Appendix A.

Table A1 shows the contribution of the four local search operators proposed in this paper for each large-size instance, with all values expressed as percentages.

**Table A1** Contribution of each local search operator on each large-size instance

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Operator  Instance name | Destroy Route | 2E-Swap | 2-opt | Remove SI |
| c101 | 7.28 | 1.37 | 1.50 | 18.85 |
| c102 | 7.17 | 3.06 | 1.90 | 21.85 |
| c103 | 9.13 | 3.70 | 1.24 | 16.61 |
| c104 | 5.42 | 3.15 | 1.32 | 14.13 |
| c105 | 5.67 | 4.35 | 1.97 | 11.50 |
| c106 | 5.87 | 4.21 | 1.27 | 17.56 |
| c107 | 6.96 | 2.53 | 2.38 | 19.57 |
| c108 | 9.16 | 3.22 | 2.70 | 15.31 |
| c109 | 9.02 | 1.14 | 2.20 | 11.32 |
| **Avg** | **7.30** | **2.97** | **1.83** | **16.30** |
| r101 | 13.51 | 14.25 | 13.55 | 34.89 |
| r102 | 10.03 | 16.30 | 10.13 | 27.34 |
| r103 | 13.47 | 12.90 | 10.15 | 24.11 |
| r104 | 13.68 | 14.58 | 9.93 | 35.60 |
| r105 | 8.04 | 9.64 | 9.42 | 38.78 |
| r106 | 9.72 | 16.83 | 11.91 | 26.34 |
| r107 | 9.44 | 13.12 | 13.31 | 33.22 |
| r108 | 13.44 | 14.37 | 13.71 | 28.56 |
| r109 | 15.03 | 8.58 | 12.56 | 36.46 |
| r110 | 10.53 | 15.54 | 10.03 | 35.17 |
| r111 | 14.45 | 14.99 | 13.16 | 23.14 |
| r112 | 13.50 | 9.34 | 10.13 | 37.03 |
| **Avg** | **12.07** | **13.37** | **11.50** | **31.72** |
| rc101 | 15.59 | 13.02 | 8.84 | 22.16 |
| rc102 | 15.89 | 11.60 | 12.69 | 23.18 |
| rc103 | 20.85 | 13.08 | 12.64 | 20.21 |
| rc104 | 20.33 | 10.54 | 11.59 | 16.81 |
| rc105 | 19.71 | 11.04 | 9.32 | 22.55 |
| rc106 | 21.34 | 9.08 | 11.80 | 18.65 |
| rc107 | 21.16 | 9.69 | 10.02 | 18.29 |
| rc108 | 21.76 | 12.12 | 9.02 | 21.91 |
| **Avg** | **19.58** | **11.27** | **10.74** | **20.47** |

Appendix B.

Tables B1 and B2 present the cost components for various scenarios when BSI are equipped with multiple battery specifications and a single battery specification, respectively.

**Table B1** Distribution cost details for BSI storing multiple battery specifications

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Instance name | FC | CC | BC | DC | TC |
| c101 | 2169.20 | 299.05 | 420.00 | 1270.99 | 4159.24 |
| c102 | 1972.00 | 471.00 | 440.00 | 1239.35 | 4122.35 |
| c103 | 1972.00 | 401.76 | 420.00 | 1249.42 | 4043.18 |
| c104 | 2169.20 | 271.92 | 440.00 | 1313.40 | 4194.52 |
| c105 | 2169.20 | 519.11 | 320.00 | 1375.19 | 4383.50 |
| c106 | 1972.00 | 390.67 | 360.00 | 1236.14 | 3958.81 |
| c107 | 1972.00 | 343.11 | 560.00 | 1233.05 | 4108.16 |
| c108 | 1972.00 | 628.56 | 300.00 | 1286.71 | 4187.27 |
| c109 | 1972.00 | 12.42 | 1060.00 | 1209.75 | 4254.16 |
| **Avg** | **2037.73** | **370.84** | **480.00** | **1268.22** | **4156.80** |
| r101 | 1577.60 | 431.31 | 560.00 | 1241.22 | 3810.14 |
| r102 | 1577.60 | 437.47 | 440.00 | 1230.91 | 3685.98 |
| r103 | 1577.60 | 101.58 | 780.00 | 1223.26 | 3682.44 |
| r104 | 1577.60 | 320.00 | 560.00 | 1203.69 | 3661.29 |
| r105 | 1577.60 | 393.20 | 440.00 | 1214.10 | 3624.90 |
| r106 | 1577.60 | 248.91 | 740.00 | 1237.53 | 3804.04 |
| r107 | 1577.60 | 207.23 | 760.00 | 1134.72 | 3679.55 |
| r108 | 1577.60 | 254.62 | 560.00 | 1158.87 | 3551.10 |
| r109 | 1577.60 | 218.40 | 680.00 | 1250.61 | 3726.61 |
| r110 | 1577.60 | 227.67 | 600.00 | 1170.87 | 3576.14 |
| r111 | 1577.60 | 358.66 | 480.00 | 1258.49 | 3674.74 |
| r112 | 1577.60 | 555.64 | 300.00 | 1192.30 | 3625.54 |
| **Avg** | **1577.60** | **312.89** | **575.00** | **1209.71** | **3675.21** |
| rc101 | 1774.80 | 397.02 | 800.00 | 1536.27 | 4508.09 |
| rc102 | 1774.80 | 418.88 | 840.00 | 1563.25 | 4596.92 |
| rc103 | 1774.80 | 303.40 | 1040.00 | 1540.87 | 4659.08 |
| rc104 | 1972.00 | 378.69 | 840.00 | 1537.32 | 4728.01 |
| rc105 | 1774.80 | 374.41 | 980.00 | 1502.44 | 4631.64 |
| rc106 | 1774.80 | 603.18 | 640.00 | 1578.30 | 4596.28 |
| rc107 | 1774.80 | 353.25 | 900.00 | 1574.28 | 4602.33 |
| rc108 | 1774.80 | 720.35 | 540.00 | 1607.39 | 4642.54 |
| **Avg** | **1799.45** | **443.65** | **822.50** | **1555.01** | **4620.61** |

**Table B1** Distribution cost details for BSI storing single battery specification

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Instance name | FC | CC | BC | DC | TC |
| c101 | 1972.00 | 193.09 | 600.00 | 1198.17 | 3963.26 |
| c102 | 2169.20 | 643.87 | 200.00 | 1375.46 | 4388.53 |
| c103 | 1972.00 | 479.64 | 500.00 | 1221.75 | 4173.39 |
| c104 | 1972.00 | 364.34 | 400.00 | 1251.20 | 3987.54 |
| c105 | 2366.40 | 485.13 | 500.00 | 1435.14 | 4243.65 |
| c106 | 2169.20 | 443.93 | 400.00 | 1397.28 | 4410.41 |
| c107 | 2169.20 | 442.91 | 600.00 | 1492.09 | 4023.88 |
| c108 | 1972.00 | 330.51 | 500.00 | 1198.05 | 4000.56 |
| c109 | 2169.20 | 289.46 | 600.00 | 1273.98 | 4332.64 |
| **Avg** | **2103.47** | **408.10** | **477.78** | **1315.90** | **4169.32** |
| r101 | 1972.00 | 657.10 | 200.00 | 1297.50 | 4126.60 |
| r102 | 1972.00 | 402.95 | 400.00 | 1212.15 | 3987.09 |
| r103 | 1972.00 | 280.00 | 500.00 | 1151.99 | 3903.99 |
| r104 | 1972.00 | 374.27 | 400.00 | 1215.55 | 3961.82 |
| r105 | 2169.20 | 486.91 | 700.00 | 1407.88 | 4070.21 |
| r106 | 1972.00 | 272.63 | 600.00 | 1271.31 | 4115.94 |
| r107 | 1972.00 | 610.56 | 300.00 | 1285.36 | 4167.92 |
| r108 | 1972.00 | 420.89 | 400.00 | 1247.11 | 4040.00 |
| r109 | 1972.00 | 312.50 | 500.00 | 1224.25 | 4008.75 |
| r110 | 1972.00 | 523.85 | 300.00 | 1259.42 | 4055.28 |
| r111 | 1972.00 | 386.73 | 500.00 | 1215.17 | 4073.89 |
| r112 | 1972.00 | 270.43 | 600.00 | 1251.53 | 4093.96 |
| **Avg** | **1988.43** | **416.57** | **450.00** | **1253.27** | **4050.45** |
| rc101 | 2169.20 | 688.28 | 300.00 | 1477.95 | 4635.43 |
| rc102 | 2169.20 | 695.44 | 500.00 | 1637.64 | 5002.28 |
| rc103 | 2169.20 | 627.30 | 800.00 | 1681.09 | 5277.58 |
| rc104 | 2169.20 | 471.02 | 700.00 | 1598.92 | 4939.13 |
| rc105 | 2169.20 | 419.72 | 800.00 | 1543.57 | 4932.49 |
| rc106 | 2169.20 | 553.94 | 600.00 | 1492.82 | 4815.96 |
| rc107 | 2169.20 | 342.94 | 900.00 | 1540.24 | 4952.38 |
| rc108 | 2169.20 | 606.17 | 600.00 | 1563.88 | 4939.25 |
| **Avg** | **2169.20** | **550.60** | **650.00** | **1567.01** | **4936.81** |

Appendix .C

Table C1 provides a comprehensive breakdown of the cost components for instance c109 under various CI/BSI Ratios.

**Table C1** cost details for instance c109 under diffrent CI/BSI Ratios

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Ratio | FC | CC | BC | DC | TC |
| 1.59 | 1972.00 | 12.12 | 1060.00 | 1209.75 | 4254.16 |
| 3.59 | 1972.00 | 475..22 | 440.00 | 1287.99 | 4175.21 |
| 5.59 | 1972.00 | 550.87 | 300.00 | 1333.38 | 4156.26 |
| 7.59 | 2169.20 | 606.39 | 220.00 | 1420.07 | 4415.66 |
| 9.59 | 2169.20 | 705.49 | 120.00 | 1482.84 | 4477.53 |

Appendix .D

Table D1 presents the number of used vehicles, total cost, and visit frequencies to CI () and BSI () for delivery tasks of Y Company, based on both manual experience and the proposed algorithm.

**Table D1** Performance of manual experience and BR-GRASP in solving real-world case

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Order date | Size | Manual | | | | BR-GRASP | | | |
| Veh | TC |  |  | Veh | TC |  |  |
| 2024/3/6 | 220 | 24 | 15281.25 | 19 | 10 | 25 | 14287.42 | 17 | 5 |
| 2024/3/5 | 235 | 29 | 17294.70 | 26 | 7 | 28 | 15515.70 | 22 | 3 |
| 2024/3/12 | 232 | 26 | 16683.75 | 20 | 11 | 26 | 14804.49 | 20 | 8 |
| 2024/3/16 | 287 | 31 | 19019.94 | 26 | 7 | 30 | 16547.79 | 25 | 6 |
| 2024/3/25 | 253 | 28 | 17397.21 | 19 | 10 | 27 | 15770.71 | 21 | 5 |
| 2024/3/27 | 272 | 30 | 18844.58 | 25 | 9 | 29 | 16903.68 | 22 | 8 |
| 2024/3/22 | 296 | 32 | 19727.45 | 28 | 7 | 28 | 15391.18 | 25 | 4 |
| 2024/3/4 | 255 | 26 | 17528.12 | 25 | 9 | 27 | 14764.09 | 21 | 4 |
| 2024/3/18 | 231 | 25 | 16337.87 | 20 | 9 | 24 | 14418.52 | 20 | 4 |
| 2024/3/15 | 305 | 36 | 23742.07 | 23 | 9 | 34 | 20933.48 | 23 | 7 |
| 2024/3/3 | 338 | 42 | 27759.86 | 28 | 9 | 40 | 24729.91 | 20 | 6 |
| 2024/3/29 | 321 | 37 | 25687.80 | 22 | 11 | 37 | 22592.13 | 21 | 9 |
| 2024/3/9 | 393 | 46 | 32344.72 | 27 | 16 | 40 | 27076.37 | 25 | 12 |
| 2024/3/13 | 388 | 44 | 31906.69 | 24 | 17 | 39 | 26319.55 | 19 | 10 |
| 2024/3/24 | 347 | 43 | 29149.99 | 24 | 12 | 37 | 23325.70 | 21 | 7 |
| 2024/3/21 | 342 | 43 | 29046.06 | 31 | 8 | 41 | 25277.52 | 23 | 9 |
| 2024/3/8 | 386 | 42 | 29201.57 | 22 | 17 | 42 | 26294.96 | 22 | 8 |
| 2024/3/28 | 415 | 49 | 31186.79 | 26 | 10 | 47 | 28089.88 | 27 | 7 |
| 2024/3/19 | 402 | 46 | 29426.90 | 26 | 14 | 43 | 26862.44 | 28 | 5 |
| 2024/3/26 | 410 | 49 | 31618.58 | 32 | 8 | 47 | 28139.09 | 29 | 7 |
| 2024/3/14 | 492 | 60 | 40913.99 | 27 | 27 | 53 | 34206.81 | 23 | 14 |
| 2024/3/17 | 460 | 52 | 36338.95 | 29 | 19 | 49 | 31072.03 | 21 | 11 |
| 2024/3/2 | 491 | 58 | 38163.17 | 33 | 15 | 53 | 33220.25 | 26 | 12 |
| 2024/3/10 | 461 | 57 | 37109.49 | 29 | 14 | 53 | 33137.92 | 23 | 14 |
| 2024/3/20 | 454 | 57 | 36297.60 | 27 | 14 | 53 | 33383.14 | 30 | 9 |
| 2024/3/1 | 503 | 74 | 51329.99 | 27 | 22 | 66 | 43273.96 | 22 | 16 |
| 2024/3/30 | 503 | 63 | 43400.38 | 24 | 21 | 63 | 41186.99 | 20 | 20 |
| 2024/3/7 | 546 | 75 | 57273.14 | 28 | 40 | 65 | 47516.64 | 19 | 32 |
| 2024/3/11 | 597 | 77 | 58937.55 | 29 | 38 | 68 | 48465.24 | 19 | 27 |
| 2024/3/23 | 581 | 79 | 58415.65 | 26 | 37 | 73 | 51235.23 | 27 | 24 |
| 2024/3/31 | 520 | 73 | 53439.20 | 25 | 32 | 68 | 47722.54 | 19 | 27 |