, 42, 43, 116, 65, 59, 118, 51, 176, 80, 94, 63, 79, 133, 151, 162, 123, 127, 70, 135, 154, 180, 53, 100, 26, 86, 75, 101, 1, 97, 152, 2, 120, 44, 25, 16, 171, 175, 113, 56, 31, 78, 145, 196, 81, 90, 165, 40, 185

LNS_d-0.40_RANDOM_REMOVAL_Is-Off_hood-TWO_OPT



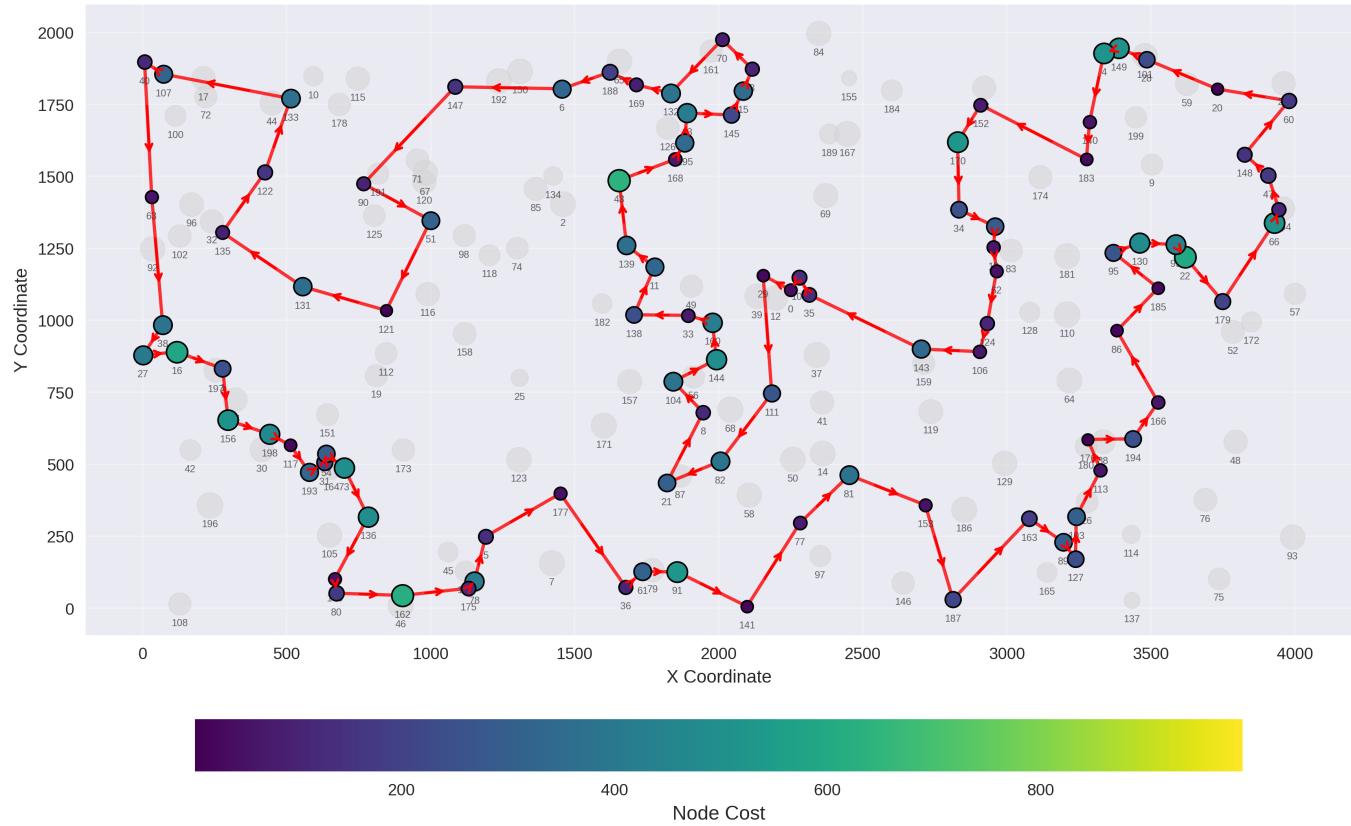
Node Order (Route): 70, 135, 154, 180, 53, 100, 26, 86, 75, 101, 1, 97, 152, 2, 120, 44, 25, 16, 171, 175, 113, 56, 31, 78, 145, 179, 92, 129, 57, 55, 52, 178, 106, 185, 40, 196, 81, 90, 165, 138, 14, 144, 49, 102, 62, 9, 148, 124, 94, 63, 79, 80, 176, 137, 23, 186, 89, 183, 143, 0, 117, 93, 140, 68, 46, 115, 139, 41, 193, 159, 69, 108, 18, 22, 146, 181, 34, 160, 48, 54, 177, 10, 190, 4, 112, 84, 35, 184, 42, 43, 116, 65, 59, 118, 51, 151, 133, 162, 123, 127

Instance: TSPB

LNS_d-0.30_RANDOM_REMOVAL_Is-Off_hood-TWO_OPT

TSPB - LNS_d-0.30_RANDOM_REMOVAL_Is-Off_hood-TWO_OPT

Objective: 43671.00 | Path: 19299.00 | Costs: 24372.00 | VALIDATED

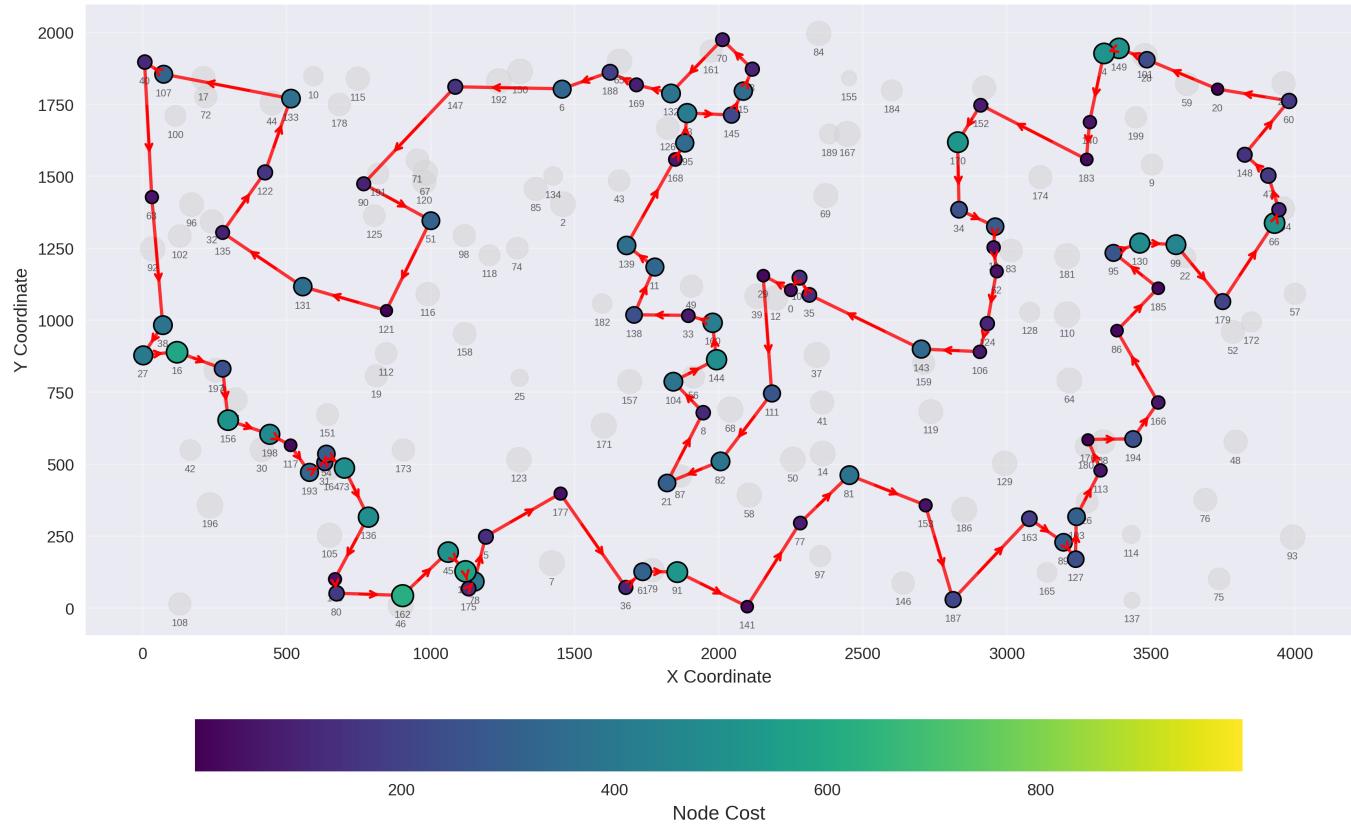


Node Order (Route): 90, 51, 121, 131, 135, 122, 133, 107, 40, 63, 38, 27, 16, 1, 156, 198, 117, 193, 31, 54, 73, 136, 190, 80, 162, 175, 78, 5, 177, 36, 61, 91, 141, 77, 81, 153, 187, 163, 89, 127, 103, 113, 176, 194, 166, 86, 185, 95, 130, 99, 22, 179, 66, 94, 47, 148, 60, 20, 28, 149, 4, 140, 183, 152, 170, 34, 55, 18, 62, 124, 106, 143, 35, 109, 0, 29, 111, 82, 21, 8, 104, 144, 160, 33, 138, 11, 139, 43, 168, 195, 13, 145, 15, 3, 70, 132, 169, 188, 6, 147

LNS_d-0.20_RANDOM_REMOVAL_Is-On_hood-TWO_OPT

TSPB - LNS_d-0.20_RANDOM_REMOVAL_Is-On_hood-TWO_OPT

Objective: 43565.00 | Path: 19347.00 | Costs: 24218.00 | VALIDATED

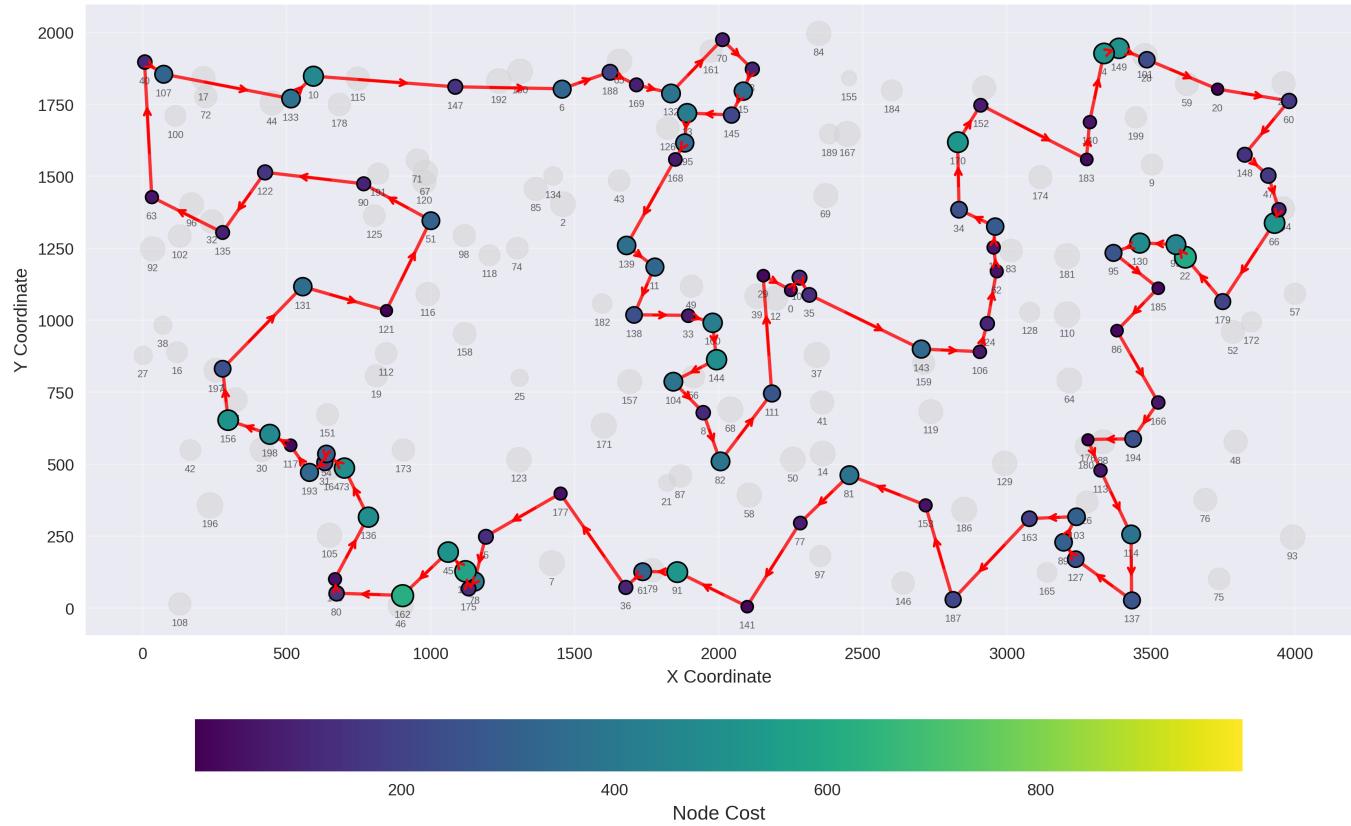


Node Order (Route): 121, 131, 135, 122, 133, 107, 40, 63, 38, 27, 16, 1, 156, 198, 117, 193, 31, 54, 73, 136, 190, 80, 162, 45, 142, 175, 78, 5, 177, 36, 61, 91, 141, 77, 81, 153, 187, 163, 89, 127, 103, 113, 176, 194, 166, 86, 185, 95, 130, 99, 179, 66, 94, 47, 148, 60, 20, 28, 149, 4, 140, 183, 152, 170, 34, 55, 18, 62, 124, 106, 143, 35, 109, 0, 29, 111, 82, 21, 8, 104, 144, 160, 33, 138, 11, 139, 168, 195, 13, 145, 15, 3, 70, 132, 169, 188, 6, 147, 90, 51

LNS_d-0.40_RANDOM_REMOVAL_Is-On_hood-TWO_OPT

TSPB - LNS_d-0.40_RANDOM_REMOVAL_Is-On_hood-TWO_OPT

Objective: 43509.00 | Path: 19249.00 | Costs: 24260.00 | VALIDATED

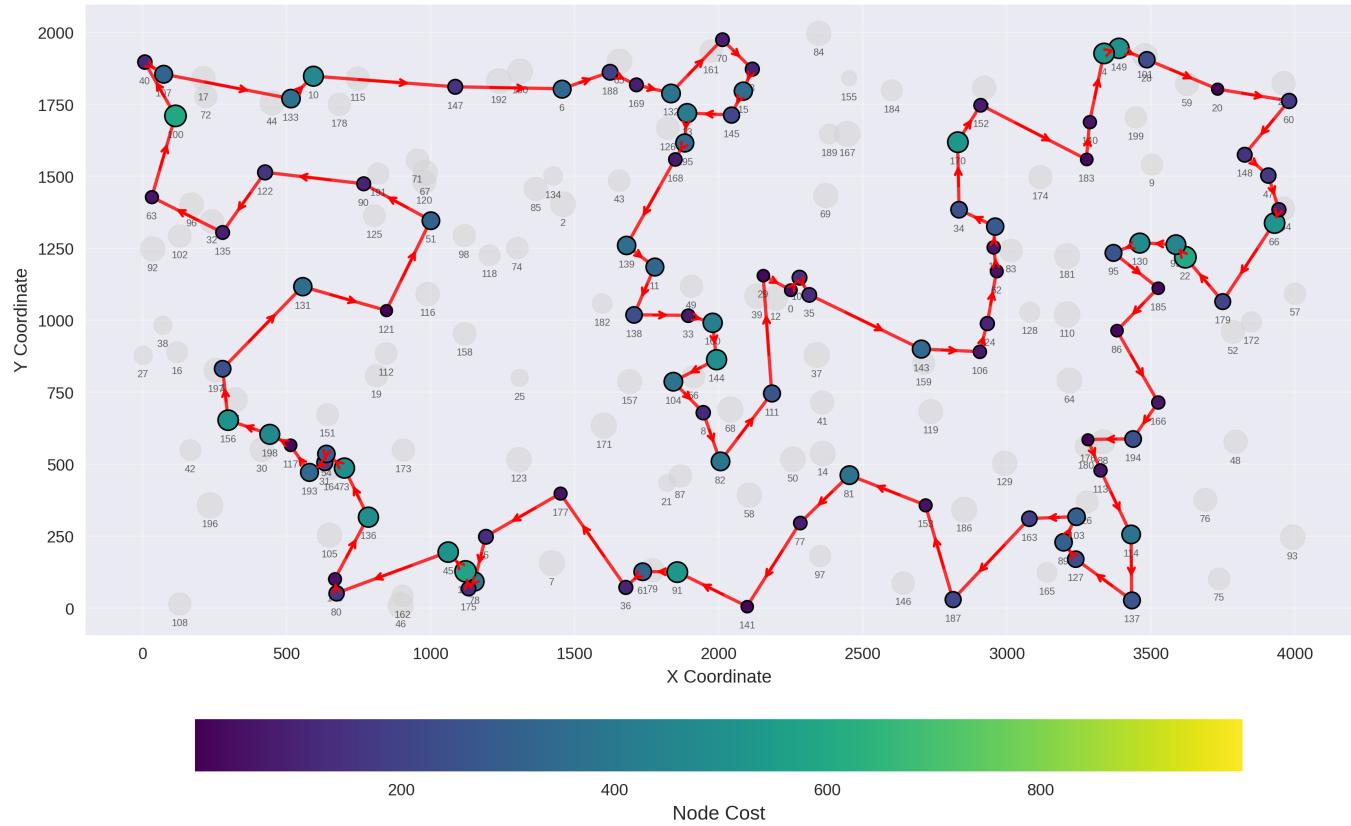


Node Order (Route): 187, 153, 81, 77, 141, 91, 61, 36, 177, 5, 78, 175, 142, 45, 162, 80, 190, 136, 73, 54, 31, 193, 117, 198, 156, 1, 131, 121, 51, 90, 122, 135, 63, 40, 107, 133, 10, 147, 6, 188, 169, 132, 70, 3, 15, 145, 13, 195, 168, 139, 11, 138, 33, 160, 144, 104, 8, 82, 111, 29, 0, 109, 35, 143, 106, 124, 62, 18, 55, 34, 170, 152, 183, 140, 4, 149, 28, 20, 60, 148, 47, 94, 66, 179, 22, 99, 130, 95, 185, 86, 166, 194, 176, 113, 114, 137, 127, 89, 103, 163

LNS_d-0.30_RANDOM_REMOVAL_Is-On_hood-TWO_OPT

TSPB - LNS_d-0.30_RANDOM_REMOVAL_Is-On_hood-TWO_OPT

Objective: 43484.00 | Path: 19253.00 | Costs: 24231.00 | VALIDATED

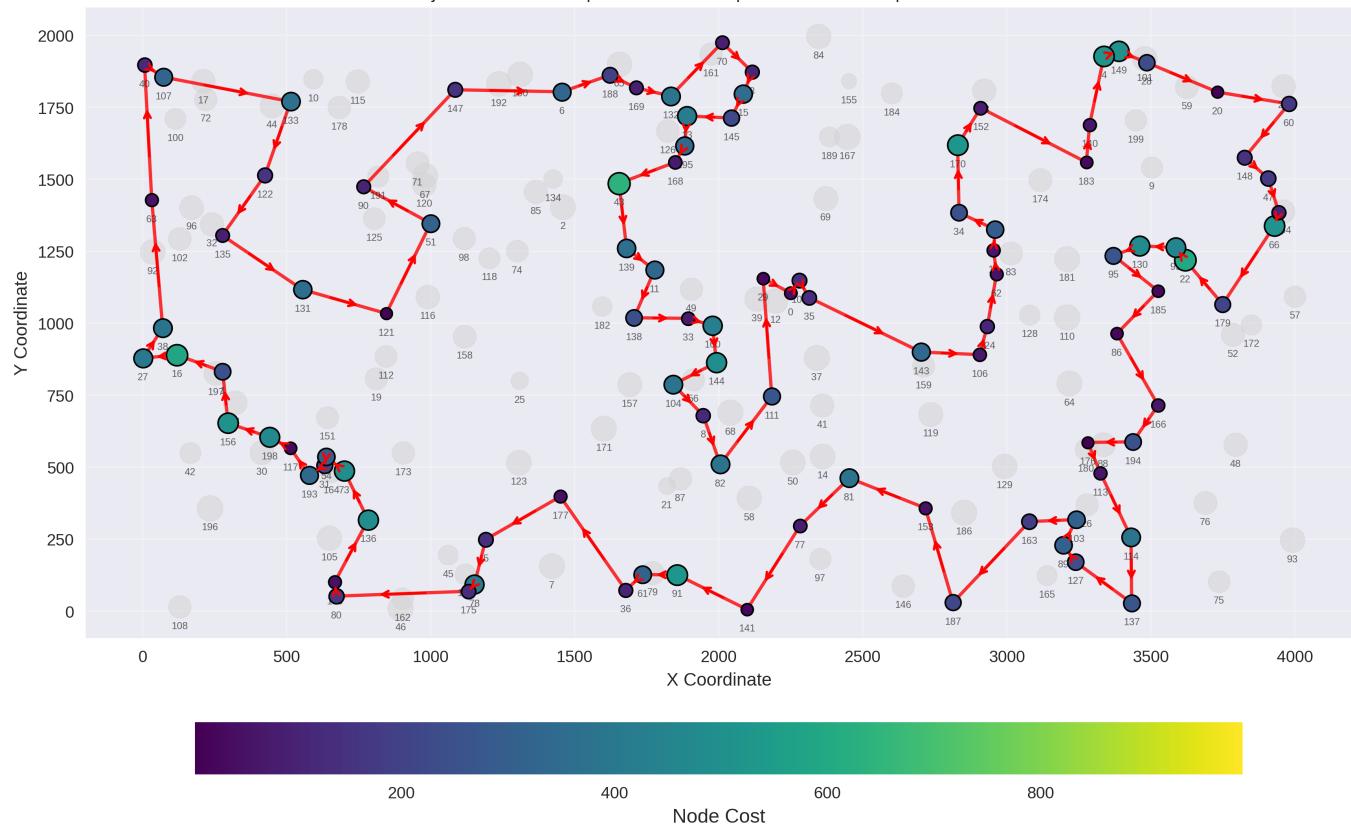


Node Order (Route): 133, 10, 147, 6, 188, 169, 132, 70, 3, 15, 145, 13, 195, 168, 139, 11, 138, 33, 160, 144, 104, 8, 82, 111, 29, 0, 109, 35, 143, 106, 124, 62, 18, 55, 34, 170, 152, 183, 140, 4, 149, 28, 20, 60, 148, 47, 94, 66, 179, 22, 99, 130, 95, 185, 86, 166, 194, 176, 113, 114, 137, 127, 89, 103, 163, 187, 153, 81, 77, 141, 91, 61, 36, 177, 5, 78, 175, 142, 45, 80, 190, 136, 73, 54, 31, 193, 117, 198, 156, 1, 131, 121, 51, 90, 122, 135, 63, 100, 40, 107

LNS_d-0.20_RANDOM_REMOVAL_Is-Off_hood-TWO_OPT

TSPB - LNS_d-0.20_RANDOM_REMOVAL_Is-Off_hood-TWO_OPT

Objective: 43602.00 | Path: 19509.00 | Costs: 24093.00 | VALIDATED

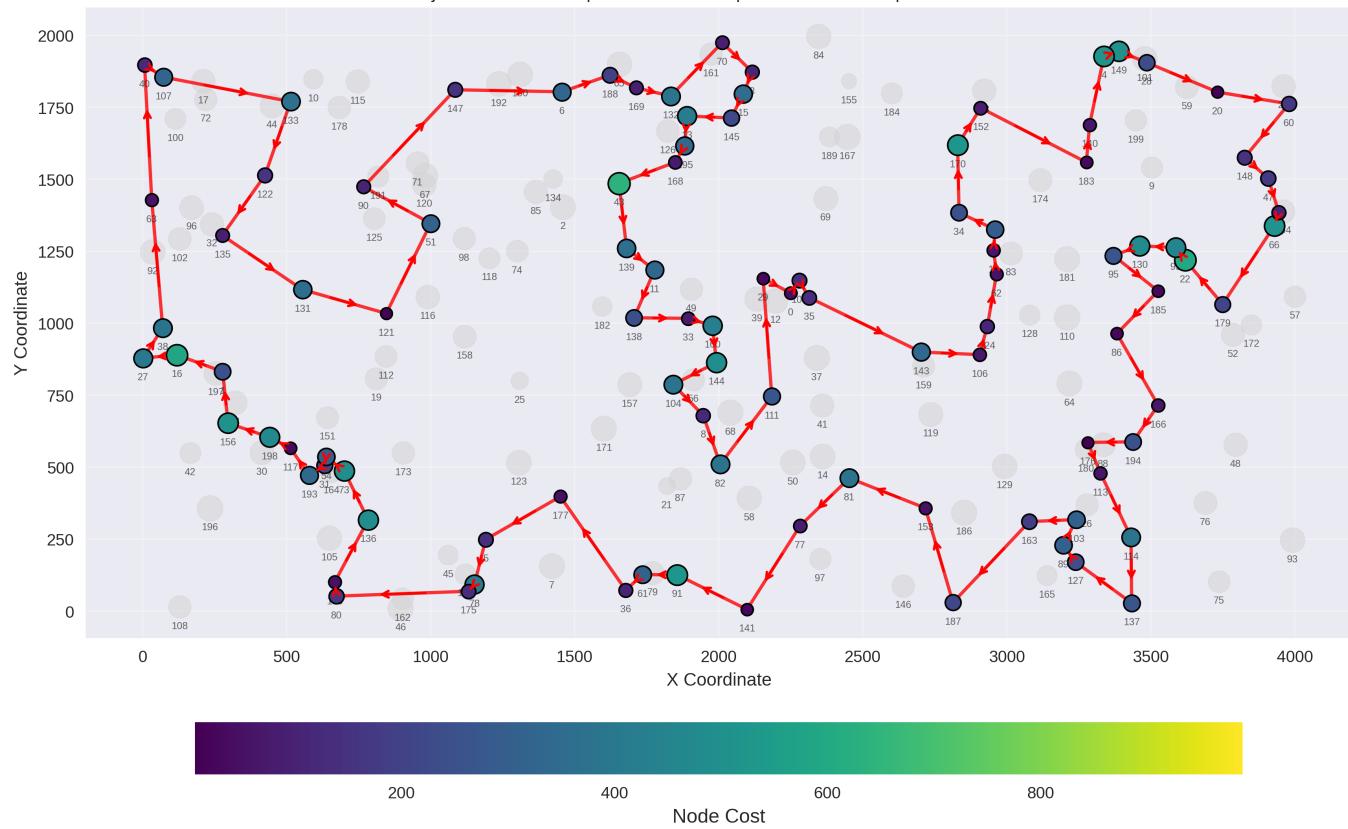


Node Order (Route): 80, 190, 136, 73, 54, 31, 193, 117, 198, 156, 1, 16, 27, 38, 63, 40, 107, 133, 122, 135, 131, 121, 51, 90, 147, 6, 188, 169, 132, 70, 3, 15, 145, 13, 195, 168, 43, 139, 11, 138, 33, 160, 144, 104, 8, 82, 111, 29, 0, 109, 35, 143, 106, 124, 62, 18, 55, 34, 170, 152, 183, 140, 4, 149, 28, 20, 60, 148, 47, 94, 66, 179, 22, 99, 130, 95, 185, 86, 166, 194, 176, 113, 114, 137, 127, 89, 103, 163, 187, 153, 81, 77, 141, 91, 61, 36, 177, 5, 78, 175

LNS_d-0.40_RANDOM_REMOVAL_Is-Off_hood-TWO_OPT

TSPB - LNS_d-0.40_RANDOM_REMOVAL_Is-Off_hood-TWO_OPT

Objective: 43602.00 | Path: 19509.00 | Costs: 24093.00 | VALIDATED



Node Order (Route): 80, 190, 136, 73, 54, 31, 193, 117, 198, 156, 1, 16, 27, 38, 63, 40, 107, 133, 122, 135, 131, 121, 51, 90, 147, 6, 188, 169, 132, 70, 3, 15, 145, 13, 195, 168, 43, 139, 11, 138, 33, 160, 144, 104, 8, 82, 111, 29, 0, 109, 35, 143, 106, 124, 62, 18, 55, 34, 170, 152, 183, 140, 4, 149, 28, 20, 60, 148, 47, 94, 66, 179, 22, 99, 130, 95, 185, 86, 166, 194, 176, 113, 114, 137, 127, 89, 103, 163, 187, 153, 81, 77, 141, 91, 61, 36, 177, 5, 78, 175

Conclusions

Key Findings

- LNS outperforms all previous methods
- Higher destruction rate is beneficial: destroying 40% of nodes gives better results than destroying 20%
- Local search after repair provides higher quality results
- Both turning on local search and increasing destructionRate decrease the number of iterations performed