# Supplementary material

# for

# Extended p-median problems for balancing service efficiency and equality

### Appendix 1: Proof of the inequity-averse property of MDELP

Let be a set of candidate facility locations, be a set of demand locations, each location has service demand. Variable is the distance between locations and. The travel distance vector of the demand locations is denoted, where. The objective function (13) can be equivalently transformed into:

where weight parameter,.

The objective function satisfies the following conditions of inequity averse function:

***Condition* 1 (**Anonymity):, where is an arbitrary permutation of the vector.

***Condition* 2 (**Monotonicity): , where .

***Condition* 3 (**Pigou–Dalton Principle of Transfers): , where .

#### Appendix 1.1: Proof of Condition 1: Anonymity

The objective function does not take into account special groups or individuals, so the ***Condition* 1 (**anonymity) is naturally satisfied.

#### Appendix 1.2 Proof of Condition 2: Monotonicity

Assuming, it can be established that the inequalityis true.

Assuming, we consider the following two scenarios:

If, the first term in function experiences an increment while the second term remains unchanged. Consequently, the overall function value increases, and the aforementioned inequality remains valid.

If, both terms in the function increase, thereby satisfying the inequality.

In summary, the function satisfies the property of monotonicity.

#### Appendix 1.3 Proof of Condition 3: Pigou–Dalton Principle of Transfers

Let, where , it can be established that the inequalities and . Given that the transfer from  to do not affect the total travel distance, the first part of function , , can be neglected. As a result, the weight *β* in the second section can be ignored in the proofs.

Based on the initial position relationship of, and , we consider six cases:

***Case1***:;

***Case2***:;

***Case3a***:, and ;

***Case3b***:, and ;

***Case3c***:, and ; and

***Case3d***:, and .

For ***Case1***, since and , the equality holds.

For ***Case2***,

)

.

For ***Case3a***, .

For ***Case3b***, due to, we have:

.

For ***Case3c***, depending on the relationship between and , ***Case3c*** is divided into the following two scenarios:

If : Since , , and the inequality holds. Therefore,

.

Given and, it follows that , hence.

If: Since,, and , we have:

.

For ***Case3d***, under the condition that, we can derive

.

Additionally, given that , we proceed to analyze the difference in function values scaled by:

.

Relying on the fact that and, we conclude

.

Hence .

In essence, for all considered cases, the function satisfies the Pigou–Dalton principle of transfers in a weak sense, as it either remains constant or decreases in value when subject to the specified type of transfer.

### Appendix 2: Proof of the analytical properties of MDELP

There are four analytical properties to understand the relationships between parameter and model performance.

Let be the optimal solution of the PMP. Let and be the total travel distance and the total spatial envy of solution , respectively.

Let be the optimal solution of the MELP. Let and be the total travel distance and the total spatial envy of solution , respectively. the total spatial envy.

Let be the optimal solution of the MDELP with parameters and . Let be the optimal objective value, where is total travel distance, and is the total spatial envy.

Let be the optimal solution of the MDELP with parameters and . Let be the optimal objective value, where is total travel distance, and is the total spatial envy.

***Property 1: If and , then and* .**

If , then . If , then , since is the optimal solution of the PMP.

If , then . If , then , since is the optimal solution of the MELP.

*Property* 1 indicates that, for the optimal solution of MDELP with any parameters and , is the lower bound of total travel distance, and is the lower bound of total spatial envy.

***Property 2: If and , then .***

If , obviously, ，, then .

If , then , since solution is an optimal solution of the MDELP with parameters and . As a result, .

*Property* 2 indicates that keeping the value of the same, and increasing the weight of spatial envy, , the optimal objective of the MDELP will be increased or remained the same.

***Property 3: If and ，then and .***

Since solution is an optimal solution of the MDELP with parameters and , . Similarly, .

A new inequality is yielded by adding the two inequalities: . It can be rewritten as , and . Since , then .

Rewrite the inequality as . Since , then .

*Property* 3 shows that keeping the value of parameter the same, and increasing the weight of spatial envy, , the optimal travel distance of the MDELP will be increased or remained the same, and the optimal spatial envy of the MDELP will be reduced or remained the same.

***Property 4: If and , then and*** *.*

For , the optimal solution is dominated by the envy, then , and .

For , the optimal solution is dominated by the distance, then , and .

According to ***Property*** 3, and.

*Properties* 1, 3 and 4 show that and This indicates that the optimal travel distance of the MDELP located in the interval [], and the optimal spatial envy of the MDELP located in the interval [].

### Appendix 3: Location models used in Section 4.4 and 4.5

Let be a set of *n* candidate facility locations. Let be a set of *m* demand locations, each location has service demand . Variable is the distance between locations *i* and *j*. Let () be a binary variable indicating whether a facility is opened at location . Let ( be a binary variable denoting whether customer is served by facility at location . The well-known PMP is formulated as follows.

In public services, spatial equity is one of the most important criteria for service planning and delivering. Let be the travel distance from demand location *j* to it its nearest opened facility, and be the mean travel distance. Spatial inequity indicators, the standard deviation (SD), the mean absolute deviation (MAD), the sum of absolute difference (AD), the coefficient of variance (CV), the Schutz indicator (SI), the Gini coefficient (GC), can be defined as follows.

Note that the inequity indicators defined above are different from others in two aspects. First, the demand weight is considered in all indicators. Second, the MAD and AD are averaged, and thus they can be compared with the mean distance and the SD.

The objective function of the PMP can be directly replaced by minimizing an inequity indictor. Using indictors (S6) ~ (S11), six minimum inequity location problems can be formulated, denoted as MinSD, MinMAD, MinAD, MinCV, MinSI and MinGC, respectively. Note that, different from the location models in Barbati and Bruno (2018), the demand weights are considered in the objective functions. Usually, constraints (S12) are used to ensure that each demand location is assigned to the nearest facility (Barbati and Bruno, 2018), where *M* is a constant, ).

The objective functions (6) ~ (11) can be formulated as mixed integer linear programs (MILP) or mixed integer quadratic programs (MIQP) by introducing additional variables and constraints. The MinSD is formulated as follows.

The objective function (S13) minimizes the variance of travel distances, in which, the travel distances () and the mean travel distance () are defined by equalities (S14) and (S15), respectively.

The MinCV problem is formulated as follows. Since the coefficient of variance is scale-invariant, the CV function can be rewritten as a quadratic function. In objective (S17), the variables are scaled distances () defined by constraints (S18) ~ (S21).

The MinMAD problem is formulated as follows. In objective (S23), variables are absolution deviations ( defined by constraints (S24) and (S25).

The MinSI problem is formulated as follows. In objective (S27), variables are scaled absolution deviations ( defined by constraints (S28) ~ (S31).

The MinAD problem is formulated as follows. In objective (S33), variables are absolute differences () defined by constraints (S34) and (S35).

The MinGC problem is formulated as follows. In objective (S38), variables are scaled absolution difference (), defined by constraints (S39) ~ (S42).

The above location problems use particular functions in order to capture equity concerns. The inequality indicators can be combined with the efficiency objective (1), resulting in mean-inequity bi-objective location problems (Berman, 1990). The mean-variance bi-objective optimization technique has been widely used in economy, finance and public service. In this paper, a mean-variance bi-objective location problem (Mean-SD) can be defined by minimizing objectives (S1) and (S13) subject to constraints (S2) ~ (S5), (S12) and (S14) ~ (S16). Similarly, a mean-deviation bi-objective location problem (Mean-MAD) can be defined by minimizing objectives (S1) and (S23) subject to constraints (S2) ~ (S5), (12) and (S24) ~ (S26).

The ordered median problem (OMP) (Nickel & Puerto, 2005; Puerto & Rodríguez-Chía 2019) is considered by some studies as the “most equitable” solution (Karsu and Morton, 2015). It provides a common framework for several classical location problems such as the median, the center, the k-centrum (Slater 1978; Ogryczak and Zawadzki 2002), and -centdian (Halpern 1976) problems. The trade-off between efficiency and equality can be implementing by assigning appropriate weights to the ordered travel distances. Filippi et al. (2021) proposed a fair facility location problem (FFLP) which minimizes the average of worst distances traveled by the *β*% of customers. It is a special case of OMP with a weighting vector, where . Inspired by Filippi et al. (2021), a *k*-centdian problem is formulated in this paper as follows.

In objective (45), the first part denotes the mean travel distance, and the second part denotes the mean of *k* worst distances. The two parts are summed with weights and (), respectively. It is different from the FFLP in that the demand weights are considered in the first part of the objective function. Noticeably, some location problems are special cases of the problem: the PMP (), the PCP ( and ), the -centdian problem ( and ), and the *k*-centrum problem ().

In addition, the demand weight can be incorporated into objective (S48) by defining .

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### Figure S1: The mean distance and the standard deviation from the MDELP solutions with different parameter . The horizontal axis shows the value of parameter ; the vertical axis shows the mean distance (upper line) and the standard deviation (lower line).

### Figure S2: The mean distance and the standard deviation from the CMDELP solutions with different parameter . The horizontal axis shows the value of parameter ; the vertical axis shows the mean distance (upper line) and the standard deviation (lower line).

### Figure S3: The mean distance and the standard deviation from the MDELP solutions with different parameter . The horizontal axis shows the value of parameter ; the vertical axis shows the mean distance (upper line) and the standard deviation (lower line).

### Figure S4: The mean distance and the standard deviation from the CMDELP solutions with different parameter . The horizontal axis shows the value of parameter ; the vertical axis shows the mean distance (upper line) and the standard deviation (lower line).

### Figure S5: The mean distance and the standard deviation versus the number of facilities. The horizontal axis shows the number of facilities for the MDELP; the vertical axis shows the mean distance (upper line) and the standard deviation (lower line).

### Figure S6: The mean distance and the standard deviation versus the number of facilities. The horizontal axis shows the number of facilities for the CMDELP; the vertical axis shows the mean distance (upper line) and the standard deviation (lower line).

### Table S1: Solutions from the instance Capa1

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | capa1 | 10 | ~ | ~ | 7070447.2 | opt | 51.9 | 138.9 | 59.9 | 49.4 | 0.246 |
| PMP | capa1 | 11 | ~ | ~ | 6726618.9 | opt | 166.9 | 132.2 | 56.3 | 46.2 | 0.243 |
| PMP | capa1 | 12 | ~ | ~ | 6413109.1 | opt | 41.0 | 126.0 | 53.5 | 43.9 | 0.242 |
| PMP | capa1 | 13 | ~ | ~ | 6139107.8 | opt | 34.7 | 120.6 | 51.0 | 41.6 | 0.239 |
| PMP | capa1 | 14 | ~ | ~ | 5870738.4 | opt | 12.8 | 115.4 | 48.0 | 39.2 | 0.237 |
| MDELP | capa1 | 10 | 138.9 | 0.077 | 12905305.5 | opt | 31.4 | 139.7 | 54.5 | 44.7 | 0.223 |
| MDELP | capa1 | 11 | 132.2 | 0.083 | 12683936.2 | opt | 51.5 | 133.1 | 52.2 | 42.9 | 0.224 |
| MDELP | capa1 | 12 | 126.0 | 0.088 | 12080844.5 | opt | 35.5 | 127.3 | 49.3 | 40.9 | 0.222 |
| MDELP | capa1 | 13 | 120.6 | 0.093 | 11910391.6 | opt | 74.1 | 122.1 | 48.3 | 39.9 | 0.226 |
| MDELP | capa1 | 14 | 115.4 | 0.100 | 11707370.8 | opt | 38.2 | 116.5 | 47.2 | 39.1 | 0.231 |
| MELP | capa1 | 10 | 138.9 | ~ | 75232954.6 | opt | 39.5 | 140.1 | 54.2 | 44.3 | 0.221 |
| MELP | capa1 | 11 | 132.2 | ~ | 71110635.9 | opt | 72.2 | 134.3 | 52.3 | 43.8 | 0.223 |
| MELP | capa1 | 12 | 126.0 | ~ | 63689667.4 | opt | 32.6 | 127.3 | 49.3 | 40.9 | 0.222 |
| MELP | capa1 | 13 | 120.6 | ~ | 61077315.6 | opt | 52.2 | 122.7 | 48.0 | 39.6 | 0.223 |
| MELP | capa1 | 14 | 115.4 | ~ | 57796316.2 | opt | 55.1 | 116.5 | 47.2 | 39.1 | 0.231 |
| CPMP | capa1 | 10 | ~ | ~ | 7070447.2 | opt | 1008.3 | 138.9 | 59.9 | 49.4 | 0.246 |
| CPMP | capa1 | 11 | ~ | ~ | 6726618.9 | opt | 1131.4 | 132.2 | 56.3 | 46.2 | 0.243 |
| CPMP | capa1 | 12 | ~ | ~ | 6413109.1 | opt | 842.2 | 126.0 | 53.5 | 43.9 | 0.242 |
| CPMP | capa1 | 13 | ~ | ~ | 6139107.8 | opt | 1066.2 | 120.6 | 51.0 | 41.6 | 0.239 |
| CPMP | capa1 | 14 | ~ | ~ | 5870738.4 | opt | 405.2 | 115.4 | 48.0 | 39.2 | 0.237 |
| CMDELP | capa1 | 10 | 138.9 | 0.077 | 12905305.5 | opt | 1176.2 | 139.7 | 54.5 | 44.7 | 0.223 |
| CMDELP | capa1 | 11 | 132.2 | 0.083 | 12683936.2 | opt | 898.8 | 133.1 | 52.2 | 42.9 | 0.224 |
| CMDELP | capa1 | 12 | 126.0 | 0.088 | 12080844.5 | opt | 878.7 | 127.3 | 49.3 | 40.9 | 0.222 |
| CMDELP | capa1 | 13 | 120.6 | 0.093 | 11910391.6 | opt | 711.3 | 122.1 | 48.3 | 39.9 | 0.226 |
| CMDELP | capa1 | 14 | 115.4 | 0.100 | 11707370.8 | opt | 748.5 | 116.5 | 47.2 | 39.1 | 0.231 |
| MECLP | capa1 | 10 | 138.9 | ~ | 75232954.6 | opt | 1051.2 | 140.1 | 54.2 | 44.3 | 0.221 |
| MECLP | capa1 | 11 | 132.2 | ~ | 71110635.9 | opt | 1091.1 | 134.3 | 52.3 | 43.8 | 0.223 |
| MECLP | capa1 | 12 | 126.0 | ~ | 63689667.4 | opt | 729.5 | 127.3 | 49.3 | 40.9 | 0.222 |
| MECLP | capa1 | 13 | 120.6 | ~ | 61077315.6 | opt | 808.0 | 122.7 | 48.0 | 39.6 | 0.223 |
| MECLP | capa1 | 14 | 115.4 | ~ | 57796316.2 | opt | 538.5 | 116.5 | 47.2 | 39.1 | 0.231 |

### Table S2: Solutions from the instance Capb1

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | capb1 | 12 | ~ | ~ | 6436697.6 | opt | 14.6 | 125.2 | 52.5 | 43.0 | 0.239 |
| PMP | capb1 | 13 | ~ | ~ | 6191851.2 | opt | 25.2 | 120.4 | 53.8 | 44.5 | 0.256 |
| PMP | capb1 | 14 | ~ | ~ | 5964313.9 | opt | 29.3 | 116.0 | 51.9 | 42.6 | 0.256 |
| PMP | capb1 | 15 | ~ | ~ | 5749904.7 | opt | 23.2 | 111.9 | 50.7 | 41.4 | 0.258 |
| PMP | capb1 | 16 | ~ | ~ | 5555952.6 | opt | 17.8 | 108.1 | 49.5 | 40.2 | 0.260 |
| MDELP | capb1 | 12 | 125.2 | 0.091 | 12656400.5 | opt | 55.9 | 125.3 | 52.3 | 42.9 | 0.238 |
| MDELP | capb1 | 13 | 120.4 | 0.083 | 11778734.6 | opt | 73.5 | 122.0 | 50.0 | 40.8 | 0.233 |
| MDELP | capb1 | 14 | 116.0 | 0.086 | 11452663.1 | opt | 73.7 | 118.3 | 48.0 | 39.4 | 0.231 |
| MDELP | capb1 | 15 | 111.9 | 0.087 | 11011107.6 | opt | 159.4 | 113.4 | 46.0 | 37.1 | 0.230 |
| MDELP | capb1 | 16 | 108.1 | 0.088 | 10459755.8 | opt | 68.7 | 108.8 | 45.1 | 36.2 | 0.235 |
| MELP | capb1 | 12 | 125.2 | ~ | 68043641.8 | opt | 93.5 | 127.2 | 50.2 | 41.1 | 0.225 |
| MELP | capb1 | 13 | 120.4 | ~ | 65622728.7 | opt | 159.5 | 123.6 | 49.1 | 40.7 | 0.227 |
| MELP | capb1 | 14 | 116.0 | ~ | 62164188.8 | opt | 214.6 | 120.1 | 46.7 | 38.6 | 0.222 |
| MELP | capb1 | 15 | 111.9 | ~ | 59480107.2 | opt | 147.2 | 115.5 | 45.8 | 37.5 | 0.226 |
| MELP | capb1 | 16 | 108.1 | ~ | 55031390.2 | opt | 143.7 | 110.3 | 44.8 | 36.6 | 0.232 |
| CPMP | capb1 | 12 | ~ | ~ | 6445140.0 | opt | 537.6 | 125.4 | 52.8 | 43.2 | 0.240 |
| CPMP | capb1 | 13 | ~ | ~ | 6196126.1 | opt | 704.1 | 120.5 | 53.6 | 44.2 | 0.254 |
| CPMP | capb1 | 14 | ~ | ~ | 5967623.3 | opt | 856.5 | 116.1 | 52.0 | 42.7 | 0.256 |
| CPMP | capb1 | 15 | ~ | ~ | 5751877.3 | opt | 747.3 | 111.9 | 50.8 | 41.4 | 0.259 |
| CPMP | capb1 | 16 | ~ | ~ | 5555952.6 | opt | 718.7 | 108.1 | 49.5 | 40.2 | 0.260 |
| CMDELP | capb1 | 12 | 125.4 | 0.090 | 12652978.8 | opt | 1267.0 | 125.5 | 52.5 | 43.1 | 0.239 |
| CMDELP | capb1 | 13 | 120.5 | 0.084 | 11832650.7 | opt | 1384.0 | 123.1 | 49.0 | 40.3 | 0.227 |
| CMDELP | capb1 | 14 | 116.1 | 0.086 | 13987375.0 | opt | 1026.6 | 118.3 | 48.0 | 39.4 | 0.231 |
| CMDELP | capb1 | 15 | 111.9 | 0.087 | 11011107.6 | opt | 958.7 | 113.4 | 46.0 | 37.1 | 0.230 |
| CMDELP | capb1 | 16 | 108.1 | 0.088 | 10459755.8 | opt | 744.6 | 108.8 | 45.1 | 36.2 | 0.235 |
| MECLP | capb1 | 12 | 125.4 | ~ | 68358631.6 | opt | 1418.4 | 127.9 | 50.3 | 41.6 | 0.225 |
| MECLP | capb1 | 13 | 120.5 | ~ | 65481024.2 | opt | 1097.1 | 123.9 | 48.9 | 40.4 | 0.226 |
| MECLP | capb1 | 14 | 116.1 | ~ | 62050757.7 | opt | 1220.5 | 120.2 | 46.7 | 38.6 | 0.222 |
| MECLP | capb1 | 15 | 111.9 | ~ | 59480107.2 | opt | 1154.7 | 115.5 | 45.8 | 37.5 | 0.226 |
| MECLP | capb1 | 16 | 108.1 | ~ | 55031390.2 | opt | 841.6 | 110.3 | 44.8 | 36.5 | 0.231 |

### Table S3: Solutions from the instance Capc1

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | capc1 | 12 | ~ | ~ | 6250683.7 | opt | 15.5 | 122.7 | 53.8 | 44.6 | 0.250 |
| PMP | capc1 | 13 | ~ | ~ | 6003669.9 | opt | 12.9 | 117.9 | 53.4 | 44.6 | 0.259 |
| PMP | capc1 | 14 | ~ | ~ | 5801256.9 | opt | 13.1 | 113.9 | 52.7 | 43.9 | 0.265 |
| PMP | capc1 | 15 | ~ | ~ | 5627996.4 | opt | 25.7 | 110.5 | 51.8 | 43.0 | 0.268 |
| PMP | capc1 | 16 | ~ | ~ | 5455463.4 | opt | 16.6 | 107.1 | 49.8 | 41.3 | 0.265 |
| MDELP | capc1 | 12 | 122.7 | 0.085 | 12100632.3 | opt | 31.3 | 123.5 | 52.4 | 43.0 | 0.243 |
| MDELP | capc1 | 13 | 117.9 | 0.083 | 11380168.9 | opt | 63.6 | 119.6 | 49.8 | 40.8 | 0.238 |
| MDELP | capc1 | 14 | 113.9 | 0.082 | 10714661.3 | opt | 24.1 | 115.4 | 48.0 | 39.4 | 0.237 |
| MDELP | capc1 | 15 | 110.5 | 0.082 | 10357256.7 | opt | 54.7 | 112.3 | 46.0 | 37.2 | 0.233 |
| MDELP | capc1 | 16 | 107.1 | 0.086 | 10098363.2 | opt | 49.4 | 108.7 | 44.8 | 36.6 | 0.235 |
| MELP | capc1 | 12 | 122.7 | ~ | 68373444.9 | opt | 55.6 | 123.5 | 52.4 | 43.0 | 0.243 |
| MELP | capc1 | 13 | 117.9 | ~ | 63727381.1 | opt | 45.8 | 119.6 | 49.8 | 40.8 | 0.238 |
| MELP | capc1 | 14 | 113.9 | ~ | 58975212.1 | opt | 30.0 | 115.5 | 48.4 | 40.0 | 0.239 |
| MELP | capc1 | 15 | 110.5 | ~ | 56508158.6 | opt | 75.6 | 112.6 | 46.0 | 37.8 | 0.233 |
| MELP | capc1 | 16 | 107.1 | ~ | 52915440.9 | opt | 40.5 | 109.8 | 43.7 | 35.6 | 0.226 |
| CPMP | capc1 | 12 | ~ | ~ | 6258882.1 | opt | 731.8 | 122.9 | 54.1 | 44.7 | 0.251 |
| CPMP | capc1 | 13 | ~ | ~ | 6003669.9 | opt | 610.7 | 117.9 | 53.4 | 44.6 | 0.259 |
| CPMP | capc1 | 14 | ~ | ~ | 5801256.9 | opt | 459.0 | 113.9 | 52.7 | 43.9 | 0.265 |
| CPMP | capc1 | 15 | ~ | ~ | 5627996.4 | opt | 682.7 | 110.5 | 51.8 | 43.0 | 0.268 |
| CPMP | capc1 | 16 | ~ | ~ | 5455463.4 | opt | 527.8 | 107.1 | 49.8 | 41.3 | 0.265 |
| CMDELP | capc1 | 12 | 122.9 | 0.084 | 12010424.8 | opt | 853.1 | 123.3 | 52.6 | 43.2 | 0.243 |
| CMDELP | capc1 | 13 | 117.9 | 0.083 | 11316441.5 | opt | 695.8 | 119.6 | 49.8 | 40.8 | 0.238 |
| CMDELP | capc1 | 14 | 113.9 | 0.082 | 10773649.5 | opt | 557.7 | 115.4 | 48.0 | 39.4 | 0.237 |
| CMDELP | capc1 | 15 | 110.5 | 0.082 | 10357256.7 | opt | 720.0 | 112.3 | 46.0 | 37.2 | 0.233 |
| CMDELP | capc1 | 16 | 107.1 | 0.086 | 10098363.2 | opt | 677.5 | 108.7 | 44.8 | 36.6 | 0.235 |
| MECLP | capc1 | 12 | 122.9 | ~ | 68115396.8 | opt | 1173.0 | 123.5 | 52.4 | 43.0 | 0.243 |
| MECLP | capc1 | 13 | 117.9 | ~ | 63727381.1 | opt | 1121.3 | 119.6 | 49.8 | 40.8 | 0.238 |
| MECLP | capc1 | 14 | 113.9 | ~ | 58975212.1 | opt | 574.8 | 115.5 | 48.4 | 40.0 | 0.239 |
| MECLP | capc1 | 15 | 110.5 | ~ | 56508158.6 | opt | 663.3 | 112.6 | 46.0 | 37.8 | 0.233 |
| MECLP | capc1 | 16 | 107.1 | ~ | 52915440.9 | opt | 510.7 | 109.8 | 43.7 | 35.6 | 0.226 |

### Table S4: Solutions from the instance i300\_1

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | i300\_1 | 10 | ~ | ~ | 6596.6 | opt | 8.7 | 1.152 | 0.559 | 0.449 | 0.273 |
| PMP | i300\_1 | 20 | ~ | ~ | 4413.7 | opt | 9.7 | 0.771 | 0.368 | 0.302 | 0.271 |
| PMP | i300\_1 | 30 | ~ | ~ | 3525.1 | opt | 7.5 | 0.616 | 0.319 | 0.254 | 0.291 |
| PMP | i300\_1 | 40 | ~ | ~ | 2983.0 | opt | 9.7 | 0.521 | 0.254 | 0.209 | 0.277 |
| PMP | i300\_1 | 50 | ~ | ~ | 2643.0 | opt | 6.7 | 0.462 | 0.228 | 0.190 | 0.280 |
| MDELP | i300\_1 | 10 | 1.15 | 7.3 | 11599.8 | opt | 19.5 | 1.182 | 0.469 | 0.388 | 0.225 |
| MDELP | i300\_1 | 20 | 0.77 | 11.3 | 7885.8 | opt | 12.0 | 0.797 | 0.304 | 0.247 | 0.216 |
| MDELP | i300\_1 | 30 | 0.61 | 12.1 | 6069.8 | opt | 8.9 | 0.629 | 0.254 | 0.206 | 0.230 |
| MDELP | i300\_1 | 40 | 0.52 | 16.1 | 5460.3 | opt | 14.1 | 0.542 | 0.213 | 0.173 | 0.223 |
| MDELP | i300\_1 | 50 | 0.46 | 17.7 | 4701.0 | opt | 7.0 | 0.474 | 0.193 | 0.160 | 0.231 |
| MELP | i300\_1 | 10 | 1.15 | ~ | 661.7 | opt | 38.1 | 1.182 | 0.469 | 0.388 | 0.225 |
| MELP | i300\_1 | 20 | 0.77 | ~ | 290.0 | opt | 14.8 | 0.805 | 0.292 | 0.234 | 0.205 |
| MELP | i300\_1 | 30 | 0.61 | ~ | 199.7 | opt | 30.3 | 0.657 | 0.235 | 0.187 | 0.201 |
| MELP | i300\_1 | 40 | 0.52 | ~ | 144.2 | opt | 14.1 | 0.552 | 0.203 | 0.164 | 0.209 |
| MELP | i300\_1 | 50 | 0.46 | ~ | 111.6 | opt | 20.7 | 0.479 | 0.189 | 0.156 | 0.224 |
| CPMP | i300\_1 | 36 | ~ | ~ | 3909.7 | 0.94% | 7201.0 | 0.683 | 0.340 | 0.272 | 0.281 |
| CPMP | i300\_1 | 38 | ~ | ~ | 3624.4 | opt | 5467.6 | 0.633 | 0.319 | 0.256 | 0.284 |
| CPMP | i300\_1 | 40 | ~ | ~ | 3416.2 | opt | 150.8 | 0.597 | 0.308 | 0.247 | 0.291 |
| CPMP | i300\_1 | 42 | ~ | ~ | 3278.7 | opt | 53.6 | 0.573 | 0.298 | 0.241 | 0.294 |
| CPMP | i300\_1 | 44 | ~ | ~ | 3166.9 | opt | 45.9 | 0.553 | 0.285 | 0.232 | 0.292 |
| CMDELP | i300\_1 | 36 | 0.68 | 11.8 | 7565.6 | 2.27% | 7201.0 | 0.702 | 0.299 | 0.234 | 0.239 |
| CMDELP | i300\_1 | 38 | 0.63 | 12.4 | 6702.5 | opt | 439.4 | 0.651 | 0.272 | 0.218 | 0.237 |
| CMDELP | i300\_1 | 40 | 0.59 | 12.5 | 6383.6 | opt | 208.3 | 0.615 | 0.269 | 0.222 | 0.249 |
| CMDELP | i300\_1 | 42 | 0.57 | 12.9 | 6048.6 | opt | 249.0 | 0.593 | 0.256 | 0.213 | 0.247 |
| CMDELP | i300\_1 | 44 | 0.55 | 13.6 | 5881.5 | opt | 107.8 | 0.566 | 0.251 | 0.207 | 0.253 |
| CMELP | i300\_1 | 36 | 0.68 | ~ | 299.0 | 5.54% | 7211.4 | 0.706 | 0.297 | 0.238 | 0.239 |
| CMELP | i300\_1 | 38 | 0.63 | ~ | 238.7 | opt | 431.1 | 0.655 | 0.270 | 0.217 | 0.234 |
| CMELP | i300\_1 | 40 | 0.59 | ~ | 229.0 | opt | 428.6 | 0.616 | 0.269 | 0.221 | 0.249 |
| CMELP | i300\_1 | 42 | 0.57 | ~ | 202.5 | opt | 414.6 | 0.608 | 0.245 | 0.202 | 0.230 |
| CMELP | i300\_1 | 44 | 0.55 | ~ | 187.6 | opt | 146.4 | 0.587 | 0.234 | 0.191 | 0.226 |

### Table S5: Solutions from the instance i300\_6

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | i300\_6 | 10 | ~ | ~ | 6684.2 | opt | 8.5 | 1.107 | 0.497 | 0.407 | 0.256 |
| PMP | i300\_6 | 20 | ~ | ~ | 4490.5 | opt | 7.7 | 0.744 | 0.353 | 0.296 | 0.270 |
| PMP | i300\_6 | 30 | ~ | ~ | 3493.0 | opt | 6.8 | 0.579 | 0.292 | 0.240 | 0.286 |
| PMP | i300\_6 | 40 | ~ | ~ | 2975.2 | opt | 7.1 | 0.493 | 0.261 | 0.213 | 0.297 |
| PMP | i300\_6 | 50 | ~ | ~ | 2615.3 | opt | 6.7 | 0.433 | 0.221 | 0.178 | 0.285 |
| MDELP | i300\_6 | 10 | 1.10 | 8.9 | 12556.4 | opt | 10.2 | 1.132 | 0.435 | 0.353 | 0.219 |
| MDELP | i300\_6 | 20 | 0.74 | 11.9 | 8665.6 | opt | 8.0 | 0.761 | 0.325 | 0.275 | 0.245 |
| MDELP | i300\_6 | 30 | 0.57 | 13.6 | 6651.6 | opt | 8.6 | 0.601 | 0.243 | 0.198 | 0.231 |
| MDELP | i300\_6 | 40 | 0.49 | 14.5 | 5533.6 | opt | 7.9 | 0.522 | 0.210 | 0.173 | 0.228 |
| MDELP | i300\_6 | 50 | 0.43 | 17.6 | 5015.4 | opt | 9.5 | 0.447 | 0.189 | 0.156 | 0.241 |
| MELP | i300\_6 | 10 | 1.1 | ~ | 642.7 | opt | 36.1 | 1.134 | 0.435 | 0.352 | 0.218 |
| MELP | i300\_6 | 20 | 0.74 | ~ | 335.6 | opt | 30.2 | 0.778 | 0.310 | 0.259 | 0.228 |
| MELP | i300\_6 | 30 | 0.57 | ~ | 221.4 | opt | 11.0 | 0.613 | 0.233 | 0.186 | 0.215 |
| MELP | i300\_6 | 40 | 0.49 | ~ | 164.1 | opt | 26.4 | 0.522 | 0.210 | 0.173 | 0.228 |
| MELP | i300\_6 | 50 | 0.43 | ~ | 127.8 | opt | 10.7 | 0.462 | 0.178 | 0.147 | 0.219 |
| CPMP | i300\_6 | 22 | ~ | ~ | 4491.6 | opt | 47.3 | 0.744 | 0.354 | 0.291 | 0.270 |
| CPMP | i300\_6 | 24 | ~ | ~ | 4232.6 | opt | 30.4 | 0.701 | 0.341 | 0.279 | 0.275 |
| CPMP | i300\_6 | 26 | ~ | ~ | 4002.5 | opt | 52.5 | 0.663 | 0.325 | 0.267 | 0.279 |
| CPMP | i300\_6 | 28 | ~ | ~ | 3821.3 | opt | 77.3 | 0.633 | 0.324 | 0.263 | 0.289 |
| CPMP | i300\_6 | 30 | ~ | ~ | 3671.5 | opt | 41.6 | 0.608 | 0.307 | 0.250 | 0.285 |
| CMDELP | i300\_6 | 22 | 0.74 | 11.8 | 8992.6 | opt | 104.1 | 0.763 | 0.329 | 0.275 | 0.247 |
| CMDELP | i300\_6 | 24 | 0.70 | 12.0 | 8357.9 | opt | 137.0 | 0.717 | 0.313 | 0.259 | 0.249 |
| CMDELP | i300\_6 | 26 | 0.66 | 12.5 | 7845.3 | opt | 75.8 | 0.675 | 0.300 | 0.244 | 0.253 |
| CMDELP | i300\_6 | 28 | 0.63 | 12.0 | 7138.4 | opt | 53.9 | 0.644 | 0.284 | 0.231 | 0.251 |
| CMDELP | i300\_6 | 30 | 0.60 | 12.9 | 6858.4 | opt | 49.8 | 0.618 | 0.267 | 0.219 | 0.247 |
| CMELP | i300\_6 | 22 | 0.74 | ~ | 369.2 | opt | 160.6 | 0.773 | 0.320 | 0.267 | 0.237 |
| CMELP | i300\_6 | 24 | 0.70 | ~ | 333.7 | opt | 152.9 | 0.724 | 0.307 | 0.253 | 0.242 |
| CMELP | i300\_6 | 26 | 0.66 | ~ | 299.3 | opt | 146.2 | 0.686 | 0.292 | 0.235 | 0.241 |
| CMELP | i300\_6 | 28 | 0.63 | ~ | 266.5 | opt | 118.4 | 0.668 | 0.268 | 0.215 | 0.227 |
| CMELP | i300\_6 | 30 | 0.60 | ~ | 239.7 | opt | 72.5 | 0.629 | 0.258 | 0.207 | 0.233 |

### Table S6: Solutions from the instance i3001500\_1

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | i3001500\_1 | 10 | ~ | ~ | 347899.8 | opt | 76.2 | 12.163 | 5.224 | 4.206 | 0.243 |
| PMP | i3001500\_1 | 20 | ~ | ~ | 238254.3 | opt | 52.1 | 8.330 | 3.513 | 2.900 | 0.241 |
| PMP | i3001500\_1 | 30 | ~ | ~ | 194664.3 | opt | 76.4 | 6.806 | 2.860 | 2.307 | 0.239 |
| PMP | i3001500\_1 | 40 | ~ | ~ | 169842.5 | opt | 108.4 | 5.938 | 2.541 | 2.067 | 0.243 |
| PMP | i3001500\_1 | 50 | ~ | ~ | 151867.8 | opt | 73.5 | 5.310 | 2.328 | 1.901 | 0.250 |
| MDELP | i3001500\_1 | 10 | 12.16 | 0.8 | 596242.9 | opt | 270.8 | 12.416 | 4.570 | 3.744 | 0.210 |
| MDELP | i3001500\_1 | 20 | 8.32 | 1.3 | 451113.5 | opt | 1447.5 | 8.482 | 3.333 | 2.742 | 0.224 |
| MDELP | i3001500\_1 | 30 | 6.80 | 1.6 | 359226.6 | opt | 422.6 | 6.864 | 2.658 | 2.165 | 0.220 |
| MDELP | i3001500\_1 | 40 | 5.93 | 1.8 | 308053.3 | opt | 221.4 | 6.001 | 2.313 | 1.904 | 0.220 |
| MDELP | i3001500\_1 | 50 | 5.30 | 1.9 | 276205.4 | opt | 332.0 | 5.414 | 2.067 | 1.687 | 0.217 |
| MELP | i3001500\_1 | 10 | 12.16 | ~ | 301407.0 | opt | 208.6 | 12.416 | 4.570 | 3.744 | 0.210 |
| MELP | i3001500\_1 | 20 | 8.32 | ~ | 160020.6 | opt | 1238.1 | 8.516 | 3.292 | 2.699 | 0.220 |
| MELP | i3001500\_1 | 30 | 6.8 | ~ | 100921.3 | opt | 506.8 | 6.934 | 2.645 | 2.145 | 0.217 |
| MELP | i3001500\_1 | 40 | 5.93 | ~ | 75610.4 | opt | 475.9 | 6.018 | 2.299 | 1.882 | 0.218 |
| MELP | i3001500\_1 | 50 | 5.3 | ~ | 63503.3 | opt | 195.5 | 5.468 | 2.024 | 1.652 | 0.211 |
| CPMP | i3001500\_1 | 100 | ~ | ~ | 111856.8 | opt | 228.0 | 3.911 | 1.799 | 1.463 | 0.261 |
| CPMP | i3001500\_1 | 105 | ~ | ~ | 109576.7 | opt | 176.5 | 3.831 | 1.776 | 1.445 | 0.263 |
| CPMP | i3001500\_1 | 110 | ~ | ~ | 107492.9 | opt | 133.2 | 3.758 | 1.757 | 1.430 | 0.265 |
| CPMP | i3001500\_1 | 115 | ~ | ~ | 105550.9 | opt | 120.8 | 3.690 | 1.729 | 1.400 | 0.265 |
| CPMP | i3001500\_1 | 120 | ~ | ~ | 103849.7 | opt | 95.3 | 3.631 | 1.693 | 1.367 | 0.264 |
| CMDELP | i3001500\_1 | 100 | 3.91 | 2.4 | 217689.3 | opt | 176.7 | 3.989 | 1.670 | 1.358 | 0.238 |
| CMDELP | i3001500\_1 | 105 | 3.83 | 2.4 | 212084.5 | opt | 152.3 | 3.891 | 1.654 | 1.344 | 0.241 |
| CMDELP | i3001500\_1 | 110 | 3.75 | 2.4 | 207429.7 | opt | 103.4 | 3.807 | 1.633 | 1.318 | 0.243 |
| CMDELP | i3001500\_1 | 115 | 3.69 | 2.4 | 201307.3 | opt | 90.2 | 3.736 | 1.606 | 1.296 | 0.243 |
| CMDELP | i3001500\_1 | 120 | 3.63 | 2.5 | 201697.4 | opt | 76.8 | 3.690 | 1.575 | 1.269 | 0.241 |
| CMELP | i3001500\_1 | 100 | 3.91 | ~ | 43102.5 | opt | 236.1 | 4.005 | 1.656 | 1.346 | 0.235 |
| CMELP | i3001500\_1 | 105 | 3.83 | ~ | 41907.6 | opt | 130.6 | 3.910 | 1.637 | 1.327 | 0.237 |
| CMELP | i3001500\_1 | 110 | 3.75 | ~ | 40896.4 | opt | 205.8 | 3.857 | 1.597 | 1.285 | 0.234 |
| CMELP | i3001500\_1 | 115 | 3.69 | ~ | 39141.8 | opt | 118.7 | 3.774 | 1.574 | 1.268 | 0.236 |
| CMELP | i3001500\_1 | 120 | 3.63 | ~ | 38403.6 | opt | 105.8 | 3.721 | 1.551 | 1.242 | 0.235 |

### Table S7: Solutions from the instance i3001500\_6

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | i3001500\_6 | 10 | ~ | ~ | 358628.0 | opt | 78.0 | 12.134 | 4.823 | 3.945 | 0.227 |
| PMP | i3001500\_6 | 20 | ~ | ~ | 248351.0 | opt | 78.8 | 8.403 | 3.571 | 2.946 | 0.243 |
| PMP | i3001500\_6 | 30 | ~ | ~ | 201462.3 | opt | 60.4 | 6.817 | 3.029 | 2.474 | 0.253 |
| PMP | i3001500\_6 | 40 | ~ | ~ | 175256.3 | opt | 60.6 | 5.930 | 2.540 | 2.093 | 0.245 |
| PMP | i3001500\_6 | 50 | ~ | ~ | 157304.0 | opt | 69.3 | 5.322 | 2.346 | 1.924 | 0.251 |
| MDELP | i3001500\_6 | 10 | 12.13 | 1.0 | 670089.4 | opt | 817.1 | 12.156 | 4.720 | 3.883 | 0.222 |
| MDELP | i3001500\_6 | 20 | 8.40 | 1.3 | 471953.7 | opt | 837.3 | 8.555 | 3.373 | 2.786 | 0.225 |
| MDELP | i3001500\_6 | 30 | 6.81 | 1.4 | 369852.1 | opt | 591.4 | 6.916 | 2.816 | 2.333 | 0.233 |
| MDELP | i3001500\_6 | 40 | 5.92 | 1.8 | 330593.1 | opt | 561.8 | 6.014 | 2.374 | 1.953 | 0.225 |
| MDELP | i3001500\_6 | 50 | 5.32 | 1.9 | 293936.5 | opt | 326.0 | 5.425 | 2.142 | 1.752 | 0.225 |
| MELP | i3001500\_6 | 10 | 12.13 | ~ | 308755.2 | opt | 717.3 | 12.233 | 4.608 | 3.786 | 0.215 |
| MELP | i3001500\_6 | 20 | 8.4 | ~ | 168537.6 | opt | 705.9 | 8.555 | 3.373 | 2.786 | 0.225 |
| MELP | i3001500\_6 | 30 | 6.81 | ~ | 116556.2 | opt | 409.3 | 7.022 | 2.735 | 2.242 | 0.222 |
| MELP | i3001500\_6 | 40 | 5.92 | ~ | 84911.7 | opt | 464.5 | 6.014 | 2.374 | 1.953 | 0.225 |
| MELP | i3001500\_6 | 50 | 5.32 | ~ | 70010.4 | opt | 403.3 | 5.456 | 2.105 | 1.716 | 0.220 |
| CPMP | i3001500\_6 | 50 | ~ | ~ | 159125.0 | opt | 3934.4 | 5.384 | 2.440 | 1.992 | 0.258 |
| CPMP | i3001500\_6 | 53 | ~ | ~ | 154635.2 | opt | 2110.9 | 5.232 | 2.330 | 1.907 | 0.254 |
| CPMP | i3001500\_6 | 56 | ~ | ~ | 150513.7 | opt | 3220.1 | 5.093 | 2.279 | 1.865 | 0.255 |
| CPMP | i3001500\_6 | 59 | ~ | ~ | 146532.5 | opt | 1893.0 | 4.958 | 2.245 | 1.827 | 0.257 |
| CPMP | i3001500\_6 | 62 | ~ | ~ | 143012.1 | opt | 2535.0 | 4.839 | 2.192 | 1.787 | 0.258 |
| CMDELP | i3001500\_6 | 50 | 5.38 | 1.8 | 299391.7 | opt | 1611.4 | 5.512 | 2.208 | 1.358 | 0.229 |
| CMDELP | i3001500\_6 | 53 | 5.23 | 1.9 | 290629.7 | opt | 1903.7 | 5.330 | 2.178 | 1.347 | 0.234 |
| CMDELP | i3001500\_6 | 56 | 5.09 | 2.0 | 291828.3 | opt | 3565.9 | 5.200 | 2.117 | 1.343 | 0.233 |
| CMDELP | i3001500\_6 | 59 | 4.96 | 2.0 | 281882.6 | opt | 2234.3 | 5.043 | 2.065 | 1.342 | 0.234 |
| CMDELP | i3001500\_6 | 62 | 4.84 | 2.0 | 270590.3 | opt | 2777.0 | 4.910 | 2.018 | 1.332 | 0.235 |
| CMELP | i3001500\_6 | 50 | 5.38 | ~ | 75780.8 | opt | 2726.3 | 5.563 | 2.166 | 1.781 | 0.222 |
| CMELP | i3001500\_6 | 53 | 5.23 | ~ | 72654.4 | opt | 4729.5 | 5.383 | 2.148 | 1.771 | 0.228 |
| CMELP | i3001500\_6 | 56 | 5.09 | ~ | 69072.6 | opt | 2976.3 | 5.204 | 2.114 | 1.745 | 0.232 |
| CMELP | i3001500\_6 | 59 | 4.96 | ~ | 65354.4 | opt | 1241.6 | 5.047 | 2.063 | 1.694 | 0.233 |
| CMELP | i3001500\_6 | 62 | 4.84 | ~ | 62512.9 | opt | 1066.8 | 4.931 | 2.006 | 1.637 | 0.232 |

### Table S8: Solutions from the instance i500\_1

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | i500\_1 | 10 | ~ | ~ | 11029.3 | opt | 25.8 | 1.138 | 0.513 | 0.416 | 0.257 |
| PMP | i500\_1 | 20 | ~ | ~ | 7614.5 | opt | 27.8 | 0.785 | 0.394 | 0.324 | 0.287 |
| PMP | i500\_1 | 30 | ~ | ~ | 5937.0 | opt | 21.1 | 0.612 | 0.312 | 0.256 | 0.288 |
| PMP | i500\_1 | 40 | ~ | ~ | 5029.1 | opt | 21.2 | 0.519 | 0.273 | 0.222 | 0.297 |
| PMP | i500\_1 | 50 | ~ | ~ | 4393.8 | opt | 20.3 | 0.453 | 0.244 | 0.195 | 0.301 |
| MDELP | i500\_1 | 10 | 1.13 | 8.6 | 21102.2 | opt | 37.1 | 1.149 | 0.488 | 0.406 | 0.243 |
| MDELP | i500\_1 | 20 | 0.78 | 10.1 | 13562.7 | opt | 64.2 | 0.815 | 0.320 | 0.260 | 0.223 |
| MDELP | i500\_1 | 30 | 0.61 | 12.6 | 10957.2 | opt | 39.4 | 0.633 | 0.269 | 0.225 | 0.243 |
| MDELP | i500\_1 | 40 | 0.51 | 13.8 | 9397.3 | opt | 38.1 | 0.542 | 0.221 | 0.183 | 0.233 |
| MDELP | i500\_1 | 50 | 0.45 | 15.2 | 8013.6 | opt | 25.5 | 0.469 | 0.198 | 0.161 | 0.239 |
| MELP | i500\_1 | 10 | 1.13 | ~ | 1158.0 | opt | 67.0 | 1.149 | 0.488 | 0.406 | 0.243 |
| MELP | i500\_1 | 20 | 0.78 | ~ | 558.8 | opt | 66.9 | 0.823 | 0.317 | 0.260 | 0.218 |
| MELP | i500\_1 | 30 | 0.61 | ~ | 374.1 | opt | 45.7 | 0.650 | 0.250 | 0.206 | 0.219 |
| MELP | i500\_1 | 40 | 0.51 | ~ | 299.6 | opt | 61.7 | 0.543 | 0.221 | 0.182 | 0.232 |
| MELP | i500\_1 | 50 | 0.45 | ~ | 226.6 | opt | 35.8 | 0.476 | 0.195 | 0.158 | 0.232 |
| CPMP | i500\_1 | 70 | ~ | ~ | 4357.7 | 1.04% | 7200.9 | 0.449 | 0.247 | 0.200 | 0.305 |
| CPMP | i500\_1 | 73 | ~ | ~ | 4190.1 | 0.40% | 7200.8 | 0.432 | 0.238 | 0.189 | 0.305 |
| CPMP | i500\_1 | 76 | ~ | ~ | 4047.6 | opt | 5772.4 | 0.417 | 0.224 | 0.178 | 0.296 |
| CPMP | i500\_1 | 79 | ~ | ~ | 3921.4 | opt | 1415.7 | 0.404 | 0.222 | 0.178 | 0.303 |
| CPMP | i500\_1 | 82 | ~ | ~ | 3811.1 | opt | 426.9 | 0.393 | 0.217 | 0.175 | 0.306 |
| CMDELP | i500\_1 | 70 | 0.44 | 14.7 | 8496.7 | 5.83% | 7201.9 | 0.471 | 0.204 | 0.169 | 0.246 |
| CMDELP | i500\_1 | 73 | 0.43 | 15.2 | 7854.2 | 3.25% | 7201.1 | 0.452 | 0.196 | 0.162 | 0.247 |
| CMDELP | i500\_1 | 76 | 0.41 | 16.5 | 7863.4 | 2.37% | 7201.3 | 0.434 | 0.189 | 0.156 | 0.247 |
| CMDELP | i500\_1 | 79 | 0.40 | 16.4 | 7412.3 | 1.45% | 7201.2 | 0.423 | 0.182 | 0.150 | 0.245 |
| CMDELP | i500\_1 | 82 | 0.39 | 16.6 | 7147.2 | 0.70% | 7200.7 | 0.412 | 0.177 | 0.145 | 0.244 |
| CMELP | i500\_1 | 70 | 0.44 | ~ | 264.7 | 11.01% | 7219.7 | 0.476 | 0.203 | 0.166 | 0.242 |
| CMELP | i500\_1 | 73 | 0.43 | ~ | 224.2 | 5.33% | 7225.8 | 0.456 | 0.191 | 0.159 | 0.238 |
| CMELP | i500\_1 | 76 | 0.41 | ~ | 217.4 | 3.02% | 7223.5 | 0.440 | 0.185 | 0.152 | 0.240 |
| CMELP | i500\_1 | 79 | 0.40 | ~ | 199.6 | 2.20% | 7222.1 | 0.429 | 0.178 | 0.146 | 0.236 |
| CMELP | i500\_1 | 82 | 0.39 | ~ | 188.1 | 1.52% | 7220.2 | 0.417 | 0.173 | 0.143 | 0.237 |

### Table S9: Solutions from the instance i500\_6

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | i500\_6 | 10 | ~ | ~ | 11936.5 | opt | 45.5 | 1.166 | 0.521 | 0.442 | 0.257 |
| PMP | i500\_6 | 20 | ~ | ~ | 8189.5 | opt | 39.4 | 0.800 | 0.386 | 0.311 | 0.273 |
| PMP | i500\_6 | 30 | ~ | ~ | 6445.8 | opt | 32.6 | 0.630 | 0.304 | 0.249 | 0.274 |
| PMP | i500\_6 | 40 | ~ | ~ | 5421.8 | opt | 21.0 | 0.530 | 0.270 | 0.223 | 0.290 |
| PMP | i500\_6 | 50 | ~ | ~ | 4755.3 | opt | 21.1 | 0.465 | 0.234 | 0.189 | 0.285 |
| MDELP | i500\_6 | 10 | 1.16 | 8.5 | 21242.3 | opt | 34.6 | 1.203 | 0.423 | 0.346 | 0.201 |
| MDELP | i500\_6 | 20 | 0.80 | 10.7 | 14065.2 | opt | 60.8 | 0.822 | 0.312 | 0.256 | 0.216 |
| MDELP | i500\_6 | 30 | 0.62 | 13.6 | 11976.2 | opt | 192.7 | 0.641 | 0.265 | 0.219 | 0.236 |
| MDELP | i500\_6 | 40 | 0.52 | 14.4 | 10061.7 | opt | 55.9 | 0.553 | 0.219 | 0.180 | 0.225 |
| MDELP | i500\_6 | 50 | 0.46 | 16.9 | 9051.5 | opt | 58.5 | 0.480 | 0.204 | 0.167 | 0.242 |
| MELP | i500\_6 | 10 | 1.16 | ~ | 1051.0 | opt | 51.7 | 1.203 | 0.423 | 0.346 | 0.201 |
| MELP | i500\_6 | 20 | 0.8 | ~ | 527.8 | opt | 45.0 | 0.822 | 0.312 | 0.256 | 0.216 |
| MELP | i500\_6 | 30 | 0.62 | ~ | 396.2 | opt | 45.9 | 0.645 | 0.263 | 0.216 | 0.233 |
| MELP | i500\_6 | 40 | 0.52 | ~ | 304.4 | opt | 67.8 | 0.555 | 0.217 | 0.177 | 0.222 |
| MELP | i500\_6 | 50 | 0.46 | ~ | 237.6 | opt | 43.0 | 0.493 | 0.189 | 0.151 | 0.216 |
| CPMP | i500\_6 | 36 | ~ | ~ | 6055.5 | opt | 697.0 | 0.592 | 0.307 | 0.256 | 0.296 |
| CPMP | i500\_6 | 38 | ~ | ~ | 5827.5 | opt | 441.0 | 0.569 | 0.298 | 0.249 | 0.298 |
| CPMP | i500\_6 | 40 | ~ | ~ | 5625.9 | opt | 217.3 | 0.550 | 0.291 | 0.242 | 0.301 |
| CPMP | i500\_6 | 42 | ~ | ~ | 5448.8 | opt | 117.0 | 0.532 | 0.281 | 0.234 | 0.300 |
| CPMP | i500\_6 | 44 | ~ | ~ | 5285.1 | opt | 192.0 | 0.516 | 0.270 | 0.222 | 0.297 |
| CMDELP | i500\_6 | 36 | 0.59 | 12.5 | 11050.8 | opt | 816.9 | 0.607 | 0.262 | 0.217 | 0.247 |
| CMDELP | i500\_6 | 38 | 0.56 | 12.8 | 10901.0 | opt | 911.1 | 0.589 | 0.250 | 0.206 | 0.242 |
| CMDELP | i500\_6 | 40 | 0.54 | 12.9 | 10472.9 | opt | 830.7 | 0.571 | 0.241 | 0.200 | 0.241 |
| CMDELP | i500\_6 | 42 | 0.53 | 13.4 | 9993.8 | opt | 513.4 | 0.556 | 0.231 | 0.190 | 0.236 |
| CMDELP | i500\_6 | 44 | 0.51 | 14.1 | 9902.7 | opt | 260.2 | 0.532 | 0.229 | 0.187 | 0.245 |
| CMELP | i500\_6 | 36 | 0.59 | ~ | 381.7 | opt | 984.9 | 0.614 | 0.254 | 0.210 | 0.237 |
| CMELP | i500\_6 | 38 | 0.56 | ~ | 380.6 | opt | 1601.3 | 0.589 | 0.250 | 0.206 | 0.242 |
| CMELP | i500\_6 | 40 | 0.54 | ~ | 358.7 | opt | 680.7 | 0.571 | 0.241 | 0.200 | 0.241 |
| CMELP | i500\_6 | 42 | 0.53 | ~ | 320.6 | opt | 632.3 | 0.557 | 0.231 | 0.190 | 0.237 |
| CMELP | i500\_6 | 44 | 0.51 | ~ | 311.1 | opt | 254.7 | 0.542 | 0.223 | 0.183 | 0.234 |

### Table S10: Solutions from the instance i700\_1

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | i700\_1 | 10 | ~ | ~ | 16017.3 | opt | 130.3 | 1.184 | 0.515 | 0.417 | 0.247 |
| PMP | i700\_1 | 20 | ~ | ~ | 10778.7 | opt | 56.2 | 0.797 | 0.368 | 0.305 | 0.265 |
| PMP | i700\_1 | 30 | ~ | ~ | 8597.8 | opt | 62.7 | 0.636 | 0.316 | 0.260 | 0.283 |
| PMP | i700\_1 | 40 | ~ | ~ | 7295.3 | opt | 43.2 | 0.539 | 0.274 | 0.222 | 0.288 |
| PMP | i700\_1 | 50 | ~ | ~ | 6423.5 | opt | 55.3 | 0.475 | 0.238 | 0.193 | 0.283 |
| MDELP | i700\_1 | 10 | 1.18 | 8.9 | 29148.3 | opt | 385.2 | 1.215 | 0.447 | 0.373 | 0.210 |
| MDELP | i700\_1 | 20 | 0.79 | 11.7 | 19556.2 | opt | 507.8 | 0.823 | 0.308 | 0.248 | 0.212 |
| MDELP | i700\_1 | 30 | 0.63 | 12.7 | 15342.1 | opt | 255.7 | 0.657 | 0.256 | 0.209 | 0.221 |
| MDELP | i700\_1 | 40 | 0.53 | 14.3 | 13184.0 | opt | 217.8 | 0.554 | 0.225 | 0.185 | 0.232 |
| MDELP | i700\_1 | 50 | 0.47 | 16.7 | 11731.7 | opt | 144.8 | 0.492 | 0.197 | 0.161 | 0.228 |
| MELP | i700\_1 | 10 | 1.18 | ~ | 1428.9 | opt | 91.9 | 1.215 | 0.447 | 0.373 | 0.210 |
| MELP | i700\_1 | 20 | 0.79 | ~ | 719.1 | opt | 130.3 | 0.829 | 0.302 | 0.244 | 0.207 |
| MELP | i700\_1 | 30 | 0.63 | ~ | 500.6 | opt | 298.2 | 0.671 | 0.246 | 0.198 | 0.207 |
| MELP | i700\_1 | 40 | 0.53 | ~ | 389.4 | opt | 166.6 | 0.564 | 0.217 | 0.178 | 0.219 |
| MELP | i700\_1 | 50 | 0.47 | ~ | 303.2 | opt | 202.5 | 0.494 | 0.195 | 0.160 | 0.225 |
| CPMP | i700\_1 | 95 | ~ | ~ | 5266.9 | 1.15% | 7201.7 | 0.389 | 0.209 | 0.173 | 0.303 |
| CPMP | i700\_1 | 100 | ~ | ~ | 5038.2 | 0.45% | 7201.2 | 0.373 | 0.196 | 0.162 | 0.297 |
| CPMP | i700\_1 | 105 | ~ | ~ | 4850.4 | opt | 1831.3 | 0.359 | 0.186 | 0.156 | 0.296 |
| CPMP | i700\_1 | 110 | ~ | ~ | 4695.5 | opt | 1288.6 | 0.347 | 0.183 | 0.154 | 0.300 |
| CPMP | i700\_1 | 115 | ~ | ~ | 4562.0 | opt | 1103.4 | 0.337 | 0.175 | 0.145 | 0.295 |
| CMDELP | i700\_1 | 95 | 0.38 | 17.8 | 10223.1 | 5.51% | 7201.1 | 0.408 | 0.176 | 0.146 | 0.246 |
| CMDELP | i700\_1 | 100 | 0.37 | 19.4 | 9712.8 | 4.16% | 7201.5 | 0.388 | 0.171 | 0.143 | 0.252 |
| CMDELP | i700\_1 | 105 | 0.35 | 20.6 | 9522.6 | 0.49% | 7201.9 | 0.372 | 0.162 | 0.134 | 0.248 |
| CMDELP | i700\_1 | 110 | 0.34 | 20.7 | 9071.1 | 0.59% | 7200.9 | 0.361 | 0.157 | 0.129 | 0.247 |
| CMDELP | i700\_1 | 115 | 0.33 | 21.9 | 8954.1 | 0.76% | 7201.6 | 0.353 | 0.152 | 0.126 | 0.245 |
| CMELP | i700\_1 | 95 | 0.38 | ~ | 260.3 | 9.92% | 7228.4 | 0.409 | 0.174 | 0.144 | 0.243 |
| CMELP | i700\_1 | 100 | 0.37 | ~ | 224.3 | 6.73% | 7237.8 | 0.392 | 0.166 | 0.138 | 0.242 |
| CMELP | i700\_1 | 105 | 0.35 | ~ | 217.5 | 3.07% | 7264.8 | 0.374 | 0.159 | 0.132 | 0.243 |
| CMELP | i700\_1 | 110 | 0.34 | ~ | 200.3 | 1.70% | 7234.3 | 0.366 | 0.152 | 0.125 | 0.236 |
| CMELP | i700\_1 | 115 | 0.33 | ~ | 189.7 | 2.07% | 7242.9 | 0.358 | 0.147 | 0.121 | 0.233 |

### Table S11: Solutions from the instance i700\_6

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | i700\_6 | 10 | ~ | ~ | 15872.9 | opt | 131.0 | 1.169 | 0.484 | 0.400 | 0.237 |
| PMP | i700\_6 | 20 | ~ | ~ | 10977.6 | opt | 89.6 | 0.808 | 0.380 | 0.314 | 0.268 |
| PMP | i700\_6 | 30 | ~ | ~ | 8669.8 | opt | 46.9 | 0.639 | 0.295 | 0.243 | 0.264 |
| PMP | i700\_6 | 40 | ~ | ~ | 7393.7 | opt | 46.1 | 0.545 | 0.269 | 0.223 | 0.282 |
| PMP | i700\_6 | 50 | ~ | ~ | 6497.1 | opt | 49.2 | 0.478 | 0.246 | 0.199 | 0.290 |
| MDELP | i700\_6 | 10 | 1.16 | 9.9 | 29997.4 | opt | 132.2 | 1.178 | 0.457 | 0.379 | 0.221 |
| MDELP | i700\_6 | 20 | 0.80 | 11.2 | 19642.2 | opt | 248.9 | 0.829 | 0.323 | 0.263 | 0.221 |
| MDELP | i700\_6 | 30 | 0.63 | 14.6 | 16132.7 | opt | 74.4 | 0.656 | 0.259 | 0.212 | 0.225 |
| MDELP | i700\_6 | 40 | 0.54 | 15.0 | 13226.7 | opt | 162.3 | 0.562 | 0.222 | 0.182 | 0.224 |
| MDELP | i700\_6 | 50 | 0.47 | 15.8 | 11674.7 | opt | 76.6 | 0.495 | 0.196 | 0.158 | 0.225 |
| MELP | i700\_6 | 10 | 1.16 | ~ | 1414.0 | opt | 122.6 | 1.178 | 0.457 | 0.379 | 0.221 |
| MELP | i700\_6 | 20 | 0.80 | ~ | 745.4 | opt | 651.9 | 0.833 | 0.321 | 0.261 | 0.219 |
| MELP | i700\_6 | 30 | 0.63 | ~ | 494.7 | opt | 195.8 | 0.657 | 0.258 | 0.211 | 0.223 |
| MELP | i700\_6 | 40 | 0.54 | ~ | 369.8 | opt | 184.4 | 0.568 | 0.217 | 0.176 | 0.215 |
| MELP | i700\_6 | 50 | 0.47 | ~ | 312.6 | opt | 140.3 | 0.502 | 0.193 | 0.157 | 0.218 |
| CPMP | i700\_6 | 50 | ~ | ~ | 6955.9 | 0.43% | 7201.2 | 0.512 | 0.242 | 0.198 | 0.269 |
| CPMP | i700\_6 | 53 | ~ | ~ | 6676.4 | opt | 5255.0 | 0.492 | 0.234 | 0.191 | 0.271 |
| CPMP | i700\_6 | 56 | ~ | ~ | 6448.1 | opt | 2506.8 | 0.475 | 0.229 | 0.187 | 0.273 |
| CPMP | i700\_6 | 59 | ~ | ~ | 6248.4 | opt | 2539.3 | 0.460 | 0.226 | 0.184 | 0.278 |
| CPMP | i700\_6 | 62 | ~ | ~ | 6076.0 | opt | 1295.5 | 0.447 | 0.223 | 0.181 | 0.282 |
| CMDELP | i700\_6 | 50 | 0.51 | 17.5 | 13447.7 | 0.54% | 7201.0 | 0.531 | 0.215 | 0.176 | 0.231 |
| CMDELP | i700\_6 | 53 | 0.49 | 17.8 | 12910.8 | 0.65% | 7201.1 | 0.506 | 0.210 | 0.172 | 0.237 |
| CMDELP | i700\_6 | 56 | 0.47 | 18.1 | 12312.8 | opt | 2017.4 | 0.488 | 0.201 | 0.164 | 0.234 |
| CMDELP | i700\_6 | 59 | 0.46 | 18.0 | 11560.8 | opt | 1760.9 | 0.478 | 0.192 | 0.158 | 0.229 |
| CMDELP | i700\_6 | 62 | 0.44 | 18.0 | 11412.2 | opt | 3578.1 | 0.462 | 0.188 | 0.155 | 0.232 |
| CMELP | i700\_6 | 50 | 0.51 | ~ | 356.5 | 1.13% | 7271.6 | 0.532 | 0.214 | 0.175 | 0.229 |
| CMELP | i700\_6 | 53 | 0.49 | ~ | 336.2 | 3.19% | 7231.7 | 0.517 | 0.204 | 0.167 | 0.224 |
| CMELP | i700\_6 | 56 | 0.47 | ~ | 313.7 | opt | 3147.8 | 0.491 | 0.198 | 0.163 | 0.230 |
| CMELP | i700\_6 | 59 | 0.46 | ~ | 281.8 | opt | 2973.5 | 0.480 | 0.191 | 0.157 | 0.227 |
| CMELP | i700\_6 | 62 | 0.44 | ~ | 284.0 | 0.94% | 7228.7 | 0.467 | 0.184 | 0.153 | 0.225 |

### Table S12: Solutions from the instance i1000\_1

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | i1000\_1 | 10 | ~ | ~ | 22574.9 | opt | 759.8 | 1.195 | 0.478 | 0.391 | 0.228 |
| PMP | i1000\_1 | 20 | ~ | ~ | 15449.4 | opt | 237.1 | 0.818 | 0.368 | 0.298 | 0.256 |
| PMP | i1000\_1 | 30 | ~ | ~ | 12237.4 | opt | 161.2 | 0.648 | 0.291 | 0.237 | 0.255 |
| PMP | i1000\_1 | 40 | ~ | ~ | 10462.2 | opt | 214.8 | 0.554 | 0.256 | 0.210 | 0.263 |
| PMP | i1000\_1 | 50 | ~ | ~ | 9212.9 | opt | 262.4 | 0.488 | 0.231 | 0.190 | 0.269 |
| MDELP | i1000\_1 | 10 | 1.19 | 10.4 | 42263.6 | opt | 313.7 | 1.207 | 0.449 | 0.370 | 0.212 |
| MDELP | i1000\_1 | 20 | 0.81 | 12.0 | 28129.4 | opt | 3607.7 | 0.844 | 0.309 | 0.258 | 0.208 |
| MDELP | i1000\_1 | 30 | 0.64 | 15.3 | 23042.7 | opt | 957.6 | 0.671 | 0.248 | 0.203 | 0.210 |
| MDELP | i1000\_1 | 40 | 0.55 | 16.9 | 18671.4 | opt | 688.4 | 0.571 | 0.215 | 0.176 | 0.213 |
| MDELP | i1000\_1 | 50 | 0.48 | 18.3 | 17004.5 | opt | 1958.2 | 0.505 | 0.191 | 0.156 | 0.215 |
| MELP | i1000\_1 | 10 | 1.19 | ~ | 1870.7 | opt | 236.6 | 1.207 | 0.449 | 0.370 | 0.212 |
| MELP | i1000\_1 | 20 | 0.81 | ~ | 1014.4 | opt | 1569.7 | 0.845 | 0.307 | 0.248 | 0.206 |
| MELP | i1000\_1 | 30 | 0.64 | ~ | 677.5 | opt | 1091.1 | 0.671 | 0.248 | 0.203 | 0.210 |
| MELP | i1000\_1 | 40 | 0.55 | ~ | 464.6 | opt | 501.9 | 0.574 | 0.212 | 0.174 | 0.209 |
| MELP | i1000\_1 | 50 | 0.48 | ~ | 407.1 | opt | 1280.4 | 0.508 | 0.189 | 0.153 | 0.211 |
| CPMP | i1000\_1 | 140 | ~ | ~ | 5876.1 | 1.16% | 7204.7 | 0.311 | 0.161 | 0.135 | 0.289 |
| CPMP | i1000\_1 | 145 | ~ | ~ | 5709.3 | 0.94% | 7200.5 | 0.302 | 0.160 | 0.126 | 0.295 |
| CPMP | i1000\_1 | 150 | ~ | ~ | 5557.0 | 0.61% | 7201.7 | 0.294 | 0.157 | 0.122 | 0.297 |
| CPMP | i1000\_1 | 155 | ~ | ~ | 5418.3 | 0.09% | 7203.5 | 0.287 | 0.153 | 0.122 | 0.298 |
| CPMP | i1000\_1 | 160 | ~ | ~ | 5301.6 | opt | 4337.4 | 0.287 | 0.153 | 0.121 | 0.298 |
| CMDELP | i1000\_1 | 140 | 0.31 | 24.1 | 10981.5 | 5.42% | 7203.6 | 0.322 | 0.136 | 0.110 | 0.238 |
| CMDELP | i1000\_1 | 145 | 0.30 | 23.6 | 10414.8 | 3.87% | 7207.2 | 0.313 | 0.132 | 0.104 | 0.237 |
| CMDELP | i1000\_1 | 150 | 0.29 | 23.9 | 10193.7 | 2.13% | 7202.3 | 0.305 | 0.128 | 0.100 | 0.234 |
| CMDELP | i1000\_1 | 155 | 0.28 | 24.4 | 10104.4 | 1.15% | 7201.8 | 0.298 | 0.126 | 0.100 | 0.237 |
| CMDELP | i1000\_1 | 160 | 0.28 | 24.4 | 9537.3 | 1.12% | 7201.5 | 0.292 | 0.123 | 0.098 | 0.236 |
| CMELP | i1000\_1 | 140 | 0.31 | ~ | 198.8 | 10.03% | 7256.9 | 0.328 | 0.131 | 0.105 | 0.225 |
| CMELP | i1000\_1 | 145 | 0.30 | ~ | 193.3 | 10.18% | 7265.5 | 0.321 | 0.126 | 0.099 | 0.219 |
| CMELP | i1000\_1 | 150 | 0.29 | ~ | 184.5 | 5.19% | 7271.9 | 0.310 | 0.124 | 0.097 | 0.225 |
| CMELP | i1000\_1 | 155 | 0.28 | ~ | 181.9 | 2.69% | 7264.5 | 0.303 | 0.122 | 0.096 | 0.226 |
| CMELP | i1000\_1 | 160 | 0.28 | ~ | 163.0 | 3.20% | 7303.5 | 0.298 | 0.118 | 0.093 | 0.223 |

### Table S13: Solutions from the instance i1000\_6

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | i1000\_6 | 10 | ~ | ~ | 23651.4 | opt | 263.3 | 1.191 | 0.512 | 0.419 | 0.245 |
| PMP | i1000\_6 | 20 | ~ | ~ | 16093.6 | opt | 255.6 | 0.810 | 0.366 | 0.305 | 0.259 |
| PMP | i1000\_6 | 30 | ~ | ~ | 12915.4 | opt | 224.4 | 0.650 | 0.304 | 0.245 | 0.264 |
| PMP | i1000\_6 | 40 | ~ | ~ | 10877.1 | opt | 262.9 | 0.548 | 0.255 | 0.211 | 0.265 |
| PMP | i1000\_6 | 50 | ~ | ~ | 9519.1 | opt | 169.3 | 0.479 | 0.234 | 0.193 | 0.278 |
| MDELP | i1000\_6 | 10 | 1.19 | 9.0 | 41581.4 | opt | 455.0 | 1.199 | 0.458 | 0.376 | 0.217 |
| MDELP | i1000\_6 | 20 | 0.81 | 12.1 | 29417.7 | opt | 3383.3 | 0.826 | 0.327 | 0.266 | 0.225 |
| MDELP | i1000\_6 | 30 | 0.65 | 14.1 | 22496.3 | opt | 1622.3 | 0.666 | 0.257 | 0.211 | 0.219 |
| MDELP | i1000\_6 | 40 | 0.54 | 16.8 | 20263.1 | opt | 226.1 | 0.561 | 0.220 | 0.183 | 0.224 |
| MDELP | i1000\_6 | 50 | 0.47 | 17.5 | 17768.2 | opt | 325.2 | 0.491 | 0.201 | 0.164 | 0.233 |
| MELP | i1000\_6 | 10 | 1.19 | ~ | 1971.9 | opt | 492.4 | 1.207 | 0.449 | 0.368 | 0.212 |
| MELP | i1000\_6 | 20 | 0.81 | ~ | 1074.7 | opt | 3690.7 | 0.838 | 0.318 | 0.261 | 0.216 |
| MELP | i1000\_6 | 30 | 0.65 | ~ | 655.5 | opt | 839.5 | 0.669 | 0.256 | 0.209 | 0.216 |
| MELP | i1000\_6 | 40 | 0.54 | ~ | 540.0 | opt | 474.4 | 0.564 | 0.217 | 0.179 | 0.219 |
| MELP | i1000\_6 | 50 | 0.47 | ~ | 454.9 | opt | 511.5 | 0.499 | 0.193 | 0.158 | 0.220 |
| CPMP | i1000\_6 | 72 | ~ | ~ | 8203.3 | 0.58% | 7204.4 | 0.413 | 0.208 | 0.166 | 0.283 |
| CPMP | i1000\_6 | 76 | ~ | ~ | 7875.4 | 0.20% | 7202.2 | 0.396 | 0.199 | 0.159 | 0.282 |
| CPMP | i1000\_6 | 80 | ~ | ~ | 7613.9 | opt | 4898.4 | 0.383 | 0.190 | 0.153 | 0.280 |
| CPMP | i1000\_6 | 84 | ~ | ~ | 7386.2 | opt | 2940.0 | 0.372 | 0.184 | 0.148 | 0.279 |
| CPMP | i1000\_6 | 88 | ~ | ~ | 7178.1 | opt | 4061.9 | 0.361 | 0.179 | 0.143 | 0.278 |
| CMDELP | i1000\_6 | 72 | 0.41 | 19.1 | 15848.7 | 6.14% | 7200.6 | 0.427 | 0.182 | 0.150 | 0.243 |
| CMDELP | i1000\_6 | 76 | 0.40 | 20.0 | 14682.9 | 3.89% | 7201.2 | 0.409 | 0.174 | 0.146 | 0.242 |
| CMDELP | i1000\_6 | 80 | 0.38 | 21.1 | 14600.6 | 3.45% | 7201.3 | 0.395 | 0.167 | 0.134 | 0.241 |
| CMDELP | i1000\_6 | 84 | 0.37 | 21.9 | 13864.0 | 1.32% | 7202.2 | 0.381 | 0.160 | 0.130 | 0.239 |
| CMDELP | i1000\_6 | 88 | 0.36 | 22.6 | 13366.6 | opt | 4863.6 | 0.370 | 0.154 | 0.125 | 0.236 |
| CMELP | i1000\_6 | 72 | 0.41 | ~ | 421.3 | 20.62% | 7320.7 | 0.444 | 0.180 | 0.148 | 0.231 |
| CMELP | i1000\_6 | 76 | 0.40 | ~ | 316.9 | 5.18% | 7270.9 | 0.413 | 0.169 | 0.136 | 0.232 |
| CMELP | i1000\_6 | 80 | 0.38 | ~ | 316.8 | 5.44% | 7365.5 | 0.399 | 0.163 | 0.131 | 0.231 |
| CMELP | i1000\_6 | 84 | 0.37 | ~ | 286.7 | 3.92% | 7256.7 | 0.388 | 0.155 | 0.125 | 0.227 |
| CMELP | i1000\_6 | 88 | 0.36 | ~ | 263.3 | 1.04% | 7411.0 | 0.377 | 0.148 | 0.120 | 0.222 |

### Table S14: Solutions from the instance GY

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | GY | 22 | ~ | ~ | 1567390.8 | opt | 29.9 | 1.912 | 1.384 | 1.113 | 0.407 |
| PMP | GY | 24 | ~ | ~ | 1493475.9 | opt | 21.2 | 1.822 | 1.355 | 1.088 | 0.417 |
| PMP | GY | 26 | ~ | ~ | 1427280.8 | opt | 34.6 | 1.741 | 1.341 | 1.093 | 0.431 |
| PMP | GY | 28 | ~ | ~ | 1368159.6 | opt | 27.7 | 1.669 | 1.319 | 1.085 | 0.442 |
| PMP | GY | 30 | ~ | ~ | 1315066.7 | opt | 27.8 | 1.604 | 1.250 | 1.045 | 0.441 |
| MDELP | GY | 22 | 1.912 | 2.0 | 3033435.1 | opt | 22.9 | 1.999 | 1.210 | 0.977 | 0.343 |
| MDELP | GY | 24 | 1.822 | 2.0 | 2868516.6 | opt | 23.1 | 1.922 | 1.159 | 0.943 | 0.343 |
| MDELP | GY | 26 | 1.741 | 1.9 | 2675030.6 | opt | 22.4 | 1.839 | 1.127 | 0.916 | 0.348 |
| MDELP | GY | 28 | 1.669 | 1.9 | 2565966.4 | opt | 42.3 | 1.786 | 1.074 | 0.893 | 0.342 |
| MDELP | GY | 30 | 1.604 | 2.1 | 2567714.0 | opt | 32.6 | 1.675 | 1.112 | 0.929 | 0.379 |
| MELP | GY | 22 | 1.912 | ~ | 679029.1 | opt | 6.8 | 2.134 | 1.095 | 0.844 | 0.287 |
| MELP | GY | 24 | 1.822 | ~ | 642119.7 | opt | 55.4 | 1.944 | 1.149 | 0.931 | 0.335 |
| MELP | GY | 26 | 1.741 | ~ | 614147.9 | opt | 62.7 | 1.841 | 1.125 | 0.918 | 0.347 |
| MELP | GY | 28 | 1.669 | ~ | 577288.6 | opt | 45.0 | 1.798 | 1.078 | 0.879 | 0.341 |
| MELP | GY | 30 | 1.604 | ~ | 544852.2 | opt | 24.1 | 1.794 | 0.988 | 0.793 | 0.312 |
| CPMP | GY | 22 | ~ | ~ | 1670208.4 | opt | 2380.0 | 2.037 | 1.615 | 1.302 | 0.439 |
| CPMP | GY | 24 | ~ | ~ | 1537200.6 | opt | 658.0 | 1.875 | 1.480 | 1.228 | 0.445 |
| CPMP | GY | 26 | ~ | ~ | 1459800.1 | opt | 887.0 | 1.781 | 1.441 | 1.174 | 0.454 |
| CPMP | GY | 28 | ~ | ~ | 1389821.2 | opt | 225.4 | 1.695 | 1.382 | 1.133 | 0.456 |
| CPMP | GY | 30 | ~ | ~ | 1333953.7 | opt | 142.7 | 1.627 | 1.337 | 1.100 | 0.459 |
| CMDELP | GY | 22 | 2.037 | 1.6 | 3219160.3 | opt | 5605.4 | 2.111 | 1.402 | 1.132 | 0.375 |
| CMDELP | GY | 24 | 1.875 | 1.7 | 3007883.6 | opt | 2180.8 | 1.973 | 1.317 | 1.082 | 0.380 |
| CMDELP | GY | 26 | 1.781 | 1.8 | 2864941.0 | opt | 638.9 | 1.858 | 1.267 | 1.040 | 0.387 |
| CMDELP | GY | 28 | 1.695 | 1.8 | 2722588.7 | opt | 287.2 | 1.757 | 1.235 | 1.013 | 0.399 |
| CMDELP | GY | 30 | 1.627 | 1.9 | 2652549.6 | opt | 367.3 | 1.703 | 1.188 | 0.982 | 0.396 |
| CMELP | GY | 22 | 2.037 | ~ | 908204.5 | 0.96% | 7201.2 | 2.318 | 1.224 | 0.942 | 0.293 |
| CMELP | GY | 24 | 1.875 | ~ | 805152.0 | 1.59% | 7201.6 | 2.084 | 1.196 | 0.958 | 0.324 |
| CMELP | GY | 26 | 1.781 | ~ | 738429.7 | 1.65% | 7203.3 | 2.016 | 1.119 | 0.888 | 0.312 |
| CMELP | GY | 28 | 1.695 | ~ | 695903.0 | opt | 6541.0 | 1.909 | 1.115 | 0.917 | 0.331 |
| CMELP | GY | 30 | 1.627 | ~ | 650760.6 | opt | 3543.2 | 1.894 | 1.032 | 0.817 | 0.308 |

### Table S15: Solutions from the instance ZY

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | ZY | 10 | ~ | ~ | 1655.2 | opt | 4.7 | 0.427 | 0.217 | 0.169 | 0.285 |
| PMP | ZY | 11 | ~ | ~ | 1594.5 | opt | 4.8 | 0.412 | 0.217 | 0.167 | 0.294 |
| PMP | ZY | 12 | ~ | ~ | 1540.1 | opt | 7.1 | 0.398 | 0.207 | 0.160 | 0.291 |
| PMP | ZY | 13 | ~ | ~ | 1487.9 | opt | 9.0 | 0.384 | 0.203 | 0.155 | 0.294 |
| PMP | ZY | 14 | ~ | ~ | 1436.9 | opt | 12.0 | 0.371 | 0.192 | 0.147 | 0.287 |
| MDELP | ZY | 10 | 0.427 | 18.1 | 3148.4 | opt | 17.6 | 0.432 | 0.206 | 0.161 | 0.267 |
| MDELP | ZY | 11 | 0.412 | 17.5 | 2825.4 | opt | 5.1 | 0.425 | 0.182 | 0.140 | 0.238 |
| MDELP | ZY | 12 | 0.398 | 18.5 | 2743.1 | opt | 9.5 | 0.413 | 0.174 | 0.132 | 0.232 |
| MDELP | ZY | 13 | 0.384 | 18.7 | 2605.7 | opt | 7.6 | 0.400 | 0.167 | 0.128 | 0.230 |
| MDELP | ZY | 14 | 0.371 | 20.1 | 2536.8 | opt | 6.6 | 0.383 | 0.162 | 0.126 | 0.236 |
| MELP | ZY | 10 | 0.427 | ~ | 81.4 | opt | 9.9 | 0.432 | 0.206 | 0.161 | 0.267 |
| MELP | ZY | 11 | 0.412 | ~ | 67.4 | opt | 5.9 | 0.425 | 0.182 | 0.140 | 0.238 |
| MELP | ZY | 12 | 0.398 | ~ | 61.8 | opt | 8.6 | 0.413 | 0.174 | 0.132 | 0.232 |
| MELP | ZY | 13 | 0.384 | ~ | 56.2 | opt | 5.1 | 0.402 | 0.166 | 0.128 | 0.228 |
| MELP | ZY | 14 | 0.371 | ~ | 52.3 | opt | 8.0 | 0.384 | 0.161 | 0.125 | 0.233 |
| CPMP | ZY | 10 | ~ | ~ | 1686.8 | opt | 97.4 | 0.436 | 0.221 | 0.171 | 0.284 |
| CPMP | ZY | 11 | ~ | ~ | 1598.2 | opt | 59.3 | 0.413 | 0.218 | 0.168 | 0.295 |
| CPMP | ZY | 12 | ~ | ~ | 1541.7 | opt | 48.6 | 0.398 | 0.208 | 0.160 | 0.292 |
| CPMP | ZY | 13 | ~ | ~ | 1487.9 | opt | 46.8 | 0.384 | 0.203 | 0.155 | 0.294 |
| CPMP | ZY | 14 | ~ | ~ | 1436.9 | opt | 34.7 | 0.371 | 0.192 | 0.147 | 0.287 |
| CMDELP | ZY | 10 | 0.436 | 17.8 | 3277.8 | opt | 215.4 | 0.446 | 0.211 | 0.165 | 0.265 |
| CMDELP | ZY | 11 | 0.413 | 17.4 | 2865.5 | opt | 97.3 | 0.427 | 0.184 | 0.142 | 0.240 |
| CMDELP | ZY | 12 | 0.398 | 18.4 | 2770.2 | opt | 83.9 | 0.414 | 0.175 | 0.132 | 0.234 |
| CMDELP | ZY | 13 | 0.384 | 18.7 | 2617.1 | opt | 52.2 | 0.401 | 0.167 | 0.129 | 0.231 |
| CMDELP | ZY | 14 | 0.371 | 20.1 | 2546.3 | opt | 38.8 | 0.382 | 0.163 | 0.122 | 0.233 |
| CMELP | ZY | 10 | 0.436 | ~ | 87.1 | opt | 166.8 | 0.446 | 0.211 | 0.165 | 0.265 |
| CMELP | ZY | 11 | 0.413 | ~ | 69.7 | opt | 69.0 | 0.427 | 0.184 | 0.142 | 0.240 |
| CMELP | ZY | 12 | 0.398 | ~ | 63.4 | opt | 67.5 | 0.414 | 0.175 | 0.133 | 0.234 |
| CMELP | ZY | 13 | 0.384 | ~ | 57.0 | opt | 52.2 | 0.401 | 0.167 | 0.129 | 0.231 |
| CMELP | ZY | 14 | 0.371 | ~ | 52.9 | opt | 43.8 | 0.387 | 0.162 | 0.124 | 0.231 |

### Table S16: Solutions from the instance KF

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | KF | 18 | ~ | ~ | 589019.6 | opt | 63.9 | 0.824 | 0.461 | 0.361 | 0.308 |
| PMP | KF | 20 | ~ | ~ | 562264.5 | opt | 70.8 | 0.787 | 0.434 | 0.338 | 0.303 |
| PMP | KF | 22 | ~ | ~ | 538545.4 | opt | 104.0 | 0.754 | 0.417 | 0.321 | 0.302 |
| PMP | KF | 24 | ~ | ~ | 517626.7 | opt | 126.1 | 0.725 | 0.403 | 0.310 | 0.304 |
| PMP | KF | 26 | ~ | ~ | 498859.5 | opt | 102.8 | 0.698 | 0.396 | 0.303 | 0.307 |
| MDELP | KF | 18 | 0.824 | 7.8 | 1172066.8 | opt | 351.7 | 0.858 | 0.405 | 0.328 | 0.266 |
| MDELP | KF | 20 | 0.787 | 8.4 | 1126444.3 | opt | 472.7 | 0.821 | 0.381 | 0.304 | 0.260 |
| MDELP | KF | 22 | 0.754 | 8.7 | 1067318.9 | opt | 237.3 | 0.781 | 0.367 | 0.290 | 0.262 |
| MDELP | KF | 24 | 0.725 | 8.9 | 1023839.7 | opt | 493.3 | 0.749 | 0.355 | 0.280 | 0.264 |
| MDELP | KF | 26 | 0.698 | 8.9 | 979802.4 | opt | 1306.6 | 0.731 | 0.340 | 0.271 | 0.261 |
| MELP | KF | 18 | 0.824 | ~ | 71448.7 | opt | 336.1 | 0.871 | 0.398 | 0.322 | 0.258 |
| MELP | KF | 20 | 0.787 | ~ | 64237.1 | opt | 1597.4 | 0.821 | 0.381 | 0.304 | 0.260 |
| MELP | KF | 22 | 0.754 | ~ | 57743.1 | opt | 401.1 | 0.793 | 0.360 | 0.285 | 0.254 |
| MELP | KF | 24 | 0.725 | ~ | 53935.1 | opt | 541.7 | 0.769 | 0.345 | 0.274 | 0.251 |
| MELP | KF | 26 | 0.698 | ~ | 50919.2 | opt | 2042.2 | 0.752 | 0.329 | 0.264 | 0.246 |
| CPMP | KF | 18 | ~ | ~ | 589019.6 | opt | 1743.9 | 0.824 | 0.461 | 0.361 | 0.308 |
| CPMP | KF | 20 | ~ | ~ | 562264.5 | opt | 2343.4 | 0.787 | 0.434 | 0.338 | 0.303 |
| CPMP | KF | 22 | ~ | ~ | 538545.4 | opt | 1815.2 | 0.754 | 0.417 | 0.321 | 0.296 |
| CPMP | KF | 24 | ~ | ~ | 517626.7 | opt | 2187.6 | 0.725 | 0.403 | 0.310 | 0.303 |
| CPMP | KF | 26 | ~ | ~ | 498859.5 | opt | 2911.1 | 0.698 | 0.396 | 0.303 | 0.307 |
| CMDELP | KF | 18 | 0.820 | 10.0 | 1346720.0 | opt | 3185.2 | 0.845 | 0.413 | 0.331 | 0.274 |
| CMDELP | KF | 20 | 0.790 | 10.0 | 1222288.4 | opt | 4622.2 | 0.822 | 0.381 | 0.304 | 0.260 |
| CMDELP | KF | 22 | 0.750 | 10.0 | 1154739.1 | opt | 2750.0 | 0.780 | 0.368 | 0.290 | 0.263 |
| CMDELP | KF | 24 | 0.730 | 10.0 | 1073426.7 | opt | 2565.6 | 0.749 | 0.355 | 0.280 | 0.264 |
| CMDELP | KF | 26 | 0.700 | 10.0 | 1031951.9 | opt | 4913.9 | 0.731 | 0.340 | 0.271 | 0.261 |
| CMELP | KF | 18 | 0.820 | ~ | 73175.4 | opt | 4204.6 | 0.873 | 0.399 | 0.323 | 0.258 |
| CMELP | KF | 20 | 0.790 | ~ | 63531.8 | opt | 4251.3 | 0.822 | 0.381 | 0.304 | 0.247 |
| CMELP | KF | 22 | 0.750 | ~ | 59112.5 | opt | 2989.6 | 0.794 | 0.361 | 0.286 | 0.254 |
| CMELP | KF | 24 | 0.730 | ~ | 53254.9 | opt | 4501.7 | 0.770 | 0.345 | 0.275 | 0.252 |
| CMELP | KF | 26 | 0.700 | ~ | 50459.0 | opt | 2920.3 | 0.752 | 0.329 | 0.264 | 0.246 |

### Table S17: Solutions from the instance ZZ

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Inst. | P |  |  | Objective | Gap | Time | Mean | SD | MAD | GC |
| PMP | ZZ | 48 | ~ | ~ | 3457717.6 | ~ | 615.7 | 0.819 | 0.420 | 0.326 | 0.283 |
| PMP | ZZ | 52 | ~ | ~ | 3335783.4 | ~ | 526.6 | 0.790 | 0.415 | 0.318 | 0.284 |
| PMP | ZZ | 56 | ~ | ~ | 3231183.1 | ~ | 474.5 | 0.765 | 0.403 | 0.308 | 0.287 |
| PMP | ZZ | 60 | ~ | ~ | 3124620.2 | ~ | 667.4 | 0.740 | 0.385 | 0.294 | 0.283 |
| PMP | ZZ | 64 | ~ | ~ | 3032341.2 | ~ | 1028.4 | 0.718 | 0.376 | 0.293 | 0.285 |
| MDELP | ZZ | 48 | 0.819 | 9.3 | 6697982.9 | ~ | 1001.3 | 0.839 | 0.373 | 0.302 | 0.251 |
| MDELP | ZZ | 52 | 0.790 | 9.2 | 6381031.2 | ~ | 771.5 | 0.815 | 0.361 | 0.292 | 0.250 |
| MDELP | ZZ | 56 | 0.765 | 9.4 | 5992260.2 | ~ | 754.7 | 0.789 | 0.340 | 0.271 | 0.242 |
| MDELP | ZZ | 60 | 0.740 | 10.0 | 5897516.8 | ~ | 804.7 | 0.772 | 0.325 | 0.260 | 0.237 |
| MDELP | ZZ | 64 | 0.718 | 10.1 | 5650278.0 | ~ | 1136.8 | 0.741 | 0.320 | 0.255 | 0.244 |
| MELP | ZZ | 48 | 0.819 | ~ | 325283.5 | ~ | 588.6 | 0.851 | 0.365 | 0.296 | 0.243 |
| MELP | ZZ | 52 | 0.790 | ~ | 310763.3 | ~ | 514.3 | 0.827 | 0.349 | 0.282 | 0.239 |
| MELP | ZZ | 56 | 0.765 | ~ | 282470.7 | ~ | 933.2 | 0.795 | 0.337 | 0.269 | 0.239 |
| MELP | ZZ | 60 | 0.740 | ~ | 258928.6 | ~ | 1008.1 | 0.769 | 0.325 | 0.260 | 0.238 |
| MELP | ZZ | 64 | 0.718 | ~ | 243616.0 | ~ | 1115.7 | 0.748 | 0.313 | 0.249 | 0.235 |
| CPMP | ZZ | 48 | ~ | ~ | 3640336.9 | ~ | 4617.5 | 0.862 | 0.546 | 0.408 | 0.333 |
| CPMP | ZZ | 52 | ~ | ~ | 3443420.1 | ~ | 1833.9 | 0.815 | 0.452 | 0.355 | 0.305 |
| CPMP | ZZ | 56 | ~ | ~ | 3288316.7 | ~ | 3543.1 | 0.778 | 0.418 | 0.325 | 0.295 |
| CPMP | ZZ | 60 | ~ | ~ | 3153313.4 | ~ | 1515.4 | 0.747 | 0.401 | 0.312 | 0.295 |
| CPMP | ZZ | 64 | ~ | ~ | 3059409.7 | ~ | 1534.6 | 0.724 | 0.388 | 0.303 | 0.295 |
| CMDELP | ZZ | 48 | 0.862 | 5.8 | 7973447.3 | ~ | 7399.1 | 0.873 | 0.510 | 0.379 | 0.309 |
| CMDELP | ZZ | 52 | 0.815 | 8.0 | 7017243.0 | ~ | 4574.8 | 0.828 | 0.415 | 0.329 | 0.279 |
| CMDELP | ZZ | 56 | 0.778 | 8.9 | 6555152.0 | ~ | 6056.7 | 0.789 | 0.382 | 0.302 | 0.271 |
| CMDELP | ZZ | 60 | 0.747 | 9.3 | 6371246.3 | ~ | 3455.4 | 0.767 | 0.365 | 0.289 | 0.266 |
| CMDELP | ZZ | 64 | 0.724 | 9.6 | 6048518.9 | ~ | 3230.8 | 0.737 | 0.353 | 0.281 | 0.269 |
| CMELP | ZZ | 48 | 0.862 | ~ | 702660.8 | ~ | 8295.0 | 0.899 | 0.489 | 0.365 | 0.292 |
| CMELP | ZZ | 52 | 0.815 | ~ | 451594.2 | ~ | 4247.8 | 0.840 | 0.411 | 0.321 | 0.270 |
| CMELP | ZZ | 56 | 0.778 | ~ | 354079.8 | ~ | 4599.6 | 0.805 | 0.369 | 0.293 | 0.257 |
| CMELP | ZZ | 60 | 0.747 | ~ | 332435.7 | ~ | 6241.8 | 0.776 | 0.356 | 0.279 | 0.256 |
| CMELP | ZZ | 64 | 0.724 | ~ | 303376.8 | ~ | 3714.1 | 0.750 | 0.345 | 0.273 | 0.257 |

### Table S18: Various model solutions from the instance Cap121

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | P | Parameters | Max | Mean | SD | MAD | AD | CV | SI | GC | Time |
| PMP | 8 | ~ | 38.650 | 13.225 | 8.464 | 6.684 | 8.783 | 0.640 | 0.253 | 0.332 | 0.5 |
| PCP | 8 | ~ | 31.138 | 19.020 | 7.656 | 6.606 | 8.677 | 0.403 | 0.174 | 0.228 | 0.7 |
| MELP | 8 | =13.2 | 36.813 | 13.581 | 7.988 | 6.186 | 8.501 | 0.588 | 0.228 | 0.313 | 0.6 |
| MDELP | 8 | =13.2,=0.37 | 36.813 | 13.352 | 8.033 | 6.145 | 8.410 | 0.602 | 0.230 | 0.315 | 0.6 |
| MinMAD | 8 | ~ | 32.100 | 26.085 | 3.820 | 2.680 | 4.033 | 0.146 | 0.051 | 0.077 | 30.3 |
| MinSI | 8 | ~ | 44.213 | 35.103 | 4.984 | 3.443 | 5.030 | 0.142 | 0.049 | 0.072 | 276.5 |
| MinAD | 8 | ~ | 32.100 | 26.085 | 3.820 | 2.680 | 4.033 | 0.146 | 0.051 | 0.077 | 222.3 |
| MinGC | 8 | ~ | 44.213 | 35.093 | 4.881 | 3.455 | 5.012 | 0.139 | 0.049 | 0.071 | 3737.8 |
| MinSD | 8 | ~ | 32.100 | 26.085 | 3.820 | 2.680 | 4.033 | 0.146 | 0.051 | 0.077 | 67.3 |
| MinCV | 8 | ~ | 44.213 | 35.275 | 4.902 | 3.542 | 5.092 | 0.139 | 0.050 | 0.072 | 1474.0 |
| K-centrum | 8 | K=5 | 31.138 | 19.020 | 7.656 | 6.606 | 8.677 | 0.403 | 0.174 | 0.228 | 1.2 |
| K-centrum | 8 | K=10 | 34.388 | 17.416 | 7.824 | 6.563 | 8.856 | 0.449 | 0.188 | 0.254 | 2.3 |
| K-centrum | 8 | K=15 | 40.150 | 16.935 | 9.002 | 7.083 | 9.966 | 0.532 | 0.209 | 0.294 | 1.0 |
| K-centrum | 8 | K=25 | 46.213 | 15.313 | 10.994 | 7.866 | 10.622 | 0.718 | 0.257 | 0.347 | 0.8 |
| -centdian | 8 | =0.1 | 31.138 | 19.020 | 7.656 | 8.677 | 8.677 | 0.403 | 0.174 | 0.228 | 0.7 |
| -centdian | 8 | =0.3 | 32.100 | 14.759 | 7.932 | 6.647 | 8.362 | 0.537 | 0.225 | 0.283 | 1.0 |
| -centdian | 8 | =0.5 | 32.525 | 13.987 | 8.371 | 6.776 | 8.980 | 0.598 | 0.242 | 0.321 | 0.8 |
| -centdian | 8 | =0.7 | 32.525 | 13.987 | 8.371 | 6.776 | 8.980 | 0.598 | 0.242 | 0.321 | 0.7 |
| -centdian | 8 | =0.9 | 35.838 | 13.339 | 8.276 | 6.457 | 8.642 | 0.620 | 0.242 | 0.324 | 0.7 |
| K-centdian | 8 | K=5, =0.3 | 33.613 | 13.737 | 8.327 | 6.641 | 8.854 | 0.606 | 0.242 | 0.322 | 0.9 |
| K-centdian | 8 | K=5, =0.5 | 33.613 | 13.737 | 8.327 | 6.641 | 8.854 | 0.606 | 0.242 | 0.322 | 0.7 |
| K-centdian | 8 | K=10, =0.3 | 40.150 | 13.998 | 9.065 | 6.833 | 9.307 | 0.648 | 0.244 | 0.332 | 0.8 |
| K-centdian | 8 | K=10, =0.5 | 40.150 | 13.998 | 9.065 | 6.833 | 9.307 | 0.648 | 0.244 | 0.332 | 0.7 |
| K-centdian | 8 | K=25, =0.3 | 40.150 | 13.804 | 9.050 | 6.778 | 9.235 | 0.656 | 0.246 | 0.334 | 0.6 |
| K-centdian | 8 | K=25, =0.5 | 40.150 | 13.804 | 9.050 | 6.778 | 9.235 | 0.656 | 0.246 | 0.334 | 0.6 |

### Table S19: Various model solutions from the instance Pmed2

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | P | Parameters | Max | Mean | SD | MAD | AD | CV | SI | GC | Time |
| PMP | 10 | ~ | 132 | 40.930 | 32.244 | 25.923 | 35.990 | 0.788 | 0.317 | 0.440 | 1.0 |
| PCP | 10 | ~ | 98 | 47.970 | 29.997 | 26.069 | 34.535 | 0.625 | 0.272 | 0.360 | 2.4 |
| MELP | 10 | =41.0 | 118 | 42.040 | 28.414 | 23.442 | 32.342 | 0.676 | 0.279 | 0.385 | 1.0 |
| MDELP | 10 | =41.0,=0.08 | 118 | 42.040 | 28.414 | 23.442 | 32.342 | 0.676 | 0.279 | 0.385 | 1.1 |
| MinMAD | 10 | ~ | - | - | - | - | - | - | - | - | 4h |
| MinSI | 10 | ~ | - | - | - | - | - | - | - | - | 4h |
| MinAD | 10 | ~ | - | - | - | - | - | - | - | - | 4h |
| MinGC | 10 | ~ | - | - | - | - | - | - | - | - | 4h |
| MinSD | 10 | ~ | - | - | - | - | - | - | - | - | 4h |
| MinCV | 10 | ~ | - | - | - | - | - | - | - | - | 4h |
| K-centrum | 10 | K=5 | 102 | 49.000 | 29.266 | 24.760 | 33.571 | 0.597 | 0.253 | 0.343 | 80.1 |
| K-centrum | 10 | K=10 | 108 | 46.860 | 29.367 | 24.943 | 33.705 | 0.627 | 0.266 | 0.360 | 345.5 |
| K-centrum | 10 | K=20 | 118 | 42.530 | 28.213 | 23.350 | 32.110 | 0.663 | 0.275 | 0.377 | 444.7 |
| K-centrum | 10 | K=50 | 118 | 41.890 | 28.588 | 23.028 | 32.421 | 0.682 | 0.275 | 0.387 | 23.0 |
| -centdian | 10 | =0.3 | 98 | 47.570 | 29.493 | 25.321 | 33.941 | 0.620 | 0.266 | 0.357 | 25.9 |
| -centdian | 10 | =0.4 | 98 | 47.570 | 29.493 | 25.321 | 33.941 | 0.620 | 0.266 | 0.357 | 55.4 |
| -centdian | 10 | =0.5 | 102 | 42.690 | 29.657 | 24.824 | 33.948 | 0.695 | 0.291 | 0.398 | 52.7 |
| K-centdian | 10 | K=10, =0.3 | 118 | 41.680 | 29.564 | 25.075 | 33.766 | 0.709 | 0.301 | 0.405 | 269.8 |
| K-centdian | 10 | K=10, =0.5 | 118 | 41.370 | 29.744 | 25.362 | 33.986 | 0.719 | 0.307 | 0.411 | 39.6 |
| K-centdian | 10 | K=10, =0.7 | 118 | 41.370 | 29.744 | 25.362 | 33.986 | 0.719 | 0.307 | 0.411 | 10.0 |
| K-centdian | 10 | K=20, =0.3 | 118 | 41.980 | 28.398 | 23.040 | 32.221 | 0.676 | 0.274 | 0.384 | 327.8 |
| K-centdian | 10 | K=20, =0.5 | 118 | 41.280 | 29.578 | 25.159 | 33.763 | 0.717 | 0.305 | 0.409 | 82.8 |
| K-centdian | 10 | K=20, =0.7 | 118 | 41.280 | 29.578 | 25.159 | 33.763 | 0.717 | 0.305 | 0.409 | 18.5 |
| K-centdian | 10 | K=50, =0.3 | 118 | 41.890 | 28.588 | 23.028 | 32.421 | 0.682 | 0.275 | 0.387 | 38.7 |
| K-centdian | 10 | K=50,=0.5 | 120 | 41.050 | 30.043 | 24.956 | 34.135 | 0.732 | 0.304 | 0.416 | 9.2 |
| K-centdian | 10 | K=50,=0.7 | 120 | 41.050 | 30.043 | 24.956 | 34.135 | 0.732 | 0.304 | 0.416 | 4.2 |

Note 1: The MinMAD, MinSI, MinAD, MinGC, MinSD, and MinCV models cannot be optimally or near-optimally (MIPGap<10%) solved by Gurobi Optimizer 9 in 4 hours.

### Table S20: Various model solutions from the instance ZY

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | p | Parameters | Max | Mean | SD | MAD | AD | CV | SI | GC | Time |
| PMP | 12 | ~ | 1.071 | 0.398 | 0.207 | 0.160 | 0.232 | 0.522 | 0.201 | 0.291 | 7.1 |
| PCP | 12 | ~ | 0.779 | 0.448 | 0.194 | 0.160 | 0.219 | 0.433 | 0.179 | 0.244 | 13.9 |
| MELP | 12 | =0.4 | 1.006 | 0.413 | 0.174 | 0.132 | 0.192 | 0.422 | 0.159 | 0.232 | 8.6 |
| MDELP | 12 | =0.4,=18.5 | 1.006 | 0.413 | 0.174 | 0.132 | 0.192 | 0.422 | 0.159 | 0.232 | 9.5 |
| MinMAD | 12 | ~ | - | - | - | - | - | - | - | - | 4h |
| MinSI | 12 | ~ | - | - | - | - | - | - | - | - | 4h |
| MinAD | 12 | ~ | - | - | - | - | - | - | - | - | 4h |
| MinGC | 12 | ~ | - | - | - | - | - | - | - | - | 4h |
| MinSD | 12 | ~ | - | - | - | - | - | - | - | - | 4h |
| MinCV | 12 | ~ | - | - | - | - | - | - | - | - | 4h |
| K-centrum | 12 | K=16 | 0.874 | 0.440 | 0.179 | 0.141 | 0.200 | 0.407 | 0.160 | 0.227 | 3447.1 |
| K-centrum | 12 | K=32 | 0.874 | 0.441 | 0.180 | 0.145 | 0.202 | 0.408 | 0.164 | 0.229 | 2h |
| K-centrum | 12 | K=96 | 1.006 | 0.421 | 0.178 | 0.137 | 0.198 | 0.424 | 0.163 | 0.235 | 2h |
| K-centrum | 12 | K=160 | 1.051 | 0.420 | 0.183 | 0.140 | 0.202 | 0.435 | 0.167 | 0.241 | 2h |
| -centdian | 12 | =0.1 | 0.779 | 0.448 | 0.194 | 0.145 | 0.202 | 0.408 | 0.164 | 0.229 | 43.8 |
| -centdian | 12 | =0.3 | 0.779 | 0.448 | 0.194 | 0.160 | 0.219 | 0.433 | 0.179 | 0.244 | 471.3 |
| -centdian | 12 | =0.5 | 0.779 | 0.448 | 0.194 | 0.160 | 0.219 | 0.433 | 0.179 | 0.244 | 1541.4 |
| -centdian | 12 | =0.7 | 0.832 | 0.422 | 0.188 | 0.160 | 0.219 | 0.433 | 0.179 | 0.244 | 690.2 |
| -centdian | 12 | =0.9 | 0.896 | 0.403 | 0.201 | 0.152 | 0.213 | 0.446 | 0.180 | 0.252 | 41.8 |
| K-centdian | 12 | K=32,=0.3 | 0.874 | 0.441 | 0.180 | 0.160 | 0.227 | 0.500 | 0.199 | 0.282 | 2h |
| K-centdian | 12 | K=32,=0.5 | 1.006 | 0.418 | 0.176 | 0.138 | 0.196 | 0.421 | 0.165 | 0.234 | 2h |
| K-centdian | 12 | K=96,=0.3 | 1.006 | 0.415 | 0.178 | 0.135 | 0.197 | 0.428 | 0.163 | 0.237 | 2h |
| K-centdian | 12 | K=96,=0.5 | 1.006 | 0.412 | 0.179 | 0.137 | 0.198 | 0.434 | 0.166 | 0.240 | 2h |
| K-centdian | 12 | K=160,=0.3 | 1.006 | 0.416 | 0.181 | 0.140 | 0.201 | 0.433 | 0.168 | 0.242 | 2h |
| K-centdian | 12 | K=160,=0.5 | 1.006 | 0.411 | 0.181 | 0.139 | 0.201 | 0.440 | 0.169 | 0.245 | 1576.9 |

Note 1: The MinMAD, MinSI, MinAD, MinGC, MinSD, and MinCV models cannot be optimally or near-optimally (MIPGap<10%) solved by Gurobi Optimizer 9 in 4 hours.

Note 2: Most K-centrum and K-centdian model are near-optimally MIPGap<10%) solved in 2 hours.

### Table S21: Mean-variance Pareto optimal solutions from the instances Cap121, Pmde2 and ZY

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cap121 (P=8) | | Pmed2 (P=10) | | ZY (P=12) | |
| Mean | SD | Mean | SD | Mean | SD |
| 13.225 | 8.464 | 40.93 | 32.24 | 0.398 | 0.207 |
| 13.310 | 8.217 | 41.10 | 30.00 | 0.398 | 0.199 |
| 13.352 | 8.033 | 41.20 | 29.61 | 0.400 | 0.196 |
| 13.581 | 7.988 | 41.28 | 29.58 | 0.402 | 0.191 |
| 13.947 | 7.743 | 41.36 | 29.47 | 0.403 | 0.191 |
| 14.098 | 7.618 | 41.50 | 29.20 | 0.405 | 0.186 |
| 14.248 | 7.567 | 41.60 | 29.19 | 0.406 | 0.181 |
| 14.384 | 7.456 | 41.77 | 28.92 | 0.409 | 0.176 |
| 14.506 | 7.324 | 41.98 | 28.40 | 0.411 | 0.175 |
| 14.649 | 7.309 | 41.98 | 28.40 | 0.413 | 0.174 |
| 15.038 | 7.196 | 42.71 | 28.13 | 0.415 | 0.173 |
| 15.174 | 7.144 | 43.53 | 28.01 | 0.416 | 0.172 |
| 15.285 | 7.036 | 44.14 | 27.94 | 0.418 | 0.172 |
| 15.390 | 7.013 | 44.94 | 27.93 | 0.421 | 0.172 |
| 15.555 | 6.985 | 45.86 | 27.36 | 0.424 | 0.170 |
| 15.699 | 6.906 | 49.78 | 27.38 | 0.426 | 0.170 |
| 15.769 | 6.835 | 50.68 | 27.00 | 0.429 | 0.169 |
| 15.871 | 6.810 |  |  | 0.434 | 0.168 |
| 16.088 | 6.697 |  |  | 0.436 | 0.168 |
| 16.191 | 6.667 |  |  | 0.452 | 0.166 |
| 16.334 | 6.636 |  |  |  |  |
| 16.493 | 6.475 |  |  |  |  |
| 16.618 | 6.441 |  |  |  |  |
| 16.718 | 6.415 |  |  |  |  |
| 16.831 | 6.284 |  |  |  |  |
| 16.973 | 6.241 |  |  |  |  |
| 17.155 | 6.062 |  |  |  |  |
| 17.220 | 5.982 |  |  |  |  |
| 17.363 | 5.923 |  |  |  |  |
| 17.684 | 5.875 |  |  |  |  |
| 17.904 | 5.832 |  |  |  |  |
| 18.215 | 5.767 |  |  |  |  |
| 18.464 | 5.744 |  |  |  |  |
| 19.577 | 5.205 |  |  |  |  |
| 21.465 | 5.088 |  |  |  |  |
| 21.926 | 5.018 |  |  |  |  |
| 24.498 | 4.745 |  |  |  |  |
| 24.992 | 4.395 |  |  |  |  |
| 26.085 | 3.820 |  |  |  |  |