**Appendix E.** Problem instances (small-size network)

The original data of different sizes of problem instances consists of three parts: i) the data of the parking spaces, which includes the coordinates of the locations and the available parking time. ii) the data of customers, which includes the coordinates of the locations, time-windows of the current location, demand, customers’ ID it belongs to, and the parking spaces’ ID it belongs to. iii) task list obtained from the task generator, which includes a set of sub-tasks determined, the coordinates of the parking space that will perform the current task, the sub-time interval of the task, the total demands of the sub-task, and the corresponding service time. Due to the page limitations, we provide the data of four small-size problem instances (, =5; , =10, , =5, and , =10).

**Table E.1** The original data of the parking spaces (, =5)

|  |  |  |  |
| --- | --- | --- | --- |
| **Parking spaces ID** |  |  | **Available parking time (min)** |
| **0** | 2.521287 | 0.912737 | 265 |
| **1** | 3.205659 | 3.703741 | 247 |
| **2** | 3.830499 | 0.193539 | 231 |

**Table E.2** The original data of customers (, =5)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Locations** |  |  | **Earliest time** | **Latest time** | **Demand** | **Customers’ ID** | **Parking spaces’ ID** |
| **0** | 4.001592 | -0.08038 | 620 | 645 | 3 | 0 | 2 |
| **1** | 3.627509 | 0.206915 | 725 | 752 | 1 | 0 | 2 |
| **2** | 3.863388 | 0.277737 | 540 | 588 | 2 | 1 | 2 |
| **3** | 3.919225 | 0.227169 | 1008 | 1044 | 4 | 1 | 2 |
| **4** | 3.74078 | 0.336257 | 780 | 815 | 2 | 1 | 2 |
| **5** | 3.231472 | 3.2122 | 925 | 958 | 4 | 1 | 1 |
| **6** | 2.979996 | 4.002823 | 790 | 850 | 4 | 2 | 1 |
| **7** | 3.081792 | 3.645949 | 710 | 763 | 1 | 3 | 1 |
| **8** | 3.343271 | 3.763546 | 1013 | 1050 | 3 | 3 | 1 |
| **9** | 3.391767 | 3.894187 | 870 | 918 | 4 | 3 | 1 |
| **10** | 2.52824 | 1.798009 | 968 | 1032 | 4 | 3 | 0 |
| **11** | 2.194383 | 0.448486 | 590 | 616 | 3 | 4 | 0 |
| **12** | 2.163809 | 0.487288 | 986 | 1062 | 1 | 4 | 0 |
| **13** | 2.700833 | 1.202472 | 680 | 711 | 2 | 5 | 0 |
| **14** | 3.019168 | 0.627427 | 991 | 1040 | 4 | 5 | 0 |
| **Notes:** 1) represents the duration of staying at the current location; 2)*Customers’ ID* represents the current location/whereabout belongs to which customer; 2) *Parking spaces’ ID* represents the current location/whereabout to be fulfilled by which parking space if the customer will be served at this location. | | | | | | | |

**Table E.3** The task list obtained from the task generator (, =5)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Tasks ID** |  |  | **Earliest time of task execution** | **Latest time of task execution** | **Total demands to be fulfilled (units)** | **Service time**  **(mins)** |
| **0** | 2.521287 | 0.912737 | 590 | 855 | 5 | 17.097 |
| **1** | 2.521287 | 0.912737 | 968 | 1233 | 9 | 21.066 |
| **2** | 3.205659 | 3.703741 | 710 | 957 | 9 | 14.683 |
| **3** | 3.205659 | 3.703741 | 925 | 1172 | 7 | 16.153 |
| **4** | 3.830499 | 0.193539 | 540 | 771 | 6 | 14.037 |
| **5** | 3.830499 | 0.193539 | 780 | 1011 | 6 | 12.107 |
| **Notes:** 1)] represents the location of the parking space that will serve the current task; | | | | | | | |

**Table E.4** The original data of the parking spaces (, =10)

|  |  |  |  |
| --- | --- | --- | --- |
| **Parking spaces ID** |  |  | **Available parking time (min)** |
| **0** | 3.83562 | 0.182881 | 246 |
| **1** | 0.989961 | 3.786384 | 263 |
| **2** | 2.502348 | 1.084103 | 238 |
| **3** | 3.051987 | 3.740668 | 250 |

**Table E.5** The original data of customers (, =10)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Locations** |  |  | **Earliest time** | **Latest time** | **Demand** | **Customers’ ID** | **Parking spaces’ ID** |
| **0** | 3.648962 | 0.197255 | 970 | 1039 | 1 | 0 | 0 |
| **1** | 3.862753 | 0.261446 | 580 | 653 | 2 | 1 | 0 |
| **2** | 3.913361 | 0.215613 | 773 | 817 | 2 | 1 | 0 |
| **3** | 3.751626 | 0.314485 | 1037 | 1089 | 3 | 1 | 0 |
| **4** | 3.964835 | 0.125219 | 540 | 604 | 3 | 1 | 0 |
| **5** | 3.676114 | 0.039873 | 1070 | 1090 | 3 | 2 | 0 |
| **6** | 3.944436 | 0.07442 | 730 | 779 | 2 | 2 | 0 |
| **7** | 3.82332 | 0.163161 | 740 | 790 | 1 | 3 | 0 |
| **8** | 3.86323 | 0.17962 | 920 | 953 | 1 | 3 | 0 |
| **9** | 3.907567 | 0.257714 | 1020 | 1063 | 1 | 4 | 0 |
| **10** | 3.633678 | 3.538136 | 830 | 863 | 3 | 4 | 3 |
| **11** | 2.701789 | 3.517024 | 863 | 887 | 4 | 4 | 3 |
| **12** | 2.652172 | 3.887856 | 1057 | 1103 | 4 | 4 | 3 |
| **13** | 3.22244 | 4.107676 | 810 | 841 | 1 | 5 | 3 |
| **14** | 2.825353 | 4.150459 | 1071 | 1118 | 4 | 5 | 3 |
| **15** | 2.999279 | 4.034054 | 740 | 816 | 2 | 5 | 3 |
| **16** | 2.935849 | 4.18131 | 816 | 885 | 4 | 5 | 3 |
| **17** | 2.969505 | 3.362484 | 980 | 1036 | 2 | 6 | 3 |
| **18** | 3.045836 | 3.280985 | 830 | 889 | 3 | 7 | 3 |
| **19** | 3.533969 | 3.346694 | 1019 | 1043 | 1 | 7 | 3 |
| **20** | 2.453585 | 1.414691 | 600 | 676 | 3 | 8 | 2 |
| **21** | 2.270908 | 1.210781 | 936 | 1011 | 1 | 8 | 2 |
| **22** | 2.851622 | 1.154788 | 1051 | 1076 | 4 | 8 | 2 |
| **23** | 2.572941 | 0.713296 | 1060 | 1086 | 3 | 9 | 2 |
| **24** | 2.365226 | 0.749248 | 990 | 1015 | 4 | 10 | 2 |
| **25** | 2.319121 | 0.973085 | 1045 | 1084 | 1 | 10 | 2 |
| **26** | 2.429684 | 0.959008 | 720 | 748 | 1 | 10 | 2 |
| **27** | 2.614204 | 0.987016 | 910 | 989 | 2 | 11 | 2 |
| **28** | 2.727189 | 1.461021 | 1019 | 1052 | 2 | 11 | 2 |
| **29** | 2.419002 | 1.218096 | 550 | 586 | 4 | 11 | 2 |
| **30** | 1.100306 | 3.535327 | 700 | 772 | 3 | 12 | 1 |
| **31** | 0.768909 | 3.512685 | 1072 | 1147 | 3 | 12 | 1 |
| **32** | 1.055046 | 3.876299 | 640 | 700 | 4 | 13 | 1 |
| **33** | 0.962357 | 3.569709 | 760 | 800 | 2 | 13 | 1 |
| **34** | 0.810107 | 3.797087 | 1070 | 1132 | 3 | 13 | 1 |
| **35** | 1.526668 | 3.736069 | 960 | 1018 | 3 | 13 | 1 |
| **36** | 0.786009 | 3.82491 | 700 | 779 | 4 | 14 | 1 |
| **37** | 1.078158 | 4.20056 | 969 | 1038 | 4 | 14 | 1 |
| **38** | 0.504752 | 3.762778 | 850 | 916 | 4 | 14 | 1 |
| **39** | 1.307293 | 4.048416 | 1076 | 1140 | 4 | 14 | 1 |
| **Notes:** 1) represents the duration of staying at the current location; 2)*Customers’ ID* represents the current location/whereabout belongs to which customer; 2) *Parking spaces’ ID* represents the current location/whereabout to be fulfilled by which parking space if the customer will be served at this location. | | | | | | | |

**Table E.6** The task list obtained from the task generator (, =10)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Tasks ID** |  |  | **Earliest time of task execution** | **Latest time of task execution** | **Total demands to be fulfilled (units)** | **Service time**  **(min)** |
| **0** | 3.83562 | 0.182881 | 540 | 786 | 8 | 11.92 |
| **1** | 3.83562 | 0.182881 | 773 | 1019 | 4 | 12.34 |
| **2** | 3.83562 | 0.182881 | 1020 | 1266 | 7 | 12.678 |
| **3** | 0.989961 | 3.786384 | 640 | 903 | 7 | 13.428 |
| **4** | 0.989961 | 3.786384 | 700 | 963 | 10 | 16.072 |
| **5** | 0.989961 | 3.786384 | 960 | 1223 | 10 | 16.738 |
| **6** | 0.989961 | 3.786384 | 1072 | 1335 | 7 | 15.144 |
| **7** | 2.502348 | 1.084103 | 550 | 788 | 8 | 14.177 |
| **8** | 2.502348 | 1.084103 | 910 | 1148 | 10 | 15.486 |
| **9** | 2.502348 | 1.084103 | 1051 | 1289 | 7 | 14.718 |
| **10** | 3.051987 | 3.740668 | 740 | 990 | 7 | 15.696 |
| **11** | 3.051987 | 3.740668 | 830 | 1080 | 12 | 17.699 |
| **12** | 3.051987 | 3.740668 | 1019 | 1269 | 9 | 17.781 |
| **Notes:** 1)] represents the location of the parking space that will serve the current task; | | | | | | | |

**Table E.7** The original data of the parking spaces (, =5)

|  |  |  |  |
| --- | --- | --- | --- |
| **Parking spaces ID** |  |  | **Available parking time (min)** |
| **0** | 3.429408 | 3.712662 | 235 |
| **1** | 0.814192 | 0.131808 | 232 |
| **2** | 2.55478 | 1.052008 | 241 |
| **3** | 1.137501 | 3.555553 | 243 |
| **4** | 3.791613 | 0.352651 | 254 |

**Table E.8** The original data of customers (, =5)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Locations** |  |  | **Earliest time** | **Latest time** | **Demand** | **Customers’ ID** | **Parking spaces’ ID** |
| **0** | 3.874083 | 0.551948 | 580 | 629 | 2 | 0 | 4 |
| **1** | 4.017926 | 0.421679 | 1039 | 1106 | 1 | 0 | 4 |
| **2** | 3.558227 | 0.702701 | 970 | 1030 | 3 | 0 | 4 |
| **3** | 4.164229 | 0.164753 | 780 | 830 | 1 | 1 | 4 |
| **4** | 3.343601 | -0.07782 | 1020 | 1063 | 3 | 2 | 4 |
| **5** | 3.086026 | 3.650752 | 820 | 880 | 3 | 2 | 0 |
| **6** | 3.334698 | 3.76259 | 930 | 1005 | 3 | 2 | 0 |
| **7** | 3.380819 | 3.886832 | 1075 | 1151 | 1 | 2 | 0 |
| **8** | 3.599656 | 3.774616 | 740 | 790 | 1 | 3 | 0 |
| **9** | 3.745842 | 3.48852 | 920 | 953 | 1 | 3 | 0 |
| **10** | 2.420224 | 0.983926 | 1020 | 1063 | 1 | 4 | 2 |
| **11** | 2.538355 | 1.141249 | 830 | 863 | 3 | 4 | 2 |
| **12** | 2.608381 | 1.014753 | 863 | 887 | 4 | 4 | 2 |
| **13** | 2.62201 | 1.070159 | 1057 | 1103 | 4 | 4 | 2 |
| **14** | 2.584928 | 1.049953 | 810 | 841 | 1 | 5 | 2 |
| **15** | 0.677791 | 3.202668 | 1071 | 1118 | 4 | 5 | 3 |
| **16** | 0.797825 | 3.074506 | 740 | 816 | 2 | 5 | 3 |
| **17** | 1.565442 | 3.177837 | 816 | 885 | 4 | 5 | 3 |
| **18** | 0.782753 | 4.598363 | 980 | 1036 | 2 | 6 | 3 |
| **19** | 1.863693 | 3.724391 | 830 | 889 | 3 | 7 | 3 |
| **20** | 0.426117 | 0.605967 | 1019 | 1043 | 1 | 7 | 1 |
| **21** | 1.52514 | 0.499999 | 600 | 676 | 3 | 8 | 1 |
| **22** | 0.997726 | -0.33554 | 936 | 1011 | 1 | 8 | 1 |
| **23** | 0.604617 | -0.2675 | 1051 | 1076 | 4 | 8 | 1 |
| **24** | 0.517361 | 0.156119 | 1060 | 1086 | 3 | 9 | 1 |
| **Notes:** 1) represents the duration of staying at the current location; 2)*Customers’ ID* represents the current location/whereabout belongs to which customer; 2) *Parking spaces’ ID* represents the current location/whereabout to be fulfilled by which parking space if the customer will be served at this location. | | | | | | | |

**Table E.9** The task list obtained from the task generator (, =5)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Tasks ID** |  |  | **Earliest time of task execution** | **Latest time of task execution** | **Total demands to be fulfilled (units)** | **Service time**  **(min)** |
| **0** | 3.429408 | 3.712662 | 740 | 975 | 8 | 14.847 |
| **1** | 3.429408 | 3.712662 | 1075 | 1310 | 1 | 12.26 |
| **2** | 0.814192 | 0.131808 | 600 | 832 | 3 | 20.008 |
| **3** | 0.814192 | 0.131808 | 936 | 1168 | 9 | 17.659 |
| **4** | 2.55478 | 1.052008 | 810 | 1051 | 9 | 11.885 |
| **5** | 2.55478 | 1.052008 | 1057 | 1298 | 4 | 10.87 |
| **6** | 1.137501 | 3.555553 | 740 | 983 | 9 | 19.32 |
| **7** | 1.137501 | 3.555553 | 980 | 1223 | 6 | 23.769 |
| **8** | 3.791613 | 0.352651 | 580 | 834 | 3 | 15.216 |
| **9** | 3.791613 | 0.352651 | 970 | 1224 | 7 | 17.766 |
| **Notes:** 1)] represents the location of the parking space that will serve the current task; | | | | | | | |

**Table E.10** The original data of the parking spaces (, =10)

|  |  |  |  |
| --- | --- | --- | --- |
| **Parking spaces ID** |  |  | **Available parking time (min)** |
| **0** | 3.412416 | 4.807321 | 259 |
| **1** | 2.514307 | 1.035503 | 256 |
| **2** | 0.989961 | 3.786384 | 257 |
| **3** | 3.856962 | 0.140871 | 254 |
| **4** | 0.800079 | 0.221703 | 266 |
| **5** | 3.048543 | 3.790156 | 252 |

**Table E.11** The original data of customers (, =10)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Locations** |  |  | **Earliest time** | **Latest time** | **Demand** | **Customers’ ID** | **Parking spaces’ ID** |
| **0** | 3.859128 | 0.168506 | 610 | 675 | 3 | 0 | 3 |
| **1** | 3.879908 | 0.149687 | 1075 | 1104 | 1 | 0 | 3 |
| **2** | 3.813499 | 0.190284 | 590 | 625 | 2 | 0 | 3 |
| **3** | 3.901043 | 0.112571 | 735 | 787 | 2 | 0 | 3 |
| **4** | 3.782494 | 0.077528 | 670 | 722 | 2 | 1 | 3 |
| **5** | 3.892667 | 0.091713 | 1052 | 1097 | 4 | 1 | 3 |
| **6** | 3.842937 | 0.12815 | 650 | 700 | 3 | 1 | 3 |
| **7** | 3.859324 | 0.134908 | 1050 | 1095 | 2 | 1 | 3 |
| **8** | 3.877529 | 0.166974 | 1060 | 1085 | 3 | 2 | 3 |
| **9** | 3.861086 | 0.188394 | 980 | 1031 | 3 | 2 | 3 |
| **10** | 2.851001 | 3.589637 | 750 | 795 | 3 | 2 | 5 |
| **11** | 2.817256 | 3.841845 | 880 | 958 | 1 | 3 | 5 |
| **12** | 3.205103 | 3.991347 | 988 | 1017 | 1 | 3 | 5 |
| **13** | 2.935038 | 4.020445 | 1047 | 1075 | 4 | 3 | 5 |
| **14** | 3.053328 | 3.941276 | 690 | 720 | 3 | 4 | 5 |
| **15** | 3.010188 | 4.041426 | 600 | 649 | 1 | 5 | 5 |
| **16** | 3.033078 | 3.484532 | 779 | 799 | 2 | 5 | 5 |
| **17** | 3.084992 | 3.429104 | 919 | 947 | 1 | 5 | 5 |
| **18** | 3.416978 | 3.473793 | 930 | 991 | 2 | 6 | 5 |
| **19** | 3.078473 | 4.088155 | 1011 | 1035 | 1 | 6 | 5 |
| **20** | 2.406117 | 1.768965 | 570 | 623 | 3 | 6 | 1 |
| **21** | 2.000821 | 1.316558 | 680 | 755 | 2 | 7 | 1 |
| **22** | 3.289226 | 1.192329 | 975 | 1053 | 1 | 7 | 1 |
| **23** | 2.670929 | 0.212809 | 620 | 668 | 2 | 7 | 1 |
| **24** | 2.21008 | 0.292573 | 1068 | 1094 | 3 | 7 | 1 |
| **25** | 2.107788 | 0.789192 | 990 | 1015 | 4 | 8 | 1 |
| **26** | 2.35309 | 0.757959 | 1045 | 1084 | 1 | 8 | 1 |
| **27** | 2.762477 | 0.8201 | 720 | 748 | 1 | 8 | 1 |
| **28** | 3.013153 | 1.871755 | 910 | 989 | 2 | 9 | 1 |
| **29** | 2.329391 | 1.332787 | 1019 | 1052 | 2 | 9 | 1 |
| **30** | 1.100306 | 3.535327 | 550 | 586 | 4 | 9 | 2 |
| **31** | 0.768909 | 3.512685 | 700 | 772 | 3 | 10 | 2 |
| **32** | 1.055046 | 3.876299 | 1072 | 1147 | 3 | 10 | 2 |
| **33** | 0.962357 | 3.569709 | 640 | 700 | 4 | 11 | 2 |
| **34** | 0.810107 | 3.797087 | 760 | 800 | 2 | 11 | 2 |
| **35** | 1.526668 | 3.736069 | 1070 | 1132 | 3 | 11 | 2 |
| **36** | 0.786009 | 3.82491 | 960 | 1018 | 3 | 11 | 2 |
| **37** | 1.078158 | 4.20056 | 700 | 779 | 4 | 12 | 2 |
| **38** | 0.504752 | 3.762778 | 969 | 1038 | 4 | 12 | 2 |
| **39** | 1.307293 | 4.048416 | 850 | 916 | 4 | 12 | 2 |
| **40** | 0.264682 | 0.254297 | 1076 | 1140 | 4 | 12 | 4 |
| **41** | 0.924848 | 0.190392 | 770 | 811 | 1 | 13 | 4 |
| **42** | 0.861032 | 0.659372 | 1061 | 1105 | 2 | 13 | 4 |
| **43** | 0.642039 | -0.05012 | 740 | 781 | 3 | 13 | 4 |
| **44** | 0.676609 | 0.0888 | 670 | 745 | 1 | 14 | 4 |
| **45** | 1.162396 | -0.0516 | 815 | 884 | 1 | 14 | 4 |
| **46** | 1.152492 | 0.403784 | 924 | 986 | 3 | 14 | 4 |
| **47** | 0.968849 | -0.00048 | 750 | 789 | 3 | 15 | 4 |
| **48** | 0.449069 | 0.623741 | 550 | 574 | 4 | 16 | 4 |
| **49** | 0.89877 | 0.098843 | 600 | 663 | 4 | 17 | 4 |
| **50** | 3.485976 | 4.79664 | 973 | 1036 | 2 | 17 | 0 |
| **51** | 3.491542 | 5.025621 | 780 | 809 | 1 | 18 | 0 |
| **52** | 3.481372 | 5.10149 | 929 | 1006 | 2 | 18 | 0 |
| **53** | 3.501442 | 4.952121 | 1046 | 1124 | 2 | 18 | 0 |
| **54** | 3.11521 | 4.703535 | 760 | 832 | 4 | 18 | 0 |
| **55** | 3.598691 | 4.416446 | 630 | 670 | 2 | 19 | 0 |
| **56** | 3.373257 | 4.471041 | 820 | 872 | 3 | 20 | 0 |
| **57** | 3.432986 | 5.049805 | 1002 | 1068 | 2 | 20 | 0 |
| **58** | 3.484536 | 4.846177 | 1010 | 1081 | 4 | 21 | 0 |
| **59** | 3.159153 | 4.710333 | 940 | 968 | 4 | 21 | 0 |
| **Notes:** 1) represents the duration of staying at the current location; 2)*Customers’ ID* represents the current location/whereabout belongs to which customer; 2) *Parking spaces’ ID* represents the current location/whereabout to be fulfilled by which parking space if the customer will be served at this location. | | | | | | | |

**Table E.12** The task list obtained from the task generator (, =10)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Tasks ID** |  |  | **Earliest time of task execution** | **Latest time of task execution** | **Total demands to be fulfilled (units)** | **Service time**  **(min)** |
| **0** | 3.412416 | 4.807321 | 630 | 889 | 7 | 15.412 |
| **1** | 3.412416 | 4.807321 | 820 | 1079 | 11 | 14.232 |
| **2** | 3.412416 | 4.807321 | 1002 | 1261 | 8 | 13.042 |
| **3** | 2.514307 | 1.035503 | 570 | 826 | 8 | 20.468 |
| **4** | 2.514307 | 1.035503 | 910 | 1166 | 10 | 22.172 |
| **5** | 2.514307 | 1.035503 | 1068 | 1324 | 3 | 20.035 |
| **6** | 0.989961 | 3.786384 | 550 | 807 | 8 | 13.428 |
| **7** | 0.989961 | 3.786384 | 700 | 957 | 9 | 15.293 |
| **8** | 0.989961 | 3.786384 | 850 | 1107 | 11 | 16.072 |
| **9** | 0.989961 | 3.786384 | 1070 | 1327 | 6 | 16.738 |
| **10** | 3.856962 | 0.140871 | 590 | 844 | 8 | 10.823 |
| **11** | 3.856962 | 0.140871 | 670 | 924 | 4 | 11.222 |
| **12** | 3.856962 | 0.140871 | 980 | 1234 | 12 | 10.759 |
| **13** | 3.856962 | 0.140871 | 1075 | 1329 | 1 | 10.307 |
| **14** | 0.800079 | 0.221703 | 550 | 816 | 9 | 16.671 |
| **15** | 0.800079 | 0.221703 | 740 | 1006 | 11 | 15.673 |
| **16** | 0.800079 | 0.221703 | 1061 | 1327 | 6 | 16.705 |
| **17** | 3.048543 | 3.790156 | 600 | 852 | 9 | 13.825 |
| **18** | 3.048543 | 3.790156 | 880 | 1132 | 10 | 16.07 |
| **Notes:** 1)] represents the location of the parking space that will serve the current task; | | | | | | | |

**Appendix F.** Implementation results for small-size networks

We now provide detailed and traceable routes for the problem instances presented in the Appendix C. For each delivery route of MPL, the result consists of the task execution sequence, arriving time and leaving time of MPLs against parking space, service delay of each MPL at different parking spaces, and the real-time demand fulfilment of MPLs.

**Table F.1** Implementation result of the problem instance with BTD applied (, =5)

|  |  |
| --- | --- |
| **Delivery Route** | |
| MPL’s ID | Task execution sequence (Task’ ID) |
| 0 | [6, 0, 4, 6, 3, 2, 6, 1, 5, 6] |
| **Arriving Time When Executing Task** | |
| MPL’s ID | Starting Time of the Corresponding Task |
| 0 | [420, 590.0, 609.2, 628.7, 925, 941.2, 962.8, 968, 991.2, 1008.8] |
| **Leaving Time When Task Completed** | |
| MPL’s ID | Ending Time of the Corresponding Task |
| 0 | [586.2, 607.1, 623.3, 918.0, 941.2, 955.8, 964.2, 989.1, 1003.3, 0] |
| **Service Delays** | |
| MPL’s ID | Delays of the Corresponding Task (min) |
| 0 | [0, 0.0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0] |
| **Real-time Demand Fulfilment** | |
| MPL’s ID | Accumulated Number of Parcels that have been fulfilled (units) |
| 0 | [0, 5, 11, 0, 7, 16, 0, 9, 15, 0] |
| **Notes:** 1) MPLs depart from the depot and will return to the depot once all tasks are completed. Therefore, ‘6’ represent the depot here. Other numbering represents the task ID. 2) The MPLs may return to the depot during a delivery round to meet time windows or demand constraints. 3) The start time of executing task 0 is 590.0, and the task is completed at 607.1. Following this logic to understand the duration of performing other tasks. 4) If MPLs have returned to the depot, the real-time demand fulfilment of the corresponding task will reset to 0, and will recalculate once MPLs start to perform the remaining tasks. | |
|  |  |

**Table F.2** Implementation result of the problem instance with HCPS applied (, =5)

|  |  |
| --- | --- |
| **Delivery Route** | |
| MPL’s ID | Task execution sequence (Task’ ID) |
| 0 | [6, 1, 5, 6, 4, 0, 6, 3, 2, 6] |
| **Arriving Time When Executing Task** | |
| MPL’s ID | Starting Time of the Corresponding Task |
| 0 | [420, 968.0, 991.2, 1008.8, 540, 590.0, 610.9, 925, 941.2, 962.8] |
| **Leaving Time When Task Completed** | |
| MPL’s ID | Ending Time of the Corresponding Task |
| 0 | [964.2, 989.1, 1003.3, 534.5, 554.0, 607.1, 918.0, 941.2, 955.8, 0] |
| **Service Delays** | |
| MPL’s ID | Delays of the Corresponding Task (min) |
| 0 | [0, 0.0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0] |
| **Real-time Demand Fulfilment** | |
| MPL’s ID | Accumulated Number of Parcels that have been fulfilled (units) |
| 0 | [0, 9, 15, 0, 6, 11, 0, 7, 16, 0] |

**Table F.3** Implementation result of the problem instance with BTD applied (, =10)

|  |  |
| --- | --- |
| **Delivery Route** | |
| MPL’s ID | Task execution sequence (Task’ ID) |
| 0 | [13, 0, 13, 1, 13, 2, 8, 13, 7, 13, 10, 3, 13, 12, 13, 11, 13, 4, 13, 9, 13, 6, 5, 13] |
| **Arriving Time When Executing Task** | |
| MPL’s ID | Starting Time of the Corresponding Task |
| 0 | [420, 540.0, 557.4, 773, 790.8, 1020, 1035.0, 1054.4, 550, 568.1, 740, 758.6, 777.7, 1019, 1043.7, 830, 854.6, 700, 721.7, 1051, 1069.6, 1072, 1087.1, 1109.5] |
| **Leaving Time When Task Completed** | |
| MPL’s ID | Ending Time of the Corresponding Task |
| 0 | [534.5, 551.9, 767.5, 785.3, 1014.5, 1032.7, 1050.5, 546.1, 564.2, 733.1, 755.7, 772.1, 1012.1, 1036.8, 823.1, 847.7, 694.4, 716.1, 1047.1, 1065.7, 1066.4, 1087.1, 1103.9, 0] |
| **Service Delays** | |
| MPL’s ID | Delays of the Corresponding Task (min) |
| 0 | [0, 0.0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0] |
| **Real-time Demand Fulfilment** | |
| MPL’s ID | Accumulated Number of Parcels that have been fulfilled (units) |
| 0 | [0, 8, 0, 4, 0, 7, 17, 0, 8, 0, 7, 14, 0, 9, 0, 12, 0, 10, 0, 7, 0, 7, 17, 0] |
| **Notes:** Number‘13’ represents the central depot in this case. | |

**Table F.4** Implementation result of the problem instance with HCPS applied (, =10)

|  |  |
| --- | --- |
| **Delivery Route** | |
| MPL’s ID | Task execution sequence (Task’ ID) |
| 0 | [13, 2, 8, 13, 10, 11, 13, 4, 3, 13, 9, 13] |
| 1 | [13, 0, 13, 5, 12, 13] |
| 2 | [13, 1, 7, 13, 6, 13] |
| **Arriving Time When Executing Task** | |
| MPL’s ID | Starting Time of the Corresponding Task |
| 0 | [420, 1020.0, 1035.0, 1054.4, 740, 830.0, 854.6, 700, 716.1, 735.1, 1051, 1069.6] |
| 1 | [420, 540.0, 557.4, 960, 1019.0, 1043.7] |
| 2 | [420, 773.0, 787.6, 805.7, 1072, 1092.7] |
| **Leaving Time When Task Completed** | |
| MPL’s ID | Ending Time of the Corresponding Task |
| 0 | [1014.5, 1032.7, 1050.5, 733.1, 755.7, 847.7, 694.4, 716.1, 729.5, 1047.1, 1065.7, 0] |
| 1 | [534.5, 551.9, 954.4, 976.7, 1036.8, 0] |
| 2 | [767.5, 785.3, 801.8, 1066.4, 1087.1, 0] |
| **Service Delays** | |
| MPL’s ID | Delays of the Corresponding Task (min) |
| 0 | [0, 0.0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0] |
| 1 | [0, 0.0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0] |
| 2 | [0, 0.0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0] |
| **Real-time Demand Fulfilment** | |
| MPL’s ID | Accumulated Number of Parcels that have been fulfilled (units) |
| 0 | [0, 7, 17, 0, 7, 19, 0, 10, 17, 0, 7, 0] |
| 1 | [0, 8, 0, 10, 19, 0] |
| 2 | [0, 4, 12, 0, 7, 0] |
| **Notes:** Number‘13’ represents the central depot in this case. | |

**Table F.5** Implementation result of the problem instance with BTD applied (, =5)

|  |  |
| --- | --- |
| **Delivery Route** | |
| MPL’s ID | Task execution sequence (Task’ ID) |
| 0 | [10, 6, 8, 0, 10, 3, 4, 10, 2, 10, 9, 10, 5, 10, 1, 7, 10] |
| **Arriving Time When Executing Task** | |
| MPL’s ID | Starting Time of the Corresponding Task |
| 0 | [420, 740.0, 765.3, 785.3, 807.4, 936, 956.5, 972.3, 600, 621.2, 970, 993.2, 1057, 1071.8, 1075, 1090.5, 1119.6] |
| **Leaving Time When Task Completed** | |
| MPL’s ID | Ending Time of the Corresponding Task |
| 0 | [734.7, 759.3, 780.5, 800.2, 934.8, 953.7, 968.4, 598.8, 620.0, 964.6, 987.8, 1053.1, 1067.9, 1067.8, 1087.3, 1114.3, 0] |
| **Service Delays** | |
| MPL’s ID | Delays of the Corresponding Task (min) |
| 0 | [0, 0.0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0] |
| **Real-time Demand Fulfilment** | |
| MPL’s ID | Accumulated Number of Parcels that have been fulfilled (units) |
| 0 | [0, 9, 12, 20, 0, 9, 18, 0, 3, 0, 7, 0, 4, 0, 1, 7, 0] |
| **Notes:** Number‘10’ represents the central depot in this case. | |

**Table F.6** Implementation result of the problem instance with HCPS applied (, =5)

|  |  |
| --- | --- |
| **Delivery Route** | |
| MPL’s ID | Task execution sequence (Task’ ID) |
| 0 | [10, 8, 2, 0, 10, 6, 7, 1, 5, 10] |
| 1 | [10, 9, 4, 10, 3, 10] |
| **Arriving Time When Executing Task** | |
| MPL’s ID | Starting Time of the Corresponding Task |
| 0 | [420, 580.0, 600.0, 740.0, 762.1, 740, 980.0, 1075.0, 1091.3, 1106.1] |
| 1 | [420, 970.0, 989.8, 1005.6, 936, 954.8] |
| **Leaving Time When Task Completed** | |
| MPL’s ID | Ending Time of the Corresponding Task |
| 0 | [574.6, 595.2, 620.0, 754.8, 734.7, 759.3, 1003.8, 1087.3, 1102.1, 0] |
| 1 | [964.6, 987.8, 1001.7, 934.8, 953.7, 0] |
| **Service Delays** | |
| MPL’s ID | Delays of the Corresponding Task (min) |
| 0 | [0, 0.0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0] |
| 1 | [0, 0.0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0] |
| **Real-time Demand Fulfilment** | |
| MPL’s ID | Accumulated Number of Parcels that have been fulfilled (units) |
| 0 | [0, 3, 6, 14, 0, 9, 15, 16, 20, 0] |
| 1 | [0, 7, 16, 0, 9, 0] |
| **Notes:** Number‘10’ represents the central depot in this case. | |

**Table F.7** Implementation result of the problem instance with BTD applied (, =10)

|  |  |
| --- | --- |
| **Delivery Route** | |
| MPL’s ID | Task execution sequence (Task’ ID) |
| 0 | [19, 11, 17, 19, 15, 14, 19, 7, 6, 19, 13, 18, 19, 12, 19] |
| 1 | [19, 0, 19, 8, 19] |
| 2 | [19, 10, 3, 19] |
| 3 | [19, 1, 19, 16, 5, 19] |
| 4 | [19, 2, 19, 9, 4, 19] |
| **Arriving Time When Executing Task** | |
| MPL’s ID | Starting Time of the Corresponding Task |
| 0 | [420, 670.0, 686.6, 707.3, 740, 755.7, 773.5, 700, 715.3, 734.3, 1075, 1090.6, 1113.7, 980, 996.3] |
| 1 | [420, 630.0, 653.8, 850, 871.7] |
| 2 | [420, 590.0, 603.1, 627.5] |
| 3 | [420, 820.0, 842.7, 1061, 1080.4, 1104.3] |
| 4 | [420, 1002.0, 1023.5, 1070, 1091.2, 1117.3] |
| **Leaving Time When Task Completed** | |
| MPL’s ID | Ending Time of the Corresponding Task |
| 0 | [664.5, 681.2, 700.4, 738.8, 755.7, 772.3, 694.4, 715.3, 728.7, 1069.5, 1085.3, 1106.7, 974.5, 990.8, 0] |
| 1 | [621.6, 645.4, 844.4, 866.1, 0] |
| 2 | [584.5, 600.8, 623.6, 0] |
| 3 | [811.6, 834.2, 1059.8, 1077.7, 1100.5, 0] |
| 4 | [993.6, 1015.0, 1064.4, 1086.7, 1113.4, 0] |
| **Service Delays** | |
| MPL’s ID | Delays of the Corresponding Task (min) |
| 0 | [0, 0.0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0, 0, 0] |
| 1 | [0, 0.0, 0, 0, 0] |
| 3 | [0, 0.0, 0.0, 0] |
| 3 | [0, 0.0, 0, 0, 0.0, 0] |
| 4 | [0, 0.0, 0, 0, 0.0, 0] |
| **Real-time Demand Fulfilment** | |
| MPL’s ID | Accumulated Number of Parcels that have been fulfilled (units) |
| 0 | [0, 4, 13, 0, 11, 20, 0, 9, 17, 0, 1, 11, 0, 12, 0] |
| 1 | [0, 7, 0, 11, 0] |
| 2 | [0, 8, 16, 0] |
| 3 | [0, 11, 0, 6, 9, 0] |
| 4 | [0, 8, 0, 6, 16, 0] |
| **Notes:** Number‘19’ represents the central depot in this case. | |

**Table F.8** Implementation result of the problem instance with HCPS applied (, =10)

|  |  |
| --- | --- |
| **Delivery Route** | |
| MPL’s ID | Task execution sequence (Task’ ID) |
| 0 | [19, 0, 11, 19, 15, 3, 19, 10, 7, 19, 14, 19, 16, 8, 19, 18, 5, 19] |
| 1 | [19, 17, 6, 19] |
| 2 | [19, 12, 19] |
| 3 | [19, 9, 19] |
| 4 | [19, 1, 2, 13, 19, 4, 19] |
| **Arriving Time When Executing Task** | |
| MPL’s ID | Starting Time of the Corresponding Task |
| 0 | [420, 630.0, 670.0, 686.7, 740, 758.4, 782.7, 590, 700.0, 720.9, 550, 567.9, 1061, 1082.8, 1104.5, 880, 1068.0, 1091.9] |
| 1 | [420, 600.0, 616.8, 635.8] |
| 2 | [420, 980.0, 996.3] |
| 3 | [420, 1070.0, 1092.3] |
| 4 | [420, 820.0, 1002.0, 1075.0, 1090.8, 910, 936.1] |
| **Leaving Time When Task Completed** | |
| MPL’s ID | Ending Time of the Corresponding Task |
| 0 | [621.6, 645.4, 681.2, 738.8, 755.7, 778.9, 584.5, 600.8, 715.3, 548.8, 566.7, 1059.8, 1077.7, 1098.9, 873.1, 896.1, 1088.0, 0] |
| 1 | [593.1, 613.8, 630.2, 0] |
| 2 | [974.5, 990.8, 0] |
| 3 | [1064.4, 1086.7, 0] |
| 4 | [811.6, 834.2, 1015.0, 1085.3, 906.1, 932.2, 0] |
| **Service Delays** | |
| MPL’s ID | Delays of the Corresponding Task (min) |
| 0 | [0, 0.0, 0.0, 0, 0, 0.0, 0, 0, 0.0, 0, 0, 0, 0, 0.0, 0, 0, 0.0, 0] |
| 1 | [0, 0.0, 0.0, 0] |
| 3 | [0, 0.0, 0] |
| 3 | [0, 0.0, 0] |
| 4 | [0, 0.0, 0.0, 0.0, 0, 0, 0] |
| **Real-time Demand Fulfilment** | |
| MPL’s ID | Accumulated Number of Parcels that have been fulfilled (units) |
| 0 | [0, 7, 11, 0, 11, 19, 0, 8, 17, 0, 9, 0, 6, 17, 0, 10, 13, 0] |
| 1 | [0, 9, 17, 0] |
| 2 | [0, 12, 0] |
| 3 | [0, 6, 0] |
| 4 | [0, 11, 19, 20, 0, 10, 0] |
| **Notes:** Number‘19’ represents the central depot in this case. | |