

Supplementary Material for “REMS: A Unified Solution Representation, Problem Modeling and Metaheuristic Algorithm Design for General Combinatorial Optimization Problems”

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1 Problem Model and Information

1.1 Multi-depot vehicle routing problem with time windows (MDVRPTW)^[1]

MDVRPTW is an extension of the Vehicle Routing Problem (VRP), incorporating multiple depots and time window constraints. In MDVRPTW, a fleet of vehicles is stationed at several depots, and the goal is to determine the optimal set of routes for each vehicle.

Assume that there are n customers and m vehicles, which are respectively put into task set T and resource set R . For $R_i, i \in \mathcal{I} = \{1, \dots, m\}$, the attributes of resources include index d_i^R , capacity $A_{i,1}^R$, maximum transportation distance $A_{i,2}^R$, departure and return depot $A_{i,3}^R$, fixed cost $A_{i,4}^R$, and transportation cost $A_{i,5}^R$ per unit distance. Regarding $T_j, j \in \mathcal{J} = \{1, \dots, n\}$, the attributes involve index d_j^T , demand $A_{j,1}^T$, earliest allowed service time $A_{j,2}^T$, latest allowed service time $A_{j,3}^T$, and service duration $A_{j,4}^T$. There are also some other problem data, like the number of depots np and depot capacity $c_i^{depot}, i \in \{1, \dots, np\}$. Moreover, $d_{j,j'}, j, j' \in \mathcal{J} \cup \{n+1, \dots, n+np\}$ is the travel distance from j to j' , and $t_{j,j'}, j, j' \in \mathcal{J} \cup \{n+1, \dots, n+np\}$ is the travel time from j to j' , where $\mathcal{J}$ is the task index set and $\{n+1, \dots, n+np\}$ corresponds to the index of depots.

About the variables in Eq. (6), $X_i, i \in \mathcal{I}$ is a sequence variable. $x_{i,k}, i \in \mathcal{I}, k \in \mathcal{K}_i = \{1, \dots, n_i\}$ is the task arranged in the k th position of R_i . The attribute variables include the binary assignment matrix Y^C shown in Eq. (7), start serve time Y^S in Eq. (8), and end serve time Y^E in Eq. (9). Moreover, Y^U is employed to determine whether any task is assigned to a resource, where $y_i^U, i \in \mathcal{I}$ is calculated by

$$y_i^U = \begin{cases} 0, & \text{if } |X_i| = 0 \\ 1, & \text{otherwise} \end{cases}. \quad (\text{S-1})$$

Another attribute variable Y^D can denote the cumulative travel distance when arriving at a task, where $y_{i,j,k}^D, i \in \mathcal{I}, j \in \mathcal{J}, k \in \mathcal{K}_i$ is expressed as

$$y_{i,j,k}^D = \begin{cases} d_{A_{i,3}^R, j} y_{i,j,k}^C, & \text{if } k = 1 \\ \sum_{j' \in \mathcal{J}} (y_{i,j',k-1}^D + d_{j',j}) y_{i,j,k}^C, & \text{otherwise} \end{cases}. \quad (\text{S-2})$$

The objective function is to minimize the total cost, which can be denoted as

$$\min \sum_{i \in \mathcal{I}} A_{i,4}^R y_i^U + \sum_{j \in \mathcal{J}} \sum_{i \in \mathcal{I}} A_{i,5}^R (y_{i,j,n_i}^D + d_{j,A_{i,3}^R}) y_{i,j,n_i}^C, \quad (\text{S-3})$$

where the first term is the fixed cost and the second term represents the cost along with the transportation distance.

The first constraint, which ensures each task is executed exactly one time on all resources, can be denoted in the form of Eq. (20), where $\rho_{i,j,k}^T = 1, i \in \mathcal{I}, j \in \mathcal{J}, k \in \mathcal{K}_i, \theta_j^T = 1, j \in \mathcal{J}$, and the relational operator is “=”, i.e.,

$$\sum_{k \in \mathcal{K}_i} \sum_{i \in \mathcal{I}} y_{i,j,k}^C = 1, j \in \mathcal{J}. \quad (\text{S-4})$$

The capacity constraint of vehicles can be expressed by Eq. (18), and

$\rho_{i,j,k}^R = A_{j,1}^T$ $i \in \mathcal{I}, k \in \mathcal{K}_i$, $\theta_i^R = A_{i,1}^R$, $i \in \mathcal{I}$, and the relational operator is “ $\leq$ ”, i.e.,

$$\sum_{k \in \mathcal{K}_i} \sum_{j \in \mathcal{J}} A_{j,1}^T y_{i,j,k}^C \leq A_{i,1}^R, i \in \mathcal{I}. \quad (\text{S-5})$$

The transportation distance constraint for vehicles can be presented as

$$\sum_{j \in \mathcal{J}} (y_{i,j,n_i}^D + d_{j,A_{i,3}^R}) y_{i,j,n_i}^C \leq A_{i,2}^R, i \in \mathcal{I}. \quad (\text{S-6})$$

The capacity constraint for depots is expressed as

$$\sum_{k \in \mathcal{K}_i} \sum_{j \in \mathcal{J}} A_{j,1}^T y_{i,j,k}^C \mid \text{if } A_{i,3}^R = r, i \in \mathcal{I} \leq c_r^{\text{depot}}, r \in \{1, \dots, np\}. \quad (\text{S-7})$$

The time window constraint can be

$$y_{i,j,k}^S \geq A_{j,2}^T, y_{i,j,k}^E \leq A_{j,3}^T, i \in \mathcal{I}, j \in \mathcal{J}, k \in \mathcal{K}_i. \quad (\text{S-8})$$

The parameters in MDVRPTW¹ are presented in Table S-1, including the number of depots ND , the number of vehicles in each depot NV , the number of customers NC , as well as maximum transportation distance MD and maximum capacity MC for each vehicle. The running time MaxTime(s) is also presented in Table S-1, which changes with the problem scale and complexity. Furthermore, the fixed cost for each vehicle is set to 1,000, and the transportation cost per unit distance is set to 5.

Table S-1 Brief information on 20 MDVRPTW problems.

Pro.	ND	NV	NC	MD	MC	MaxTime(s)
MDVRPTW01	4	2	48	500	200	1 800
MDVRPTW02	4	3	96	480	195	3 600
MDVRPTW03	4	4	144	460	190	3 600
MDVRPTW04	4	5	192	440	185	12 000
MDVRPTW05	4	6	240	420	180	18 000
MDVRPTW06	4	7	288	400	175	18 000
MDVRPTW07	6	2	72	500	200	1 800
MDVRPTW08	6	3	144	475	190	7 200
MDVRPTW09	6	4	216	450	180	12 000
MDVRPTW10	6	5	288	425	170	24 000
MDVRPTW11	4	1	48	500	200	3 600
MDVRPTW12	4	2	96	480	195	3 600
MDVRPTW13	4	3	144	460	190	7 200
MDVRPTW14	4	4	192	440	185	7 200
MDVRPTW15	4	5	240	420	180	36 000
MDVRPTW16	4	6	288	400	175	36 000
MDVRPTW17	6	1	72	500	200	3 600
MDVRPTW18	6	2	144	475	190	5 400
MDVRPTW19	6	3	216	450	180	36 000
MDVRPTW20	6	4	288	425	170	36 000

1.2 Vehicle routing problem with pickup and delivery (VRPPD)^[2]

VRPPD belongs to a variant of VRP, similar to MDVRPTW; we still regard n customers and m vehicles as tasks and resources, respectively. The attributes of R_i , $i \in \mathcal{I}$ include index d_i^R , capacity $A_{i,1}^R$, and maximum transportation distance $A_{i,2}^R$. The attributes of T_j , $j \in \mathcal{J}$ involve index d_j^T , demand $A_{j,1}^T$, pickup or delivery index $A_{j,2}^T$ ($A_{j,2}^T = 0$ denotes T_j has a pickup requirement; otherwise, T_j possesses a delivery demand). In addition,

¹ The test suit comes from <http://neumann.hec.ca/chairedistributique/data/mdvrptw/>.

$d_{j,j'}, j, j' \in \{0, \dots, n\}$ is the travel distance from j to j' , where 0 is the index of the depot and $\{1, \dots, n\}$ corresponds to the task index.

For the variables in Eq. (6), $X_i, i \in \mathcal{I}$ is a sequence variable. Similarly, the binary assignment matrix Y^C is expressed by Eq. (7), and Y^D denotes the cumulative travel distance when arriving at a task, where $y_{i,j,k}^D, i \in \mathcal{I}, j \in \mathcal{J}, k \in \mathcal{K}$ is calculated by

$$y_{i,j,k}^D = \begin{cases} d_{0,j} y_{i,j,k}^C, & \text{if } k=1 \\ \sum_{j' \in \mathcal{J}} (y_{i,j',k-1}^D + d_{j',j}) y_{i,j,k}^C, & \text{otherwise} \end{cases} \quad (\text{S-9})$$

The objective is to minimize the total travel distance and is expressed as

$$\min \sum_{j \in \mathcal{J}} \sum_{i \in \mathcal{I}} A_{i,5}^R (y_{i,j,n_i}^U + d_{j,0}) y_{i,j,n_i}^C. \quad (\text{S-10})$$

The constraint, which ensures each task is executed exactly once on all resources, can be denoted as Eq. (S-4). The capacity constraint of vehicles can be expressed by Eq. (S-5). Moreover, the transportation distance constraint of vehicles can be formulated as Eq. (S-6), i.e.,

$$\sum_{j \in \mathcal{J}} (y_{i,j,n_i}^D + d_{j,0}) y_{i,j,n_i}^C \leq A_{i,2}^R, i \in \mathcal{I}. \quad (\text{S-11})$$

Another important constraint guarantees that pickup occurs before delivery for a pair pick-up and delivery demand, which can be represented by Eq. (22).

Concerning VRPPD, we randomly select 30 VRPPD problems from the original test suite². Each instance contains 100 customers, and the number of vehicles is set at 15. The maximum transportation distance and capacity for each vehicle are established at 400 and 100, respectively. Additionally, the maximum running time (MaxTime) for each VRPPD is equal to 7,200s.

1.3 Generalized assignment problem (GAP)^[3]

GAP aims to assign jobs to agents to minimize the total cost. We consider m agents and n jobs as resources and tasks, respectively. The attributes of $R_i, i \in \mathcal{I}$ contain index d_i^R and capacity $A_{i,1}^R$. The attributes of T_j contain index d_j^T and weight $A_{j,1}^T$. Moreover, assigning T_j to R_i will generate a cost $c_{i,j}$ and a consumption $cs_{i,j}$.

For the variables in Eq. (6), $X_i, i \in \mathcal{I}$ is an assignment variable. The binary assignment matrix Y^C is expressed by Eq. (7). The objective function is to minimize the total cost, which can be denoted by

$$\min \sum_{k \in \mathcal{K}_i} \sum_{j \in \mathcal{J}} \sum_{i \in \mathcal{I}} c_{i,j} y_{i,j,k}^C. \quad (\text{S-12})$$

The constraint, which ensures each task is executed exactly one time on all resources, can be denoted by Eq. (S-4). Moreover, the capacity constraint for agents can be presented by Eq. (S-5).

There are 57 GAP problems in the test suite³, where the number of agents NA , the number of jobs NJ , and the maximum running time MaxTime(s) are illustrated in Table S-2.

Table S-2 Brief information on 57 GAP problems.

Pro.	NA	NJ	MaxTime(s)	Pro.	NA	NJ	MaxTime(s)	Pro.	NA	NJ	MaxTime(s)
GAP01	5	100	360	GAP20	20	200	720	GAP39	60	900	36 000
GAP02	5	200	360	GAP21	20	400	3 600	GAP40	20	1600	36 000
GAP03	10	100	360	GAP22	30	900	72 00	GAP41	40	1600	36 000
GAP04	10	200	360	GAP23	40	400	3 600	GAP42	80	1600	36 000

² The test suit comes from <https://neo.lcc.uma.es/vrp/vrp-instances/vehicle-routing-problem-with-pick-up-and-deliveries/> (P1 test suit).

³ The test suit is from <https://people.brunel.ac.uk/~mastjjb/jeb/orlib/gapinfo.html>.

GAP05	20	100	360	GAP24	60	900	36 000	GAP43	5	100	360
GAP06	20	200	360	GAP25	20	1600	36 000	GAP44	5	200	360
GAP07	5	100	360	GAP26	40	1600	36 000	GAP45	10	100	360
GAP08	5	200	360	GAP27	80	1600	36 000	GAP46	10	200	360
GAP09	10	100	360	GAP28	5	100	360	GAP47	10	400	3 600
GAP10	10	200	360	GAP29	5	200	360	GAP48	15	900	36 000
GAP11	20	100	360	GAP30	10	100	360	GAP49	20	100	360
GAP12	20	200	360	GAP31	10	200	360	GAP50	20	200	720
GAP13	5	100	360	GAP32	10	400	3 600	GAP51	20	400	3 600
GAP14	5	200	360	GAP33	15	900	18 000	GAP52	30	900	18 000
GAP15	10	100	360	GAP34	20	100	360	GAP53	40	400	18 000
GAP16	10	200	360	GAP35	20	200	360	GAP54	60	900	36 000
GAP17	10	400	3 600	GAP36	20	400	3 600	GAP55	20	1600	36 000
GAP18	15	900	3 600	GAP37	30	900	18 000	GAP56	40	1600	36 000
GAP19	20	100	720	GAP38	40	400	3 600	GAP57	80	1600	36 000

1.4 Capacitated facility location problem (CFLP)^[4]

CFLP, which is a variant of the location problem, concentrates on selecting locations from a set of possible locations. Considering that the problem has m available locations and n customers, we deem them as resources and tasks, respectively. The attributes of R_i comprise index d_i^R , capacity $A_{i,1}^R$, fixed cost $A_{i,2}^R$, and maximum value $A_{i,3}^R$. The attributes of T_j involve index d_j^T and demand $A_{j,1}^T$. Furthermore, assigning T_j to R_i will generate a cost $c_{i,j}$ and a value $v_{i,j}$.

Concerning the variables in Eq. (6), X_i , $i \in \mathcal{I}$ is an assignment variable. Likewise, the binary assignment matrix Y^C is expressed by Eq. (7). Moreover, an attribute variable Y^U is employed to determine whether any task is assigned to a resource, where y_i^U , $i \in \mathcal{I}$ is calculated by Eq. (S-1). The optimal objective is to minimize the total cost, which can be represented by

$$\min \sum_{i \in \mathcal{I}} A_{i,2}^R y_i^U + \sum_{k \in \mathcal{K}_i} \sum_{j \in \mathcal{J}} \sum_{i \in \mathcal{I}} c_{i,j} y_{i,j,k}^C. \quad (\text{S-13})$$

The constraint, which ensures each task is executed exactly once on all resources, can be denoted as Eq. (S-4). The capacity constraints for resources can be denoted by Eq. (S-5). The value constraints for resources can be expressed as

$$\sum_{k \in \mathcal{K}_i} \sum_{j \in \mathcal{J}} v_{i,j} y_{i,j,k}^C \leq A_{i,3}^R, \quad i \in \mathcal{I}. \quad (\text{S-14})$$

Brief information on 40 CFLP problems⁴, including the number of clients/facilities NC/NF , capacity for each facility FC , as well as maximum running time MaxTime, is presented in Table S-3.

Table S-3 Brief information on 40 CFLP problems.

Pro.	NF/NC	FC	MaxTime(s)
CFLP01-08		10	
CFLP09-16		20	
CFLP17-24	100	30	3 600
CFLP25-32		40	
CFLP33-40		50	

⁴ The test suit is from <http://old.math.nsc.ru/AP/benchmarks/CFLP/cflp-eng.html>.

1.5 Bin packing problem with conflicts (BPPC)^[5]

BPPC is a variant of the Bin Packing Problem (BPP), where several items cannot be packed into the same bin. We consider n items and m bins as tasks and resources. The attributes of R_i comprise index d_i^R and capacity $A_{i,1}^R$. The attributes of T_j include index d_j^T , weight $A_{j,1}^T$, and conflict item set $A_{j,2}^T$.

Concerning the variables in Eq. (6), X_i , $i \in \mathcal{I}$ is an assignment variable. In addition, the binary assignment matrix Y^C is expressed by Eq. (7). Moreover, another attribute variable Y^U is used to determine whether any task is assigned to a resource, where y_i^U , $i \in \mathcal{I}$ is calculated by Eq. (S-1). The objective is to minimize the number of used bins, which can be denoted by

$$\min \sum_{i \in \mathcal{I}} y_i^U. \quad (\text{S-15})$$

The constraint, which ensures each task is executed exactly one time on all resources, can also be denoted as Eq. (S-4), and the capacity constraint can be expressed by Eq. (S-5). Moreover, the item conflict constraint can be represented by Eq. (21), i.e.,

$$\sum_{k \in \mathcal{K}_i} y_{i,j',k}^C = 0, \text{ if } \sum_{k \in \mathcal{K}_i} y_{i,j,k}^C = 1, j \in \mathcal{J}, j' \in A_{j,2}^T, i \in \mathcal{I}. \quad (\text{S-16})$$

The brief information for 60 BPPC problems, which are randomly selected from a test suite⁵, is shown in Table S-4, including the number of items NT , the capacity of bins MC , and the number of bins NB , as well as maximum running time MaxTime(s).

Table S-4 Brief information on 60 BPPC problems.

Pro.	NF	MC	NB	MaxTime(s)	Pro.	NF	MC	NB	MaxTime(s)
BPPC1	250	150	150	3 600	BPPC31	120	1000	60	360
BPPC2	250	150	150	3 600	BPPC32	120	1000	60	360
BPPC3	250	150	150	3 600	BPPC33	120	1000	60	360
BPPC4	250	150	150	3 600	BPPC34	120	1000	60	360
BPPC5	250	150	150	3 600	BPPC35	120	1000	60	360
BPPC6	250	150	220	3 600	BPPC36	120	1000	80	360
BPPC7	250	150	220	3 600	BPPC37	120	1000	100	360
BPPC8	250	150	220	3 600	BPPC38	120	1000	100	360
BPPC9	250	150	220	3 600	BPPC39	120	1000	120	360
BPPC10	250	150	240	3 600	BPPC40	120	1000	120	360
BPPC11	500	150	320	3 600	BPPC41	249	1000	124	1 800
BPPC12	500	150	320	3 600	BPPC42	249	1000	124	1 800
BPPC13	500	150	320	3 600	BPPC43	249	1000	124	1 800
BPPC14	500	150	320	3 600	BPPC44	249	1000	124	1 800
BPPC15	500	150	320	3 600	BPPC45	249	1000	124	1 800
BPPC16	500	150	320	3 600	BPPC46	249	1000	166	1 800
BPPC17	500	150	370	3 600	BPPC47	249	1000	207	1 800
BPPC18	500	150	400	3 600	BPPC48	249	1000	207	1 800
BPPC19	500	150	450	3 600	BPPC49	249	1000	249	1 800
BPPC20	500	150	500	3 600	BPPC50	249	1000	249	1 800
BPPC21	60	1000	30	180	BPPC51	510	1000	250	3 600
BPPC22	60	1000	30	180	BPPC52	510	1000	250	3 600
BPPC23	60	1000	30	180	BPPC53	510	1000	250	3 600
BPPC24	60	1000	30	180	BPPC54	510	1000	250	3 600
BPPC25	60	1000	30	180	BPPC55	510	1000	334	3 600
BPPC26	60	1000	40	180	BPPC56	510	1000	334	3 600

⁵ The test suit is from <https://site.unibo.it/operations-research/en/research/library-of-codes-and-instances-1>.

BPPC27	60	1000	50	180	BPPC57	510	1000	417	3 600
BPPC28	60	1000	50	180	BPPC58	510	1000	417	3 600
BPPC29	60	1000	50	180	BPPC59	510	1000	501	3 600
BPPC30	60	1000	60	180	BPPC60	510	1000	501	3 600

1.6 Generalized bin packing problem (GBPPI)^[6]

GBPPI is also an extension of BPP, where the items can be classified into compulsory or non-compulsory. It should put all compulsory items into bins and determine whether non-compulsory items are selected to maximize the profit. Similarly, we consider n items and m bins as tasks and resources. The attributes of R_i comprise index d_i^R , capacity $A_{i,1}^R$, and cost $A_{i,2}^R$. The attributes of T_j include index d_j^T , weight $A_{j,1}^T$, and compulsory or non-compulsory index $A_{j,2}^T$ (if T_j is compulsory, we have $A_{j,2}^T=0$; otherwise, $A_{j,2}^T=1$). Furthermore, assigning T_j to R_i generates a profit $p_{i,j}$.

Regarding the variables presented in Eq. (6), X_i , $i \in \mathcal{I}$ is an assignment variable. The attribute variable Y^C is expressed by Eq. (7). Moreover, another attribute variable Y^U is used to determine whether any task is assigned to a resource, where y_i^U , $i \in \mathcal{I}$ is calculated by Eq. (S-1). The objective function is to maximize the total profit, which is converted into minimizing the total cost, i.e.,

$$\min \sum_{i \in \mathcal{I}} \sum_{j \in \mathcal{J}} \sum_{k \in \mathcal{K}_i} A_{i,2}^R y_i^U - \sum_{i \in \mathcal{I}} \sum_{j \in \mathcal{J}} \sum_{k \in \mathcal{K}_i} p_{i,j} y_{i,j,k}^C. \quad (\text{S-17})$$

The capacity constraint for bins can be expressed as Eq. (S-5). Additionally, the constraint that each compulsory task should be put into one of the bins and each non-compulsory task can be placed in at most one bin can be denoted by

$$\begin{cases} \sum_{k \in \mathcal{K}_i} \sum_{i \in \mathcal{I}} y_{i,j,k}^C = 1, \text{ if } A_{j,2}^T = 0, j \in \mathcal{J} \\ \sum_{k \in \mathcal{K}_i} \sum_{i \in \mathcal{I}} y_{i,j,k}^C \leq 1, \text{ otherwise, } j \in \mathcal{J} \end{cases}. \quad (\text{S-18})$$

The number of bins NB , the number of items NT , as well as the maximum running time MaxTime are illustrated in Table S-5, where the problems are randomly selected from a test suite⁶. Moreover, for each problem, 50% of items are randomly set as compulsory items.

Table S-5 Brief information on 40 GBPPI problems.

Pro.	NT	NB	NI	MaxTime(s)	Pro.	NT	NB	NI	MaxTime(s)
GBPPI01	3	33	25	360	GBPPI26	3	33	25	360
GBPPI02	3	48	25	360	GBPPI27	3	51	25	360
GBPPI03	3	38	25	360	GBPPI28	3	45	25	360
GBPPI04	3	65	50	720	GBPPI29	3	68	50	360
GBPPI05	3	82	50	720	GBPPI30	3	72	50	360
GBPPI06	3	94	50	720	GBPPI31	3	95	50	360
GBPPI07	3	130	100	3 600	GBPPI32	3	120	100	1 800
GBPPI08	3	154	100	3 600	GBPPI33	3	155	100	1 800
GBPPI09	3	190	100	3 600	GBPPI34	3	188	100	1 800
GBPPI10	3	248	200	12 000	GBPPI35	3	261	200	3 600
GBPPI11	3	310	200	12 000	GBPPI36	3	288	200	3 600
GBPPI12	3	372	200	12 000	GBPPI37	3	385	200	3 600
GBPPI13	3	627	500	36 000	GBPPI38	3	663	500	36 000
GBPPI14	3	758	500	36 000	GBPPI39	3	745	500	36 000

⁶ The test suit comes from https://bitbucket.org/ORGGroup/gbppl_instances/src/master/.

GBPPI15	3	949	500	36 000	GBPPI40	3	963	500	36 000
GBPPI16	5	70	25	720	GBPPI41	5	65	25	720
GBPPI17	5	88	25	720	GBPPI42	5	82	25	720
GBPPI18	5	142	50	3 600	GBPPI43	5	156	50	720
GBPPI19	5	174	50	3 600	GBPPI44	5	157	50	720
GBPPI20	5	299	100	18 000	GBPPI45	5	277	100	3 600
GBPPI21	5	322	100	18 000	GBPPI46	5	346	100	3 600
GBPPI22	5	655	200	36 000	GBPPI47	5	623	200	36 000
GBPPI23	5	551	200	21 000	GBPPI48	5	552	200	12 000
GBPPI24	5	1398	500	36 000	GBPPI49	5	1664	500	36 000
GBPPI25	5	1665	500	36 000	GBPPI50	5	1633	500	36 000

1.7 Quadratic multiple knapsack problem (QMKP)^[7]

QMKP aims to pack items into knapsacks to maximize profit. Different from the classical knapsack problem, QMKP takes into account the additional profit generated when two items are placed in the same knapsack.

We regard m knapsacks and n items as resources and tasks, respectively. The attributes of R_i have index d_i^R and capacity $A_{i,1}^R$. The attributes of T_j include index d_j^T and weight $A_{j,1}^T$. Moreover, $p_{i,j}$, $i \in \mathcal{I}, j \in \mathcal{J}$ is the profit for assigning T_j to R_i , and $cp_{j,j'}, j, j' \in \mathcal{J}$ is the additional profit when putting T_j and $T_{j'}$ into the same knapsack.

For the variables shown in Eq. (6), X_i , $i \in \mathcal{I}$ is an assignment variable. Let Y^C expressed by Eq. (7) denote the binary assignment matrix. Moreover, an attribute variable Y^P is used to reflect whether any two tasks are put into the same bins, and $y_{i,j,j'}^P$, $i \in \mathcal{I}, j, j' \in \mathcal{J}$ is calculated as

$$y_{i,j,j'}^P = \begin{cases} 1, & \text{if } \sum_{k \in K_i^C} y_{i,j,k}^C = \sum_{k \in K_i^C} y_{i,j',k}^C = 1 \\ 0, & \text{otherwise} \end{cases} \quad (\text{S-19})$$

The objective function is to maximize the total profit, i.e.,

$$\max \sum_{i \in \mathcal{I}} \sum_{j \in \mathcal{J}} p_{i,j} y_{i,j,k}^C + \sum_{i \in \mathcal{I}} \sum_{j \in \mathcal{J}} \sum_{j' \in \mathcal{J}} cp_{j,j'} y_{i,j,j'}^P \quad (\text{S-20})$$

The constraint, which ensures each task is executed exactly one time on all resources, can be denoted as Eq. (S-4) and the capacity constraint can be expressed by Eq. (S-5).

The brief information on 45 QMKP problems is presented in Table S-6⁷, including the number of items NT and the number of knapsacks NK . Furthermore, the maximum running time (MaxTime) is set to 360s.

Table S-6 Brief information on 45 QMKP problems.

Pro.	NT	NK	Pro.	NT	NK	Pro.	NT	NK
QMKP01	40	3	QMKP16	45	10	QMKP31	55	5
QMKP02	40	2	QMKP17	45	2	QMKP32	55	4
QMKP03	40	4	QMKP18	45	3	QMKP33	55	4
QMKP04	40	10	QMKP19	50	2	QMKP34	55	2
QMKP05	40	13	QMKP20	50	7	QMKP35	55	14
QMKP06	40	2	QMKP21	50	8	QMKP36	55	2
QMKP07	40	6	QMKP22	50	9	QMKP37	60	2
QMKP08	40	2	QMKP23	50	17	QMKP38	60	3
QMKP09	40	12	QMKP24	50	6	QMKP39	60	15

⁷ The test suit comes from <https://site.unibo.it/operations-research/en/research/library-of-codes-and-instances-1>.

QMKP10	45	15	QMKP25	50	2	QMKP40	60	19
QMKP11	45	3	QMKP26	50	4	QMKP41	60	2
QMKP12	45	2	QMKP27	50	4	QMKP42	60	6
QMKP13	45	11	QMKP28	55	8	QMKP43	60	2
QMKP14	45	3	QMKP29	55	2	QMKP44	60	2
QMKP15	45	9	QMKP30	55	5	QMKP45	60	4

1.8 High school timetabling problem (HTS)^[8]

HTS involves assigning teachers and classes to time slots. We regard m teachers as resources with a certain number of positions (time slots). The classes should be assigned to the positions of teachers. Since a teacher may be unoccupied at a time slot, we employ a virtual task T_1 to denote unoccupied status. The virtual task and nc classes will be regarded as tasks and are put in set T , where $T_j, j \in \mathcal{J} = \{1, \dots, n\}, n = nc + 1$. The indices of R_i and T_j are d_i^R and d_j^T , respectively. Additionally, $A_{i,k}^M, i \in \mathcal{I}, k \in \mathcal{K}_i$ denotes whether resource R_i is available at the k th position. $C_{i,j}^M, i \in \mathcal{I}, j \in \mathcal{J}$ is the number of times task T_j needs to be executed on R_i , and $P_i^{in}, i \in \mathcal{I}$ is the set of unavailable positions for R_i . Moreover, $D_{i,j}^M, i \in \mathcal{I}, j \in \mathcal{J}$ is the maximum daily meeting time, and $C_{i,j}^D, i \in \mathcal{I}, j \in \mathcal{J}$ is the minimum double-lesson number for task T_j on R_i . In the problem, a day is divided into 5 periods, and we should arrange classes for teachers within 5 working days.

About the variables in Eq. (6), $X_i, i \in \mathcal{I}$ is a sequence variable and $n_i = 25, i \in \mathcal{I}$. We employ Y^C in Eq. (7) to denote the binary assignment matrix. Moreover, the number of double lessons extracted from a solution can be denoted by an attribute variable Y^L , where $y_{i,j}^L, i \in \mathcal{I}, j \in \mathcal{J}$ is the number of double lessons for task T_j on R_i . $y_i^A, i \in \mathcal{I}$ is the number of idle periods of R_i . $y_i^B, i \in \mathcal{I}$ represents the number of days that are arranged for at least one task from $T_j, j \in \{2, \dots, n\}$, for R_i . In addition, an attribute variable $y_{i,j,r}^F, i \in \mathcal{I}, j \in \mathcal{J}, r \in \{1, \dots, 5\}$ reflects the number of meeting times for R_i and T_j on the r th day.

According to reference [8], the objective function can be denoted as:

$$\min \sum_{j \in \mathcal{J}} \sum_{i \in \mathcal{I}} y_{i,j}^L - 3 \sum_{i \in \mathcal{I}} y_i^A + 9 \sum_{i \in \mathcal{I}} y_i^B. \quad (S-21)$$

The constraint that limits the number of times a task can be executed on a resource is denoted by

$$\begin{aligned} \sum_{k \in \mathcal{K}_i} y_{i,j,k}^C &\leq C_{i,j}^M, j=1, i \in \mathcal{I} \\ \sum_{k \in \mathcal{K}_i} y_{i,j,k}^C &= C_{i,j}^M, j>1, i \in \mathcal{I} \end{aligned} \quad (S-22)$$

The unavailable positions in resources should be assigned T_1 , which can be expressed as

$$y_{i,1,k}^C = 1, \text{ if } k \in P_i^{in}, i \in \mathcal{I}. \quad (S-23)$$

Lastly, the daily meeting times for a resource on a task must not exceed the maximum daily meeting times, which can be denoted as

$$y_{i,j,r}^F \leq D_{i,j}^M, i \in \mathcal{I}, j \in \mathcal{J}, r \in \{1, \dots, 5\}. \quad (S-24)$$

Table S-7 shows some information on 37 HTS problems⁸, involving the number of classes NC , the number of teachers NT , and the maximum running time $\text{MaxTime}(s)$.

⁸ The test suit comes from <https://www.gpea.uem.br/benchmark.html>.

Table S-7 Brief information on 37 HTS problems.

Pro.	NC	NT	MaxTime(s)	Pro.	NC	NT	MaxTime(s)	Pro.	NC	NT	MaxTime(s)
HTS01	12	27	3 600	HTS13	3	15	1 800	HTS24	32	75	21 000
HTS02	12	27	3 600	HTS14	16	34	7 200	HTS25	16	35	7 200
HTS03	13	31	3 600	HTS15	4	12	3 600	HTS26	10	21	3 600
HTS04	13	31	3 600	HTS16	8	19	3 600	HTS27	9	20	3 600
HTS05	9	28	3 600	HTS17	7	21	3 600	HTS28	18	45	3 600
HTS06	14	29	3 600	HTS18	5	18	3 600	HTS29	18	44	3 600
HTS07	20	51	12 000	HTS19	4	15	3 600	HTS30	18	45	3 600
HTS08	8	30	360	HTS20	5	18	3 600	HTS31	18	45	3 600
HTS09	13	34	360	HTS21	19	37	12 000	HTS32	16	44	3 600
HTS10	5	17	360	HTS22	12	31	7 200	HTS33	16	43	3 600
HTS11	16	35	360	HTS23	31	62	21 000	HTS34	16	43	3 600
HTS12	16	38	12 000								

1.9 Job shop scheduling problem (JSSP)^[9]

The problem involves assigning jobs to machines. We treat m machines and n jobs as resources and tasks, respectively. The indices of R_i and T_j are d_i^R and d_j^T , respectively. Moreover, $p_{i,j}^T$, $i \in \mathcal{I}, j \in \mathcal{J}$ represents the processing time and P_i^O , $i \in \mathcal{I}$ is the processing order for tasks on R_i , where $p_{i,j}^O \in T, j \in \mathcal{J}$.

For the variables in (6), X_i , $i \in \mathcal{I}$ is a sequence variable. The attribute variable Y^C is expressed by Eq. (7). Moreover, $y_{i,j,k}^S$, $i \in \mathcal{I}, j \in \mathcal{J}, k \in \mathcal{K}_i$ and $y_{i,j,k}^E$, $i \in \mathcal{I}, j \in \mathcal{J}, k \in \mathcal{K}_i$ denote the start and end processing times, respectively, which can also be obtained from X . The objective is to minimize the makespan and is denoted as

$$\min \max(\{y_{i,j,k}^E \mid i \in \mathcal{I}, j \in \mathcal{J}, k \in \mathcal{K}_i\}). \quad (\text{S-25})$$

The constraint, which ensures each task is executed exactly once on a resource, can be denoted as

$$\sum_{k \in \mathcal{K}_i} y_{i,j,k}^C = 1, j \in \mathcal{J}, i \in \mathcal{I}. \quad (\text{S-26})$$

Furthermore, the process order constraint and lock constraint can also be derived accordingly. The number of jobs NJ , the number of machines NM , and MaxTime(s) for 35 JSSP instances⁹ are summarized in Table S-8.

Table S-8 Brief information on 35 JSSP problems.

Pro.	NJ	NM	MaxTime(s)
JSSP01-05	15	15	3 600
JSSP06-10	20	15	3 600
JSSP11-15	20	20	7 200
JSSP16-20	30	15	18 000
JSSP21-25	30	20	18 000
JSSP26-30	50	15	36 000
JSSP31-35	50	20	36 000

1.10 Graph coloring problem (GC)^[10]

We identify m colors and n nodes as resources and tasks, respectively. The indices of R_i and T_j are d_i^R and d_j^T , respectively. Furthermore, $e_{j,j'}, j, j' \in \mathcal{J}$ represents whether T_j and

⁹The test suit is from <https://people.brunel.ac.uk/~mastjjb/jeb/orlib/jobshopinfo.html>.

$T_{j'}$, have a connection (when there is a connection between T_j and $T_{j'}$, $e_{j,j'}=1$; otherwise, $e_{j,j'}=0$).

Regarding the variables presented in Eq. (6), X_i , $i \in \mathcal{I}$ is an assignment variable. Let Y^C in Eq. (7) denote the binary assignment matrix. Moreover, another attribute variable Y^U is used to determine whether any task is assigned to a resource, where y_i^U , $i \in \mathcal{I}$ is calculated by Eq. (S-1). The objective function is to minimize the number of used resources, which can be denoted by

$$\min \sum_{i \in \mathcal{I}} y_i^U. \quad (\text{S-27})$$

The constraint ensuring that each task is executed exactly once on all resources is represented as Eq. (S-4). Additionally, the constraint, which denotes that the two nodes connected by an edge should be assigned to two different resources, can be calculated as

$$\sum_{k \in K_j} y_{i,j,k}^C + \sum_{k \in K_{j'}} y_{i,j',k}^C \leq 1, \text{ if } e_{j,j'}=1, i \in \mathcal{I}, j, j' \in \mathcal{J}. \quad (\text{S-28})$$

Table S-9 shows the information on 30 GC problems¹⁰, including the number of nodes NO , the number of edges NE , the number of colors NC , and MaxTime.

Table S-9 Brief information on 30 GC problems.

Pro.	NO	NE	NC	MaxTime(s)	Pro.	NO	NE	NC	MaxTime(s)
GC01	100	2487	30	1 800	GC16	100	2493	30	1 800
GC02	100	2487	30	1 800	GC17	100	2503	30	1 800
GC03	100	2482	30	1 800	GC18	100	2472	30	1 800
GC04	100	2503	30	1 800	GC19	100	2527	30	1 800
GC05	100	2450	30	1 800	GC20	100	2420	30	1 800
GC06	100	2537	30	1 800	GC21	300	22482	80	36 000
GC07	100	2505	30	1 800	GC22	300	22569	80	36 000
GC08	100	2479	30	1 800	GC23	300	22393	80	36 000
GC09	100	2486	30	1 800	GC24	300	22446	80	36 000
GC10	100	2506	30	1 800	GC25	300	22360	80	36 000
GC11	100	2467	30	1 800	GC26	300	22601	80	36 000
GC12	100	2531	30	1 800	GC27	300	22327	80	36 000
GC13	100	2467	30	1 800	GC28	300	22472	80	36 000
GC14	100	2524	30	1 800	GC29	300	22520	80	36 000
GC15	100	2528	30	1 800	GC30	300	22543	80	36 000

2 Algorithm Description and Parameter Setting

To instantiate the single-point metaheuristic framework, we adopt Simulated Annealing (SA), Variable Neighborhood Search (VNS), Large Neighborhood Search (LNS), and Tabu Search (TS).

Among them, VNS, TS, and SA utilize Algorithm 3 to generate a new solution. LNS employs Algorithm 4 to destroy and repair the current solution and generate a new solution. When Algorithm 4 cannot improve the current solution within $NIter$ iterations, Algorithm 3 is applied in the following multiple iterations to perturb the current solution.

Regarding the acceptance criterion in line 16 of Algorithm 6, VNS and LNS accept S_{subopt} as S when S_{subopt} is better than S . TS employs a tabu set $\mathcal{T}$ to enhance algorithm diversity by prohibiting the solutions in $\mathcal{T}$ from being selected as the current solution. In each iteration, the best solution that is in C and not in $\mathcal{T}$ will be selected as S . When the size of $\mathcal{T}$ reaches its predefined limit, the earliest stored solution in $\mathcal{T}$ will be released. When all solutions in C

¹⁰ The test suit is from <https://people.brunel.ac.uk/~mastijb/jeb/orlib/colourinfo.html>.

are included in $\mathcal{T}$ or S_{subopt} is better than S_{best} , we accept S_{subopt} as S . SA accepts S_{subopt} as S in terms of the acceptance probability in Eq. (S-29).

$$p_{S \leftarrow S_{\text{subopt}}} = \begin{cases} 1, & \text{if } S_{\text{subopt}} \text{ is better than or equal to } S \\ 0, & \text{if } S_{\text{subopt}} \text{ is worse than } S \text{ on constraints} \\ e^{(-\Delta f / T_{\text{current}})}, & \text{otherwise} \end{cases}, \quad (\text{S-29})$$

where $\Delta f = f(X_{\text{subopt}}, Y_{\text{subopt}}) - f(X, Y)$, X_{subopt} , Y_{subopt} and X , Y denote the variables of S_{subopt} and S , respectively. T_{current} is the current temperature. At the beginning of optimization, T_{current} is set to the initial temperature T_{initial} . If the consecutive iteration time reaches a Markov length L , then T_{current} is updated by $T_{\text{current}} = \gamma_c T_{\text{current}}$, where γ_c is a cooling rate. L is set in terms of the number of resources and tasks, i.e., $L = \lfloor 0.1mn \rfloor$.

In Algorithm 6, the non-improvement threshold τ_s is set as $\lfloor 0.05mn \rfloor$. Furthermore, the number of removed nd tasks as presented in Algorithm 4 varies with the scale of problems. At the beginning of optimization, nd is initialized as

$$nd_0 = \min(100, \left\lfloor 0.8 \sum_{i \in \mathcal{I}} n_i \right\rfloor), \quad (\text{S-30})$$

where n_i is the number of tasks assigned to resource R_i . At the current iteration $Iter \in \{1, \dots, \text{MaxIter}\}$, nd is specified as

$$nd_{\text{Iter}} = \min(1, \left\lfloor nd_{\text{Iter}-1} e^{-\text{Iter} / \text{MaxIter}} \right\rfloor). \quad (\text{S-31})$$

For TS, the size of the tabu set $\mathcal{T}$ is also set based on the number of resources and tasks, and dynamically decreases as the number of iterations increases, ranging from an initial value of $\lfloor 0.1mn \rfloor$ to $\lfloor 0.02mn \rfloor$. In addition, the maximum iteration number MaxIter is set to

$$\text{MaxIter} = \begin{cases} 10,000, & \text{if } mn \leq 10,000 \\ 10mn, & \text{if } 10,000 < mn \leq 20,000 \\ 20,000, & \text{if } mn > 20,000 \end{cases}. \quad (\text{S-32})$$

The maximum iteration number MaxIter serves to compute dynamic parameters like Eq.(S-31) and is not considered a termination criterion of an algorithm. Regarding the five metaheuristic algorithms, the termination condition is triggered under either of the following scenarios: (a) the maximum runtime MaxTime is reached, or (b) the number of consecutive iterations without improvement reaches 2,000. For other algorithms, the termination criteria are defined as (a) the maximum runtime, MaxTime, is reached, or (b) the optimal solution is found.

Table S-10 presents other parameters and their possible values for the 5 algorithms in REMS, including SA, VNS, LNS, TS, and Genetic Algorithm (GA).

Table S-10 Algorithm parameters and possible values.

Algorithm	Parameter	Possible values
SA	Initial temperature(A1)	100, 200, 300
	Cooling rate(B1)	0.97, 0.98, 0.99
	Learning rate(C1)	0.1, 0.2, 0.3
	Discount factor(D1)	0.7, 0.8, 0.9
	Greedy factor(E1)	0.1, 0.2, 0.3
VNS	Learning rate(A2)	0.1, 0.2, 0.3
	Discount factor(B2)	0.7, 0.8, 0.9
	Greedy factor(C2)	0.1, 0.2, 0.3
TS	Learning rate(A3)	0.1, 0.2, 0.3
	Discount factor(B3)	0.7, 0.8, 0.9
	Greedy factor(C3)	0.1, 0.2, 0.3
GA	Population size(A4)	30, 50, 80
	Crossover rate(B4)	0.7, 0.8, 0.9
	Mutation rate(C4)	0.1, 0.2, 0.3

Table S-11 presents the S/N ratios for each parameter, calculated based on the mean gap values for the corresponding parameter combinations.

Table S-11 S/N ratios for each parameter, where the best level for each parameter is bolded.

Level	SA					VNS			TS			GA		
	A1	B1	C1	D1	E1	A2	B2	C2	A3	B3	C3	A4	B4	C4
1	3.173	3.229	3.171	3.196	3.153	3.532	3.707	3.782	2.665	2.779	2.728	5.453	5.308	4.997
2	3.177	3.268	3.174	3.223	3.244	3.484	3.664	3.686	2.715	2.776	2.726	5.271	5.250	5.433
3	3.216	3.07	3.222	3.148	3.17	3.566	3.712	3.714	2.736	2.822	2.773	5.366	5.532	5.659
Delta	0.043	0.198	0.051	0.075	0.091	0.082	0.048	0.096	0.071	0.046	0.047	0.182	0.281	0.662
Rank	5	1	4	3	2	2	3	1	1	3	2	3	2	1

The final parameter settings for SA, VNS, LNS, TS, GA, GUROBI, Routing Solver in OR-TOOLS, CP-SAT in OR-TOOLS, and SCIP are shown in Table S-12. To ensure a consistent evaluation across all algorithms, the presolve processes for SCIP, CP-SAT, and GUROBI are set to disabled.

Table S-12 Parameter settings for algorithms.

Algorithm	Parameter setting
SA	Initial Temperature T_{initial} : 100, Cooling rate γ_c : 0.99, Learning rate: 0.1, Discount factor: 0.9, Greedy factor: 0.1, Number of neighborhood solutions N : 1;
VNS	Learning rate: 0.2, Discount factor: 0.8, Greedy factor: 0.2, Number of neighborhood solutions N : 1
LNS	Number of neighborhood solutions N : 1
TS	Learning rate: 0.1, Discount factor: 0.8, Greedy factor: 0.2, Number of neighborhood solutions N : 1;
GA	Population size $popsiz$: 50; Crossover rate p_c :0.8; Mutation rate p_m :0.1;
GUROBI	Presolve: 0; Heuristics: 0;
Routing Solver	Default;
CP-SAT	Presolve: 0;
SCIP	Presolve: 0;

3 Detailed Experimental Results for the Methods in REMS and Other Solvers

The subsection will provide the experimental results on 10 problems for the compared algorithms, including the objective value (obj) and the gap value (gap) over 5 runs. The compared algorithms are GUROBI, OR-TOOLS, SCIO, SA, VNS, LNS, TS, and GA. In these tables, "NaN" indicates that an algorithm was unable to find any feasible solutions within the maximum runtime.

3.1 Multi-depot vehicle routing problem with time windows (MDVRPTW)

Table S-13 displays the experimental results for solving MDVRPTW.

Table S-13 Experimental results on MDVRPTW.

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
MDVRPTW01	obj	Best	NAN	NAN	NAN	5.33E+03	5.27E+03	5.23E+03	5.36E+03	5.31E+03
		Mean	NAN	NAN	NAN	5.68E+03	5.52E+03	6.01E+03	5.90E+03	5.52E+03
	gap	Best	NAN	NAN	NAN	3.91%	2.83%	2.11%	4.35%	3.49%
		Mean	NAN	NAN	NAN	9.36%	6.84%	11.39%	12.60%	6.82%
MDVRPTW02	obj	Best	NAN	NAN	NAN	9.99E+03	1.01E+04	9.98E+03	1.02E+04	1.03E+04
		Mean	NAN	NAN	NAN	1.01E+04	1.02E+04	1.03E+04	1.03E+04	1.04E+04
	gap	Best	NAN	NAN	NAN	21.93%	22.41%	21.84%	23.60%	24.20%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	NAN	NAN	NAN	22.56%	23.57%	24.23%	24.20%	24.69%
MDVR PTW03	obj	Best	NAN	NAN	NAN	1.37E+04	1.39E+04	1.39E+04	1.42E+04	1.51E+04
		Mean	NAN	NAN	NAN	1.40E+04	1.48E+04	1.44E+04	1.47E+04	1.52E+04
	gap	Best	NAN	NAN	NAN	74.06%	74.48%	74.31%	74.89%	76.40%
		Mean	NAN	NAN	NAN	74.50%	75.98%	75.29%	75.78%	76.53%
MDVR PTW04	obj	Best	NAN	NAN	NAN	1.84E+04	1.81E+04	1.83E+04	1.87E+04	1.89E+04
		Mean	NAN	NAN	NAN	1.85E+04	1.84E+04	1.84E+04	1.90E+04	1.95E+04
	gap	Best	NAN	NAN	NAN	79.35%	79.04%	79.26%	79.73%	79.91%
		Mean	NAN	NAN	NAN	79.51%	79.38%	79.41%	79.98%	80.48%
MDVR PTW05	obj	Best	NAN	NAN	NAN	2.34E+04	2.38E+04	2.36E+04	2.42E+04	2.49E+04
		Mean	NAN	NAN	NAN	2.37E+04	2.38E+04	2.39E+04	2.46E+04	2.56E+04
	gap	Best	NAN	NAN	NAN	87.81%	87.99%	87.90%	88.22%	88.54%
		Mean	NAN	NAN	NAN	87.95%	88.03%	88.04%	88.41%	88.86%
MDVR PTW06	obj	Best	NAN	NAN	NAN	2.69E+04	2.66E+04	2.90E+04	2.79E+04	2.87E+04
		Mean	NAN	NAN	NAN	2.75E+04	2.70E+04	2.95E+04	2.82E+04	3.42E+04
	gap	Best	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
		Mean	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
MDVR PTW07	obj	Best	NAN	8.56E+03	1.35E+04	7.92E+03	8.61E+03	7.99E+03	8.82E+03	7.89E+03
		Mean	NAN	8.64E+03	1.35E+04	8.34E+03	8.64E+03	8.43E+03	8.93E+03	8.46E+03
	gap	Best	NAN	28.20%	54.63%	22.38%	28.65%	23.06%	30.32%	22.13%
		Mean	NAN	28.88%	54.63%	26.24%	28.88%	27.10%	31.21%	27.14%
MDVR PTW08	obj	Best	NAN	NAN	NAN	1.39E+04	1.34E+04	1.42E+04	1.47E+04	1.45E+04
		Mean	NAN	NAN	NAN	1.41E+04	1.40E+04	1.44E+04	1.49E+04	1.49E+04
	gap	Best	NAN	NAN	NAN	66.14%	65.01%	66.98%	68.06%	67.53%
		Mean	NAN	NAN	NAN	66.80%	66.35%	67.40%	68.42%	68.55%
MDVR PTW09	obj	Best	NAN	1.93E+04	NAN	1.96E+04	2.00E+04	1.94E+04	2.01E+04	2.06E+04
		Mean	NAN	1.97E+04	NAN	1.98E+04	2.00E+04	1.97E+04	2.03E+04	2.09E+04
	gap	Best	NAN	79.95%	NAN	80.28%	80.20%	80.14%	80.82%	81.24%
		Mean	NAN	80.36%	NAN	80.54%	80.72%	80.38%	80.96%	81.54%
MDVR PTW10	obj	Best	NAN	NAN	NAN	2.86E+04	2.89E+04	2.77E+04	2.93E+04	3.03E+04
		Mean	NAN	NAN	NAN	2.88E+04	2.90E+04	2.85E+04	2.96E+04	3.28E+04
	gap	Best	NAN	NAN	NAN	88.34%	88.44%	87.97%	88.60%	88.97%
		Mean	NAN	NAN	NAN	88.42%	88.50%	88.30%	88.73%	89.81%
MDVR PTW11	obj	Best	NAN	NAN	NAN	5.02E+03	5.14E+03	5.07E+03	5.08E+03	5.10E+03
		Mean	NAN	NAN	NAN	5.07E+03	5.17E+03	5.16E+03	5.18E+03	5.15E+03
	gap	Best	NAN	NAN	NAN	4.01%	6.16%	4.98%	5.06%	5.46%
		Mean	NAN	NAN	NAN	4.93%	6.76%	6.49%	6.85%	6.47%
MDVR PTW12	obj	Best	NAN	NAN	NAN	8.74E+03	8.94E+03	8.45E+03	9.18E+03	8.93E+03
		Mean	NAN	NAN	NAN	8.87E+03	9.21E+03	8.69E+03	9.66E+03	9.21E+03
	gap	Best	NAN	NAN	NAN	7.74%	9.78%	4.62%	12.13%	9.74%
		Mean	NAN	NAN	NAN	9.09%	12.34%	7.18%	16.38%	12.40%
	obj	Best	NAN	NAN	NAN	1.31E+04	1.37E+04	1.19E+04	1.40E+04	1.26E+04

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
MDVR PTW13	gap	Mean	NAN	NAN	NAN	1.34E+04	1.38E+04	1.27E+04	1.43E+04	1.34E+04
		Best	NAN	NAN	NAN	75.79%	76.76%	73.20%	77.33%	74.72%
		Mean	NAN	NAN	NAN	76.31%	77.02%	74.97%	77.78%	76.14%
MDVR PTW14	obj	Best	NAN	NAN	NAN	1.70E+04	1.69E+04	1.64E+04	1.74E+04	1.74E+04
		Mean	NAN	NAN	NAN	1.72E+04	1.71E+04	1.68E+04	1.78E+04	1.75E+04
	gap	Best	NAN	NAN	NAN	85.82%	85.73%	85.28%	86.13%	86.13%
		Mean	NAN	NAN	NAN	85.98%	85.90%	85.64%	86.41%	86.23%
MDVR PTW15	obj	Best	NAN	NAN	NAN	2.21E+04	2.30E+04	2.16E+04	2.35E+04	2.33E+04
		Mean	NAN	NAN	NAN	2.27E+04	2.30E+04	2.25E+04	2.40E+04	2.40E+04
	gap	Best	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
		Mean	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
MDVR PTW16	obj	Best	NAN	2.54E+04	NAN	2.62E+04	2.65E+04	2.60E+04	2.74E+04	2.71E+04
		Mean	NAN	2.55E+04	NAN	2.67E+04	2.68E+04	2.64E+04	2.75E+04	2.73E+04
	gap	Best	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
		Mean	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
MDVR PTW17	obj	Best	NAN	7.28E+03	NAN	7.35E+03	7.38E+03	7.28E+03	7.63E+03	7.47E+03
		Mean	NAN	7.31E+03	NAN	7.47E+03	7.58E+03	7.39E+03	7.75E+03	7.55E+03
	gap	Best	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
		Mean	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
MDVR PTW18	obj	Best	NAN	NAN	NAN	1.34E+04	1.37E+04	1.29E+04	1.41E+04	1.37E+04
		Mean	NAN	NAN	NAN	1.37E+04	1.38E+04	1.32E+04	1.45E+04	1.39E+04
	gap	Best	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
		Mean	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
MDVR PTW19	obj	Best	NAN	1.87E+04	NAN	1.91E+04	1.88E+04	1.84E+04	1.95E+04	1.92E+04
		Mean	NAN	1.88E+04	NAN	1.92E+04	1.92E+04	1.89E+04	1.98E+04	1.95E+04
	gap	Best	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
		Mean	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
MDVR PTW20	obj	Best	NAN	NAN	NAN	2.82E+04	2.81E+04	2.75E+04	2.86E+04	2.96E+04
		Mean	NAN	NAN	NAN	2.86E+04	2.86E+04	2.81E+04	2.91E+04	3.09E+04
	gap	Best	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN
		Mean	NAN	NAN	NAN	NAN	NAN	NAN	NAN	NAN

3.2 Vehicle routing problem with pickup and delivery (VRPPD)

The relevant experimental results on VRPPD are presented in Table S-14.

Table S-14 Experimental results on VRPPD.

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
VRPPD01	obj	Best	NAN	1.12E+03	NAN	1.65E+03	1.67E+03	1.64E+03	1.83E+03	1.72E+03
		Mean	NAN	1.13E+03	NAN	1.72E+03	1.74E+03	1.65E+03	1.92E+03	1.75E+03
	gap	Best	NAN	10.44%	NAN	39.39%	39.76%	38.95%	45.32%	41.85%
		Mean	NAN	11.59%	NAN	41.76%	42.22%	39.09%	47.51%	42.75%
VRPPD02	obj	Best	NAN	1.12E+03	NAN	1.82E+03	1.84E+03	1.74E+03	1.76E+03	1.84E+03
		Mean	NAN	1.13E+03	NAN	1.86E+03	1.87E+03	1.74E+03	1.92E+03	1.88E+03

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
	gap	Best	NAN	10.02%	NAN	44.52%	44.91%	41.78%	42.67%	45.13%
		Mean	NAN	10.75%	NAN	45.61%	45.90%	42.02%	47.09%	46.11%
VRPPD03	obj	Best	NAN	1.19E+03	NAN	2.33E+03	2.19E+03	2.10E+03	2.35E+03	2.26E+03
		Mean	NAN	1.19E+03	NAN	2.38E+03	2.27E+03	2.14E+03	2.44E+03	2.33E+03
	gap	Best	NAN	71.21%	NAN	85.29%	84.30%	83.67%	85.39%	84.83%
		Mean	NAN	71.21%	NAN	85.60%	84.88%	83.98%	85.91%	85.26%
VRPPD04	obj	Best	NAN	6.03E+02	NAN	1.66E+03	1.67E+03	1.64E+03	1.74E+03	1.67E+03
		Mean	NAN	6.16E+02	NAN	1.68E+03	1.69E+03	1.65E+03	1.79E+03	1.70E+03
	gap	Best	NAN	44.71%	NAN	79.90%	80.01%	79.70%	80.85%	80.05%
		Mean	NAN	45.85%	NAN	80.15%	80.31%	79.81%	81.38%	80.33%
VRPPD05	obj	Best	NAN	1.12E+03	NAN	2.18E+03	2.18E+03	2.08E+03	2.31E+03	2.11E+03
		Mean	NAN	1.12E+03	NAN	2.21E+03	2.21E+03	2.11E+03	2.39E+03	2.17E+03
	gap	Best	NAN	31.66%	NAN	64.97%	64.97%	63.38%	66.98%	63.91%
		Mean	NAN	31.66%	NAN	65.56%	65.55%	63.82%	68.14%	64.84%
VRPPD06	obj	Best	NAN	1.26E+03	NAN	2.31E+03	2.34E+03	2.29E+03	2.44E+03	2.28E+03
		Mean	NAN	1.26E+03	NAN	2.35E+03	2.41E+03	2.30E+03	2.53E+03	2.36E+03
	gap	Best	NAN	37.72%	NAN	65.98%	66.39%	65.64%	67.85%	65.62%
		Mean	NAN	37.72%	NAN	66.60%	67.44%	65.84%	68.90%	66.68%
VRPPD07	obj	Best	NAN	1.42E+03	NAN	2.65E+03	2.71E+03	2.62E+03	2.83E+03	2.67E+03
		Mean	NAN	1.42E+03	NAN	2.71E+03	2.74E+03	2.64E+03	2.92E+03	2.75E+03
	gap	Best	NAN	60.59%	NAN	78.90%	79.37%	78.64%	80.26%	79.06%
		Mean	NAN	60.59%	NAN	79.34%	79.58%	78.82%	80.85%	79.68%
VRPPD08	obj	Best	NAN	1.11E+03	NAN	2.53E+03	2.50E+03	2.47E+03	2.81E+03	2.60E+03
		Mean	NAN	1.15E+03	NAN	2.63E+03	2.57E+03	2.49E+03	2.96E+03	2.65E+03
	gap	Best	NAN	25.35%	NAN	67.26%	66.86%	66.46%	70.55%	68.19%
		Mean	NAN	27.60%	NAN	68.48%	67.79%	66.66%	71.98%	68.71%
VRPPD09	obj	Best	NAN	1.12E+03	NAN	1.98E+03	2.03E+03	1.94E+03	2.15E+03	1.97E+03
		Mean	NAN	1.12E+03	NAN	2.03E+03	2.09E+03	1.95E+03	2.32E+03	2.05E+03
	gap	Best	NAN	28.13%	NAN	59.27%	60.41%	58.49%	62.52%	59.01%
		Mean	NAN	28.13%	NAN	60.33%	61.34%	58.67%	65.18%	60.63%
VRPPD10	obj	Best	NAN	1.12E+03	NAN	2.21E+03	2.15E+03	2.07E+03	2.33E+03	2.18E+03
		Mean	NAN	1.14E+03	NAN	2.24E+03	2.19E+03	2.09E+03	2.47E+03	2.22E+03
	gap	Best	NAN	25.62%	NAN	62.27%	61.28%	59.72%	64.23%	61.83%
		Mean	NAN	27.09%	NAN	62.80%	61.91%	60.22%	66.17%	62.52%
VRPPD11	obj	Best	NAN	6.92E+02	NAN	1.62E+03	1.66E+03	1.58E+03	1.73E+03	1.61E+03
		Mean	NAN	7.65E+02	NAN	1.67E+03	1.69E+03	1.59E+03	1.85E+03	1.65E+03
	gap	Best	NAN	4.40%	NAN	59.28%	60.03%	58.14%	61.79%	58.98%
		Mean	NAN	13.23%	NAN	60.36%	60.95%	58.46%	64.14%	59.79%
VRPPD12	obj	Best	NAN	8.72E+02	NAN	2.11E+03	2.04E+03	2.01E+03	2.24E+03	2.09E+03
		Mean	NAN	8.92E+02	NAN	2.14E+03	2.10E+03	2.03E+03	2.36E+03	2.16E+03
	gap	Best	NAN	60.02%	NAN	83.48%	82.93%	82.69%	84.46%	83.29%
		Mean	NAN	60.91%	NAN	83.73%	83.35%	82.85%	85.21%	83.86%
VRPPD13	obj	Best	NAN	4.24E+02	NAN	1.76E+03	1.77E+03	1.75E+03	1.86E+03	1.82E+03
		Mean	NAN	4.34E+02	NAN	1.85E+03	1.81E+03	1.76E+03	1.98E+03	1.86E+03
	gap	Best	NAN	11.75%	NAN	70.97%	71.13%	70.80%	72.43%	71.81%
		Mean	NAN	18.02%	NAN	72.25%	71.73%	70.94%	74.08%	72.43%
VRPPD14	obj	Best	NAN	5.65E+02	NAN	1.67E+03	1.70E+03	1.62E+03	1.77E+03	1.70E+03

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
VRPPD15	gap	Mean	NAN	5.65E+02	NAN	1.70E+03	1.73E+03	1.64E+03	1.89E+03	1.72E+03
		Best	NAN	33.46%	NAN	77.42%	77.90%	76.80%	78.81%	77.92%
		Mean	NAN	33.46%	NAN	77.86%	78.30%	77.12%	80.13%	78.12%
	obj	Best	NAN	6.64E+02	NAN	1.80E+03	1.78E+03	1.75E+03	1.86E+03	1.77E+03
		Mean	NAN	6.81E+02	NAN	1.82E+03	1.84E+03	1.76E+03	1.93E+03	1.81E+03
	gap	Best	NAN	28.04%	NAN	73.39%	73.23%	72.77%	74.26%	73.06%
		Mean	NAN	29.73%	NAN	73.68%	74.04%	72.92%	75.16%	73.64%
VRPPD16	obj	Best	NAN	6.07E+02	NAN	1.22E+03	1.19E+03	1.17E+03	1.24E+03	1.19E+03
		Mean	NAN	6.11E+02	NAN	1.22E+03	1.21E+03	1.18E+03	1.32E+03	1.20E+03
	gap	Best	NAN	27.15%	NAN	63.73%	62.96%	62.18%	64.28%	62.69%
		Mean	NAN	27.65%	NAN	63.76%	63.55%	62.62%	66.37%	63.14%
VRPPD17	obj	Best	NAN	5.65E+02	NAN	1.45E+03	1.45E+03	1.40E+03	1.54E+03	1.43E+03
		Mean	NAN	5.71E+02	NAN	1.46E+03	1.47E+03	1.42E+03	1.63E+03	1.47E+03
	gap	Best	NAN	19.74%	NAN	68.74%	68.80%	67.69%	70.62%	68.39%
		Mean	NAN	20.55%	NAN	68.98%	69.15%	68.06%	72.19%	69.24%
VRPPD18	obj	Best	NAN	6.17E+02	NAN	1.99E+03	1.93E+03	1.92E+03	2.06E+03	1.96E+03
		Mean	NAN	6.57E+02	NAN	2.01E+03	1.99E+03	1.94E+03	2.13E+03	2.01E+03
	gap	Best	NAN	51.59%	NAN	84.95%	84.54%	84.47%	85.53%	84.76%
		Mean	NAN	54.46%	NAN	85.15%	84.95%	84.60%	85.95%	85.13%
VRPPD19	obj	Best	NAN	5.38E+02	NAN	1.39E+03	1.41E+03	1.37E+03	1.49E+03	1.37E+03
		Mean	NAN	5.74E+02	NAN	1.43E+03	1.44E+03	1.40E+03	1.55E+03	1.40E+03
	gap	Best	NAN	32.55%	NAN	73.85%	74.28%	73.55%	75.65%	73.59%
		Mean	NAN	36.41%	NAN	74.65%	74.85%	74.09%	76.47%	74.16%
VRPPD20	obj	Best	NAN	5.73E+02	NAN	1.93E+03	1.89E+03	1.87E+03	2.04E+03	1.92E+03
		Mean	NAN	5.94E+02	NAN	1.94E+03	1.94E+03	1.88E+03	2.08E+03	1.96E+03
	gap	Best	NAN	46.60%	NAN	84.13%	83.85%	83.61%	84.98%	84.10%
		Mean	NAN	48.42%	NAN	84.26%	84.19%	83.72%	85.30%	84.35%
VRPPD21	obj	Best	NAN	6.94E+02	NAN	1.58E+03	1.55E+03	1.52E+03	1.71E+03	1.55E+03
		Mean	NAN	7.08E+02	NAN	1.61E+03	1.58E+03	1.54E+03	1.75E+03	1.56E+03
	gap	Best	NAN	46.64%	NAN	76.55%	76.13%	75.68%	78.29%	76.14%
		Mean	NAN	47.67%	NAN	77.00%	76.58%	75.93%	78.85%	76.30%
VRPPD22	obj	Best	NAN	6.40E+02	NAN	1.47E+03	1.44E+03	1.33E+03	1.56E+03	1.37E+03
		Mean	NAN	6.40E+02	NAN	1.49E+03	1.46E+03	1.35E+03	1.68E+03	1.46E+03
	gap	Best	NAN	12.69%	NAN	61.94%	61.16%	58.13%	64.14%	59.25%
		Mean	NAN	12.69%	NAN	62.55%	61.70%	58.70%	66.55%	61.76%
VRPPD23	obj	Best	NAN	7.10E+02	NAN	1.90E+03	1.91E+03	1.87E+03	2.05E+03	1.94E+03
		Mean	NAN	7.20E+02	NAN	1.96E+03	2.02E+03	1.89E+03	2.14E+03	2.00E+03
	gap	Best	NAN	55.24%	NAN	83.24%	83.39%	82.99%	84.47%	83.60%
		Mean	NAN	55.83%	NAN	83.78%	84.30%	83.19%	85.14%	84.11%
VRPPD24	obj	Best	NAN	4.41E+02	NAN	1.22E+03	1.23E+03	1.17E+03	1.27E+03	1.19E+03
		Mean	NAN	4.45E+02	NAN	1.23E+03	1.24E+03	1.18E+03	1.32E+03	1.21E+03
	gap	Best	NAN	26.61%	NAN	73.45%	73.61%	72.24%	74.54%	72.80%
		Mean	NAN	27.33%	NAN	73.71%	73.88%	72.62%	75.47%	73.16%
VRPPD25	obj	Best	NAN	4.60E+02	NAN	1.39E+03	1.41E+03	1.36E+03	1.48E+03	1.43E+03
		Mean	NAN	4.68E+02	NAN	1.43E+03	1.44E+03	1.38E+03	1.52E+03	1.45E+03
	gap	Best	NAN	19.95%	NAN	73.57%	73.82%	73.00%	75.19%	74.32%
		Mean	NAN	21.29%	NAN	74.20%	74.39%	73.31%	75.79%	74.59%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
VRPPD26	obj	Best	NAN	5.42E+02	NAN	1.90E+03	1.89E+03	1.86E+03	1.91E+03	1.89E+03
		Mean	NAN	5.43E+02	NAN	1.91E+03	1.92E+03	1.88E+03	1.97E+03	1.92E+03
	gap	Best	NAN	16.41%	NAN	76.13%	76.06%	75.67%	76.26%	76.09%
		Mean	NAN	16.54%	NAN	76.27%	76.36%	75.94%	76.93%	76.39%
VRPPD27	obj	Best	NAN	8.97E+02	NAN	1.92E+03	1.93E+03	1.85E+03	2.00E+03	1.92E+03
		Mean	NAN	9.39E+02	NAN	1.96E+03	1.97E+03	1.88E+03	2.10E+03	1.95E+03
	gap	Best	NAN	41.98%	NAN	72.88%	72.99%	71.87%	73.94%	72.91%
		Mean	NAN	44.50%	NAN	73.39%	73.58%	72.38%	75.11%	73.35%
VRPPD28	obj	Best	NAN	9.56E+02	NAN	2.42E+03	2.44E+03	2.36E+03	2.54E+03	2.46E+03
		Mean	NAN	1.02E+03	NAN	2.45E+03	2.47E+03	2.39E+03	2.66E+03	2.48E+03
	gap	Best	NAN	52.35%	NAN	81.14%	81.35%	80.71%	82.03%	81.49%
		Mean	NAN	55.11%	NAN	81.40%	81.57%	80.95%	82.86%	81.65%
VRPPD29	obj	Best	NAN	9.11E+02	NAN	1.93E+03	1.89E+03	1.85E+03	2.05E+03	1.93E+03
		Mean	NAN	9.25E+02	NAN	1.95E+03	1.93E+03	1.87E+03	2.18E+03	1.98E+03
	gap	Best	NAN	44.34%	NAN	73.73%	73.16%	72.61%	75.26%	73.67%
		Mean	NAN	45.15%	NAN	74.05%	73.73%	72.83%	76.77%	74.39%
VRPPD30	obj	Best	NAN	1.04E+03	NAN	2.37E+03	2.40E+03	2.31E+03	2.54E+03	2.40E+03
		Mean	NAN	1.07E+03	NAN	2.43E+03	2.43E+03	2.33E+03	2.61E+03	2.44E+03
	gap	Best	NAN	51.20%	NAN	78.57%	78.86%	78.04%	80.05%	78.87%
		Mean	NAN	52.64%	NAN	79.10%	79.11%	78.26%	80.58%	79.20%

3.3 Generalized assignment problem (GAP)

Table S-15 provides the experimental results for GAP.

Table S-15 Experimental results on GAP.

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
GAP01	obj	Best	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03
		Mean	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%	0.00%
		Mean	0.00%	0.00%	0.00%	0.13%	0.04%	0.00%	0.24%	0.13%
GAP02	obj	Best	3.24E+03	3.24E+03	3.24E+03	3.24E+03	3.24E+03	3.24E+03	3.24E+03	3.24E+03
		Mean	3.24E+03	3.24E+03	3.24E+03	3.24E+03	3.24E+03	3.24E+03	3.24E+03	3.24E+03
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.01%
GAP03	obj	Best	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03
		Mean	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.00%	0.12%	0.09%	0.00%	0.10%	0.04%
GAP04	obj	Best	2.62E+03	2.62E+03	2.62E+03	2.62E+03	2.62E+03	2.62E+03	2.63E+03	2.62E+03
		Mean	2.62E+03	2.62E+03	2.62E+03	2.63E+03	2.63E+03	2.62E+03	2.63E+03	2.62E+03
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%	0.00%
		Mean	0.00%	0.00%	0.00%	0.10%	0.09%	0.00%	0.18%	0.05%
GAP05	obj	Best	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03
		Mean	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03	1.16E+03
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.07%	0.00%
GAP06	obj	Best	2.34E+03	2.34E+03	2.34E+03	2.34E+03	2.34E+03	2.34E+03	2.34E+03	2.34E+03

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
	gap	Mean	2.34E+03	2.34E+03	2.34E+03	2.34E+03	2.34E+03	2.34E+03	2.34E+03	2.34E+03
		Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.00%	0.16%	0.00%	0.00%	0.07%	0.09%
GAP07	obj	Best	1.84E+03	1.84E+03	1.84E+03	2.01E+03	1.92E+03	1.93E+03	1.96E+03	1.89E+03
		Mean	1.84E+03	1.84E+03	1.84E+03	2.02E+03	1.96E+03	1.93E+03	2.02E+03	1.90E+03
	gap	Best	0.00%	0.00%	0.00%	8.31%	3.76%	4.26%	6.11%	2.44%
		Mean	0.00%	0.00%	0.00%	8.88%	6.05%	4.53%	8.74%	3.21%
GAP08	obj	Best	3.55E+03	3.55E+03	3.55E+03	3.75E+03	3.60E+03	3.63E+03	3.77E+03	3.70E+03
		Mean	3.55E+03	3.55E+03	3.55E+03	3.81E+03	3.67E+03	3.68E+03	3.79E+03	3.72E+03
	gap	Best	0.00%	0.00%	0.00%	5.18%	1.39%	2.18%	5.71%	4.08%
		Mean	0.00%	0.00%	0.00%	6.67%	3.24%	3.58%	6.37%	4.58%
GAP09	obj	Best	1.41E+03	1.41E+03	1.41E+03	1.44E+03	1.42E+03	1.41E+03	1.43E+03	1.42E+03
		Mean	1.41E+03	1.41E+03	1.41E+03	1.46E+03	1.45E+03	1.42E+03	1.48E+03	1.42E+03
	gap	Best	0.00%	0.00%	0.00%	2.49%	0.99%	0.00%	1.54%	0.92%
		Mean	0.00%	0.00%	0.00%	3.92%	3.17%	0.79%	4.64%	1.19%
GAP10	obj	Best	2.83E+03	2.83E+03	2.83E+03	3.01E+03	2.97E+03	2.85E+03	2.97E+03	2.92E+03
		Mean	2.83E+03	2.83E+03	2.83E+03	3.03E+03	3.00E+03	2.91E+03	3.04E+03	2.94E+03
	gap	Best	0.00%	0.00%	0.00%	6.20%	4.72%	0.67%	4.88%	3.28%
		Mean	0.00%	0.00%	0.00%	6.70%	5.63%	2.88%	7.00%	3.98%
GAP11	obj	Best	1.17E+03	1.17E+03	1.17E+03	1.19E+03	1.19E+03	1.17E+03	1.19E+03	1.18E+03
		Mean	1.17E+03	1.17E+03	1.17E+03	1.20E+03	1.21E+03	1.18E+03	1.20E+03	1.19E+03
	gap	Best	0.00%	0.00%	0.00%	2.10%	1.93%	0.43%	2.10%	0.93%
		Mean	0.00%	0.00%	0.00%	2.97%	3.84%	0.91%	3.04%	1.60%
GAP12	obj	Best	2.34E+03	2.34E+03	2.34E+03	2.41E+03	2.36E+03	2.35E+03	2.36E+03	2.37E+03
		Mean	2.34E+03	2.34E+03	2.34E+03	2.42E+03	2.39E+03	2.35E+03	2.38E+03	2.39E+03
	gap	Best	0.00%	0.00%	0.00%	2.95%	0.93%	0.26%	0.93%	1.47%
		Mean	0.00%	0.00%	0.00%	3.43%	2.11%	0.34%	1.77%	1.96%
GAP13	obj	Best	1.93E+03	1.93E+03	1.93E+03	2.02E+03	1.97E+03	1.98E+03	2.02E+03	1.97E+03
		Mean	1.93E+03	1.93E+03	1.93E+03	2.04E+03	2.00E+03	2.00E+03	2.08E+03	1.98E+03
	gap	Best	0.00%	0.00%	0.00%	4.45%	2.13%	2.57%	4.45%	1.98%
		Mean	0.00%	0.00%	0.00%	5.23%	3.33%	3.28%	7.26%	2.32%
GAP14	obj	Best	3.46E+03	3.46E+03	3.46E+03	3.64E+03	3.46E+03	3.53E+03	3.66E+03	3.55E+03
		Mean	3.46E+03	3.46E+03	3.46E+03	3.68E+03	3.57E+03	3.60E+03	3.70E+03	3.59E+03
	gap	Best	0.00%	0.00%	0.00%	5.16%	0.12%	2.10%	5.60%	2.70%
		Mean	0.00%	0.00%	0.00%	6.12%	3.28%	3.92%	6.49%	3.76%
GAP15	obj	Best	1.40E+03	1.40E+03	1.40E+03	1.52E+03	1.48E+03	1.43E+03	1.47E+03	1.43E+03
		Mean	1.40E+03	1.40E+03	1.40E+03	1.58E+03	1.51E+03	1.44E+03	1.50E+03	1.45E+03
	gap	Best	0.00%	0.00%	0.00%	7.70%	5.33%	2.09%	4.69%	2.23%
		Mean	0.00%	0.00%	0.00%	11.14%	7.02%	2.78%	6.64%	3.33%
GAP16	obj	Best	2.81E+03	2.81E+03	2.81E+03	2.99E+03	2.89E+03	2.81E+03	3.04E+03	2.93E+03
		Mean	2.81E+03	2.81E+03	2.81E+03	3.03E+03	2.93E+03	2.90E+03	3.07E+03	2.95E+03
	gap	Best	0.00%	0.00%	0.00%	6.12%	2.81%	0.21%	7.73%	4.17%
		Mean	0.00%	0.00%	0.00%	7.50%	4.37%	3.19%	8.71%	4.95%
GAP17	obj	Best	5.60E+03	5.60E+03	5.60E+03	5.90E+03	5.73E+03	5.67E+03	5.85E+03	6.03E+03
		Mean	5.60E+03	5.60E+03	5.60E+03	5.97E+03	5.79E+03	5.73E+03	5.96E+03	6.06E+03
	gap	Best	0.00%	0.00%	0.00%	5.06%	2.30%	1.25%	4.39%	7.20%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	0.00%	0.00%	0.00%	6.16%	3.39%	2.30%	6.06%	7.64%
GAP18	obj	Best	1.17E+04	1.13E+04	1.13E+04	1.23E+04	1.16E+04	1.15E+04	1.21E+04	1.19E+04
		Mean	1.18E+04	1.13E+04	1.13E+04	1.23E+04	1.19E+04	1.17E+04	1.22E+04	1.20E+04
	gap	Best	3.09%	0.00%	0.04%	7.57%	2.11%	1.57%	5.93%	4.78%
		Mean	3.62%	0.01%	0.04%	8.15%	4.86%	2.84%	7.12%	5.72%
GAP19	obj	Best	1.24E+03	1.24E+03	1.24E+03	1.34E+03	1.30E+03	1.23E+03	1.28E+03	1.27E+03
		Mean	1.24E+03	1.24E+03	1.24E+03	1.36E+03	1.31E+03	1.26E+03	1.31E+03	1.28E+03
	gap	Best	0.00%	0.00%	0.00%	6.96%	4.24%	1.39%	3.19%	2.20%
		Mean	0.00%	0.00%	0.00%	8.40%	4.87%	1.82%	4.93%	2.68%
GAP20	obj	Best	2.39E+03	2.39E+03	2.39E+03	2.51E+03	2.51E+03	2.36E+03	2.51E+03	2.50E+03
		Mean	2.39E+03	2.39E+03	2.39E+03	2.57E+03	2.53E+03	2.43E+03	2.54E+03	2.51E+03
	gap	Best	0.00%	0.00%	0.00%	4.59%	4.70%	1.23%	4.67%	4.21%
		Mean	0.00%	0.00%	0.00%	6.86%	5.40%	2.05%	5.79%	4.85%
GAP21	obj	Best	4.78E+03	4.78E+03	4.78E+03	5.03E+03	5.11E+03	4.79E+03	5.07E+03	4.96E+03
		Mean	4.78E+03	4.78E+03	4.78E+03	5.13E+03	5.18E+03	4.87E+03	5.14E+03	5.06E+03
	gap	Best	0.00%	0.00%	0.00%	4.87%	6.36%	0.06%	5.59%	3.65%
		Mean	0.00%	0.00%	0.00%	6.78%	7.67%	1.85%	6.88%	5.50%
GAP22	obj	Best	1.11E+04	9.98E+03	9.99E+03	1.06E+04	1.07E+04	1.01E+04	1.05E+04	1.07E+04
		Mean	1.11E+04	9.98E+03	9.99E+03	1.08E+04	1.08E+04	1.03E+04	1.07E+04	1.10E+04
	gap	Best	9.85%	0.01%	0.06%	6.08%	6.33%	1.42%	5.01%	6.43%
		Mean	9.85%	0.02%	0.06%	7.52%	7.20%	2.86%	6.30%	9.48%
GAP23	obj	Best	4.24E+03	4.24E+03	4.24E+03	4.36E+03	4.34E+03	4.26E+03	4.34E+03	4.37E+03
		Mean	4.24E+03	4.24E+03	4.24E+03	4.43E+03	4.35E+03	4.29E+03	4.40E+03	4.41E+03
	gap	Best	0.00%	0.00%	0.00%	2.68%	2.10%	0.26%	2.30%	2.93%
		Mean	0.00%	0.00%	0.00%	4.09%	2.52%	1.02%	3.48%	3.70%
GAP24	obj	Best	9.43E+03	9.33E+03	9.34E+03	9.60E+03	9.42E+03	9.34E+03	9.60E+03	9.64E+03
		Mean	9.49E+03	9.33E+03	9.34E+03	9.69E+03	9.53E+03	9.50E+03	9.63E+03	1.04E+04
	gap	Best	1.13%	0.02%	0.12%	2.89%	1.04%	0.13%	2.89%	3.22%
		Mean	1.71%	0.04%	0.12%	3.74%	2.13%	1.84%	3.18%	9.20%
GAP25	obj	Best	1.90E+04	1.88E+04	1.88E+04	2.03E+04	2.05E+04	1.92E+04	1.98E+04	2.03E+04
		Mean	1.90E+04	1.88E+04	1.88E+04	2.04E+04	2.08E+04	1.94E+04	2.03E+04	2.18E+04
	gap	Best	0.94%	0.01%	0.02%	7.57%	8.43%	2.27%	5.09%	7.37%
		Mean	0.94%	0.01%	0.02%	7.75%	9.56%	2.92%	7.22%	13.42%
GAP26	obj	Best	1.74E+04	1.71E+04	1.72E+04	1.79E+04	1.79E+04	1.73E+04	1.75E+04	1.84E+04
		Mean	1.74E+04	1.71E+04	1.72E+04	1.81E+04	1.80E+04	1.74E+04	1.80E+04	2.01E+04
	gap	Best	1.34%	0.02%	0.05%	4.24%	4.39%	1.11%	1.84%	6.63%
		Mean	1.34%	0.02%	0.05%	5.24%	4.90%	1.66%	4.51%	14.42%
GAP27	obj	Best	NAN	1.63E+04	NAN	1.67E+04	1.66E+04	1.69E+04	1.68E+04	1.70E+04
		Mean	NAN	1.63E+04	NAN	1.68E+04	1.67E+04	1.70E+04	1.68E+04	2.06E+04
	gap	Best	NAN	0.04%	NAN	2.72%	1.66%	3.81%	2.96%	4.44%
		Mean	NAN	0.04%	NAN	3.11%	2.54%	4.11%	3.20%	20.30%
GAP28	obj	Best	6.35E+03	6.35E+03	6.36E+03	6.70E+03	6.82E+03	6.59E+03	6.81E+03	6.59E+03
		Mean	6.35E+03	6.35E+03	6.36E+03	6.75E+03	6.84E+03	6.62E+03	6.84E+03	6.61E+03
	gap	Best	0.00%	0.00%	0.08%	5.15%	6.81%	3.52%	6.64%	3.57%
		Mean	0.00%	0.02%	0.08%	5.94%	7.18%	4.05%	7.16%	3.88%
GAP29	obj	Best	1.27E+04	1.27E+04	1.28E+04	1.33E+04	1.38E+04	1.31E+04	1.36E+04	1.32E+04

Pro.	Metric	Status	GUROBI	OR- TOOLS	SCIP	SA	VNS	LNS	TS	GA
	gap	Mean	1.27E+04	1.27E+04	1.28E+04	1.36E+04	1.38E+04	1.32E+04	1.36E+04	1.33E+04
		Best	0.05%	0.02%	0.06%	4.48%	7.70%	2.77%	6.09%	3.31%
		Mean	0.05%	0.03%	0.06%	6.06%	7.91%	3.37%	6.57%	3.90%
GAP30	obj	Best	6.38E+03	6.36E+03	6.38E+03	6.80E+03	6.88E+03	6.69E+03	6.84E+03	6.69E+03
		Mean	6.38E+03	6.37E+03	6.38E+03	6.91E+03	6.95E+03	6.75E+03	6.91E+03	6.72E+03
	gap	Best	0.47%	0.19%	0.56%	6.62%	7.75%	5.17%	7.22%	5.13%
		Mean	0.47%	0.33%	0.56%	8.07%	8.68%	5.94%	8.12%	5.52%
GAP31	obj	Best	1.25E+04	1.24E+04	1.25E+04	1.36E+04	1.33E+04	1.30E+04	1.35E+04	1.30E+04
		Mean	1.25E+04	1.25E+04	1.25E+04	1.37E+04	1.36E+04	1.31E+04	1.36E+04	1.32E+04
	gap	Best	0.31%	0.18%	0.30%	8.75%	6.70%	4.44%	8.17%	4.50%
		Mean	0.31%	0.22%	0.30%	9.47%	8.84%	5.38%	8.54%	6.03%
GAP32	obj	Best	2.50E+04	2.50E+04	2.50E+04	2.64E+04	2.69E+04	2.59E+04	2.65E+04	2.61E+04
		Mean	2.50E+04	2.50E+04	2.50E+04	2.66E+04	2.73E+04	2.60E+04	2.69E+04	2.63E+04
	gap	Best	0.11%	0.04%	0.08%	5.53%	7.18%	3.62%	5.81%	4.53%
		Mean	0.11%	0.05%	0.08%	6.24%	8.73%	3.97%	7.05%	5.25%
GAP33	obj	Best	5.56E+04	5.54E+04	5.55E+04	5.93E+04	6.03E+04	5.77E+04	5.96E+04	5.86E+04
		Mean	5.56E+04	5.62E+04	5.55E+04	5.95E+04	6.16E+04	5.80E+04	5.97E+04	5.92E+04
	gap	Best	0.37%	0.07%	0.11%	6.51%	8.05%	4.04%	7.06%	5.46%
		Mean	0.37%	1.30%	0.11%	6.93%	10.00%	4.46%	7.26%	6.39%
GAP34	obj	Best	6.32E+03	6.23E+03	6.29E+03	6.63E+03	6.68E+03	6.49E+03	6.71E+03	6.49E+03
		Mean	6.32E+03	6.24E+03	6.29E+03	6.75E+03	6.73E+03	6.57E+03	6.80E+03	6.54E+03
	gap	Best	2.29%	0.82%	1.73%	6.89%	7.56%	4.84%	7.94%	4.84%
		Mean	2.29%	0.99%	1.73%	8.51%	8.23%	5.96%	9.12%	5.51%
GAP35	obj	Best	1.25E+04	1.23E+04	1.24E+04	1.31E+04	1.33E+04	1.29E+04	1.34E+04	1.32E+04
		Mean	1.25E+04	1.23E+04	1.24E+04	1.32E+04	1.33E+04	1.30E+04	1.35E+04	1.32E+04
	gap	Best	1.85%	0.46%	1.15%	6.63%	7.98%	5.39%	8.68%	7.22%
		Mean	1.85%	0.65%	1.15%	7.49%	8.22%	5.83%	9.33%	7.44%
GAP36	obj	Best	2.48E+04	2.46E+04	2.47E+04	2.65E+04	2.67E+04	2.59E+04	2.69E+04	2.63E+04
		Mean	2.48E+04	2.46E+04	2.47E+04	2.67E+04	2.72E+04	2.61E+04	2.71E+04	2.65E+04
	gap	Best	1.06%	0.23%	0.41%	7.15%	7.97%	5.07%	8.57%	6.78%
		Mean	1.06%	0.36%	0.41%	7.94%	9.65%	5.76%	9.42%	7.29%
GAP37	obj	Best	5.55E+04	5.49E+04	5.50E+04	5.86E+04	6.13E+04	5.82E+04	6.01E+04	5.94E+04
		Mean	5.55E+04	5.50E+04	5.50E+04	5.97E+04	6.20E+04	5.84E+04	6.07E+04	5.96E+04
	gap	Best	1.18%	0.18%	0.39%	6.46%	10.55%	5.81%	8.84%	7.76%
		Mean	1.18%	0.25%	0.39%	8.07%	11.52%	6.03%	9.65%	8.00%
GAP38	obj	Best	2.50E+04	2.45E+04	2.46E+04	2.64E+04	2.66E+04	2.60E+04	2.70E+04	2.66E+04
		Mean	2.50E+04	2.45E+04	2.46E+04	2.67E+04	2.68E+04	2.61E+04	2.71E+04	2.67E+04
	gap	Best	2.48%	0.72%	1.22%	7.78%	8.49%	6.27%	9.72%	8.45%
		Mean	2.48%	0.82%	1.22%	8.94%	9.31%	6.74%	10.22%	8.83%
GAP39	obj	Best	NAN	5.48E+04	5.50E+04	5.89E+04	6.00E+04	5.85E+04	6.02E+04	5.95E+04
		Mean	NAN	5.48E+04	5.50E+04	5.97E+04	6.06E+04	5.87E+04	6.08E+04	5.97E+04
	gap	Best	NAN	0.46%	0.88%	7.32%	9.10%	6.76%	9.45%	8.39%
		Mean	NAN	0.50%	0.88%	8.58%	9.99%	7.03%	10.34%	8.58%
GAP40	obj	Best	9.84E+04	9.79E+04	9.79E+04	1.03E+05	1.02E+05	1.02E+05	1.06E+05	1.09E+05
		Mean	9.84E+04	9.79E+04	9.79E+04	1.05E+05	1.08E+05	1.03E+05	1.07E+05	1.09E+05
	gap	Best	0.56%	0.06%	0.11%	4.81%	4.50%	4.40%	7.68%	9.88%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	0.56%	0.07%	0.11%	6.84%	9.07%	4.58%	8.43%	10.61%
GAP41	obj	Best	NAN	9.73E+04	9.75E+04	1.06E+05	1.03E+05	1.03E+05	1.07E+05	1.08E+05
		Mean	NAN	9.73E+04	9.75E+04	1.06E+05	1.07E+05	1.06E+05	1.07E+05	1.09E+05
	gap	Best	NAN	0.17%	0.39%	8.29%	6.11%	6.11%	8.83%	10.41%
		Mean	NAN	0.19%	0.39%	8.75%	9.43%	8.00%	9.44%	11.28%
GAP42	obj	Best	NAN	9.73E+04	9.76E+04	1.06E+05	1.04E+05	1.04E+05	1.08E+05	1.09E+05
		Mean	NAN	9.74E+04	9.76E+04	1.07E+05	1.08E+05	1.06E+05	1.09E+05	1.10E+05
	gap	Best	NAN	0.32%	0.59%	8.75%	7.13%	7.13%	10.21%	11.28%
		Mean	NAN	0.35%	0.59%	9.65%	9.71%	8.04%	10.87%	11.62%
GAP43	obj	Best	1.27E+04	1.27E+04	1.27E+04	1.44E+04	1.51E+04	1.31E+04	1.39E+04	1.42E+04
		Mean	1.27E+04	1.27E+04	1.27E+04	1.54E+04	1.59E+04	1.35E+04	1.50E+04	1.45E+04
	gap	Best	0.00%	0.00%	0.00%	11.89%	16.24%	3.47%	8.87%	10.89%
		Mean	0.00%	0.00%	0.00%	17.43%	19.82%	5.69%	15.19%	12.69%
GAP44	obj	Best	2.49E+04	2.49E+04	2.49E+04	3.07E+04	3.27E+04	2.65E+04	3.17E+04	2.75E+04
		Mean	2.49E+04	2.49E+04	2.49E+04	3.26E+04	3.46E+04	2.69E+04	3.30E+04	2.83E+04
	gap	Best	0.00%	0.00%	0.00%	18.83%	23.79%	6.05%	21.34%	9.38%
		Mean	0.00%	0.00%	0.00%	23.37%	27.85%	7.33%	24.25%	11.88%
GAP45	obj	Best	1.16E+04	1.16E+04	1.16E+04	1.37E+04	1.40E+04	1.24E+04	1.32E+04	1.27E+04
		Mean	1.16E+04	1.16E+04	1.16E+04	1.46E+04	1.45E+04	1.27E+04	1.42E+04	1.30E+04
	gap	Best	0.00%	0.00%	0.00%	15.21%	17.03%	6.61%	12.58%	8.72%
		Mean	0.00%	0.01%	0.00%	20.46%	20.01%	8.62%	18.06%	11.08%
GAP46	obj	Best	2.33E+04	2.33E+04	2.33E+04	2.86E+04	2.90E+04	2.55E+04	2.68E+04	2.60E+04
		Mean	2.33E+04	2.33E+04	2.33E+04	2.99E+04	3.03E+04	2.57E+04	2.78E+04	2.71E+04
	gap	Best	0.01%	0.01%	0.01%	18.64%	19.52%	8.70%	13.09%	10.45%
		Mean	0.01%	0.01%	0.01%	21.86%	22.97%	9.19%	16.16%	13.95%
GAP47	obj	Best	4.57E+04	4.57E+04	4.57E+04	5.46E+04	5.15E+04	5.01E+04	5.48E+04	5.49E+04
		Mean	4.57E+04	4.57E+04	4.57E+04	5.51E+04	5.43E+04	5.04E+04	5.59E+04	5.58E+04
	gap	Best	0.01%	0.00%	0.00%	16.22%	11.12%	8.66%	16.51%	16.70%
		Mean	0.01%	0.00%	0.00%	16.97%	15.62%	9.28%	18.13%	17.97%
GAP48	obj	Best	1.02E+05	1.02E+05	1.02E+05	1.18E+05	1.24E+05	1.15E+05	1.25E+05	1.28E+05
		Mean	1.02E+05	1.02E+05	1.02E+05	1.24E+05	1.29E+05	1.16E+05	1.27E+05	1.32E+05
	gap	Best	0.00%	0.00%	0.00%	13.42%	17.38%	10.87%	17.93%	20.15%
		Mean	0.00%	0.00%	0.00%	17.48%	20.38%	11.57%	19.64%	22.26%
GAP49	obj	Best	8.44E+03	8.44E+03	8.44E+03	9.59E+03	9.80E+03	8.91E+03	9.77E+03	9.38E+03
		Mean	8.44E+03	8.47E+03	8.44E+03	9.82E+03	9.99E+03	9.10E+03	1.00E+04	9.87E+03
	gap	Best	0.00%	0.00%	0.00%	12.01%	13.95%	5.27%	13.65%	10.02%
		Mean	0.00%	0.41%	0.00%	14.04%	15.52%	7.24%	15.65%	14.41%
GAP50	obj	Best	2.24E+04	2.24E+04	2.24E+04	2.59E+04	2.53E+04	2.41E+04	2.72E+04	2.59E+04
		Mean	2.24E+04	2.24E+04	2.24E+04	2.67E+04	2.65E+04	2.45E+04	2.73E+04	2.65E+04
	gap	Best	0.00%	0.00%	0.00%	13.44%	11.59%	7.21%	17.81%	13.45%
		Mean	0.00%	0.00%	0.00%	16.03%	15.55%	8.76%	18.05%	15.60%
GAP51	obj	Best	4.49E+04	4.49E+04	4.49E+04	5.44E+04	5.08E+04	5.00E+04	5.43E+04	5.39E+04
		Mean	4.49E+04	4.49E+04	4.49E+04	5.52E+04	5.36E+04	5.04E+04	5.47E+04	5.55E+04
	gap	Best	0.01%	0.00%	0.00%	17.55%	11.73%	10.25%	17.32%	16.67%
		Mean	0.01%	0.00%	0.00%	18.69%	16.23%	10.94%	18.02%	19.16%
GAP52	obj	Best	1.04E+05	1.00E+05	1.00E+05	1.22E+05	1.21E+05	1.14E+05	1.17E+05	1.25E+05

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
	gap	Mean	1.04E+05	1.00E+05	1.00E+05	1.25E+05	1.24E+05	1.15E+05	1.24E+05	1.28E+05
		Best	3.86%	0.00%	0.00%	17.66%	16.95%	12.25%	13.85%	19.43%
		Mean	3.86%	0.00%	0.00%	19.54%	18.80%	12.61%	18.65%	21.20%
GAP53	obj	Best	4.64E+04	4.46E+04	4.46E+04	5.24E+04	5.05E+04	4.95E+04	5.43E+04	5.37E+04
		Mean	4.64E+04	4.46E+04	4.46E+04	5.36E+04	5.31E+04	4.99E+04	5.54E+04	5.44E+04
	gap	Best	3.92%	0.00%	0.17%	15.02%	11.85%	10.05%	17.96%	16.98%
		Mean	3.92%	0.00%	0.17%	16.86%	15.99%	10.64%	19.54%	18.05%
GAP54	obj	Best	1.04E+05	1.00E+05	1.02E+05	1.21E+05	1.19E+05	1.15E+05	1.25E+05	1.27E+05
		Mean	1.04E+05	1.00E+05	1.02E+05	1.23E+05	1.23E+05	1.17E+05	1.30E+05	1.30E+05
	gap	Best	3.83%	0.00%	1.39%	17.45%	15.81%	13.07%	19.94%	21.14%
		Mean	3.83%	0.03%	1.39%	18.42%	18.24%	14.34%	22.63%	22.95%
GAP55	obj	Best	1.85E+05	1.81E+05	1.81E+05	2.30E+05	2.56E+05	2.17E+05	2.17E+05	2.96E+05
		Mean	1.85E+05	1.81E+05	1.81E+05	2.35E+05	2.79E+05	2.27E+05	2.37E+05	3.12E+05
	gap	Best	2.41%	0.00%	0.00%	21.37%	29.35%	16.69%	16.69%	38.99%
		Mean	2.60%	0.00%	0.00%	23.07%	35.23%	20.32%	23.49%	41.92%
GAP56	obj	Best	1.82E+05	1.78E+05	1.79E+05	2.25E+05	2.50E+05	2.22E+05	2.39E+05	2.86E+05
		Mean	1.82E+05	1.78E+05	1.79E+05	2.30E+05	2.63E+05	2.23E+05	2.47E+05	3.07E+05
	gap	Best	1.92%	0.00%	0.45%	20.60%	28.72%	19.71%	25.39%	37.73%
		Mean	1.92%	0.01%	0.45%	22.50%	32.18%	20.20%	27.86%	41.78%
GAP57	obj	Best	NAN	1.77E+05	1.79E+05	2.32E+05	2.58E+05	2.24E+05	2.36E+05	2.80E+05
		Mean	NAN	1.77E+05	1.79E+05	2.34E+05	2.67E+05	2.29E+05	2.47E+05	3.22E+05
	gap	Best	NAN	0.00%	1.28%	23.68%	31.43%	20.90%	25.10%	36.83%
		Mean	NAN	0.04%	1.28%	24.54%	33.63%	22.63%	28.40%	44.83%

3.4 Capacitated facility location problem (CFLP)

The experimental results of CFLP are presented in Table S-16.

Table S-16 Experimental results on CFLP.

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
CFLP01	obj	Best	2.84E+03	2.89E+03	2.94E+03	3.22E+03	3.41E+03	3.12E+03	3.72E+03	3.37E+03
		Mean	2.84E+03	2.97E+03	2.98E+03	3.38E+03	3.52E+03	3.15E+03	3.77E+03	3.41E+03
	gap	Best	0.00%	1.51%	3.36%	11.70%	16.54%	8.95%	23.53%	15.59%
		Mean	0.00%	4.12%	4.54%	15.77%	19.18%	9.63%	24.65%	16.72%
CFLP02	obj	Best	2.98E+03	3.05E+03	3.15E+03	3.47E+03	3.57E+03	3.35E+03	3.75E+03	3.44E+03
		Mean	2.98E+03	3.07E+03	3.20E+03	3.61E+03	3.67E+03	3.38E+03	3.92E+03	3.51E+03
	gap	Best	0.00%	2.34%	5.49%	14.12%	16.60%	11.05%	20.58%	13.46%
		Mean	0.00%	3.07%	6.87%	17.44%	18.87%	11.86%	24.01%	15.13%
CFLP03	obj	Best	3.04E+03	3.12E+03	3.25E+03	3.64E+03	3.57E+03	3.25E+03	3.71E+03	3.57E+03
		Mean	3.04E+03	3.16E+03	3.25E+03	3.73E+03	3.66E+03	3.31E+03	3.85E+03	3.62E+03
	gap	Best	0.00%	2.46%	6.47%	16.46%	14.89%	6.40%	18.11%	14.86%
		Mean	0.00%	3.79%	6.52%	18.37%	17.00%	8.00%	21.04%	16.04%
CFLP04	obj	Best	2.98E+03	3.05E+03	3.17E+03	3.34E+03	3.60E+03	3.28E+03	3.74E+03	3.53E+03
		Mean	2.98E+03	3.11E+03	3.17E+03	3.53E+03	3.66E+03	3.30E+03	3.85E+03	3.58E+03
	gap	Best	0.00%	2.19%	5.89%	10.55%	17.14%	8.98%	20.15%	15.53%
		Mean	0.00%	3.96%	5.89%	15.25%	18.43%	9.56%	22.48%	16.61%
CFLP05	obj	Best	3.04E+03	3.14E+03	3.25E+03	3.45E+03	3.57E+03	3.30E+03	3.64E+03	3.39E+03
		Mean	3.04E+03	3.17E+03	3.26E+03	3.58E+03	3.62E+03	3.33E+03	3.71E+03	3.45E+03

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
	gap	Best	0.00%	3.14%	6.57%	11.87%	14.93%	7.92%	16.40%	10.32%
		Mean	0.00%	4.17%	6.59%	15.08%	16.06%	8.70%	18.11%	11.84%
CFLP06	obj	Best	2.95E+03	3.08E+03	3.13E+03	3.47E+03	3.56E+03	3.26E+03	3.74E+03	3.47E+03
		Mean	2.95E+03	3.15E+03	3.13E+03	3.57E+03	3.64E+03	3.30E+03	3.79E+03	3.53E+03
	gap	Best	0.00%	4.17%	5.57%	14.88%	16.96%	9.27%	20.91%	14.77%
		Mean	0.00%	6.14%	5.57%	17.29%	18.78%	10.50%	21.99%	16.21%
CFLP07	obj	Best	2.89E+03	3.04E+03	3.03E+03	3.37E+03	3.54E+03	3.24E+03	3.30E+03	3.36E+03
		Mean	2.89E+03	3.11E+03	3.03E+03	3.43E+03	3.66E+03	3.26E+03	3.61E+03	3.42E+03
	gap	Best	0.00%	5.21%	4.60%	14.26%	18.52%	10.85%	12.53%	14.09%
		Mean	0.00%	7.16%	4.71%	15.89%	21.11%	11.45%	19.71%	15.63%
CFLP08	obj	Best	2.94E+03	3.00E+03	3.14E+03	3.56E+03	3.51E+03	3.27E+03	3.67E+03	3.38E+03
		Mean	2.94E+03	3.09E+03	3.15E+03	3.66E+03	3.66E+03	3.28E+03	3.86E+03	3.52E+03
	gap	Best	0.00%	2.08%	6.39%	17.36%	16.20%	9.97%	19.88%	12.91%
		Mean	0.00%	4.70%	6.59%	19.64%	19.60%	10.29%	23.76%	16.26%
CFLP09	obj	Best	2.23E+03	2.28E+03	2.27E+03	2.58E+03	2.65E+03	2.50E+03	2.66E+03	2.57E+03
		Mean	2.23E+03	2.31E+03	2.28E+03	2.65E+03	2.76E+03	2.53E+03	2.73E+03	2.58E+03
	gap	Best	0.00%	1.98%	1.53%	13.30%	15.65%	10.65%	16.15%	13.10%
		Mean	0.00%	3.17%	1.92%	15.81%	19.18%	11.57%	18.09%	13.44%
CFLP10	obj	Best	2.30E+03	2.32E+03	2.33E+03	2.64E+03	2.53E+03	2.49E+03	2.70E+03	2.65E+03
		Mean	2.30E+03	2.37E+03	2.34E+03	2.67E+03	2.64E+03	2.54E+03	2.73E+03	2.68E+03
	gap	Best	0.00%	0.63%	1.28%	12.73%	9.07%	7.62%	14.67%	13.15%
		Mean	0.00%	2.62%	1.43%	13.85%	12.60%	9.14%	15.57%	14.19%
CFLP11	obj	Best	2.25E+03	2.32E+03	2.30E+03	2.52E+03	2.55E+03	2.52E+03	2.58E+03	2.66E+03
		Mean	2.25E+03	2.35E+03	2.30E+03	2.60E+03	2.63E+03	2.57E+03	2.69E+03	2.71E+03
	gap	Best	0.00%	3.20%	2.16%	10.92%	11.91%	10.67%	12.98%	15.63%
		Mean	0.00%	4.40%	2.16%	13.44%	14.55%	12.68%	16.21%	17.03%
CFLP12	obj	Best	2.24E+03	2.32E+03	2.25E+03	2.47E+03	2.63E+03	2.41E+03	2.57E+03	2.55E+03
		Mean	2.24E+03	2.36E+03	2.26E+03	2.61E+03	2.66E+03	2.49E+03	2.65E+03	2.58E+03
	gap	Best	0.00%	3.43%	0.56%	9.34%	14.90%	7.08%	12.98%	12.21%
		Mean	0.00%	5.12%	0.66%	13.98%	15.89%	9.86%	15.44%	13.21%
CFLP13	obj	Best	2.25E+03	2.34E+03	2.29E+03	2.60E+03	2.56E+03	2.45E+03	2.58E+03	2.56E+03
		Mean	2.25E+03	2.38E+03	2.29E+03	2.66E+03	2.65E+03	2.51E+03	2.70E+03	2.62E+03
	gap	Best	0.00%	3.85%	1.74%	13.22%	12.11%	7.98%	12.75%	12.05%
		Mean	0.00%	5.43%	1.74%	15.38%	15.01%	10.16%	16.37%	14.07%
CFLP14	obj	Best	2.18E+03	2.22E+03	2.21E+03	2.51E+03	2.39E+03	2.39E+03	2.44E+03	2.53E+03
		Mean	2.18E+03	2.25E+03	2.21E+03	2.57E+03	2.52E+03	2.44E+03	2.52E+03	2.54E+03
	gap	Best	0.00%	1.43%	1.26%	12.87%	8.72%	8.71%	10.33%	13.48%
		Mean	0.00%	2.68%	1.28%	15.04%	13.03%	10.55%	13.24%	13.93%
CFLP15	obj	Best	2.24E+03	2.27E+03	2.25E+03	2.50E+03	2.57E+03	2.39E+03	2.68E+03	2.49E+03
		Mean	2.24E+03	2.30E+03	2.25E+03	2.57E+03	2.64E+03	2.45E+03	2.74E+03	2.58E+03
	gap	Best	0.00%	1.36%	0.71%	10.40%	12.87%	6.33%	16.62%	10.29%
		Mean	0.00%	2.62%	0.82%	12.95%	15.27%	8.71%	18.45%	13.24%
CFLP16	obj	Best	2.27E+03	2.31E+03	2.32E+03	2.50E+03	2.60E+03	2.49E+03	2.67E+03	2.62E+03
		Mean	2.27E+03	2.32E+03	2.32E+03	2.55E+03	2.66E+03	2.54E+03	2.73E+03	2.68E+03
	gap	Best	0.00%	1.62%	2.27%	9.22%	12.87%	8.98%	14.99%	13.49%
		Mean	0.00%	2.37%	2.27%	11.11%	14.77%	10.76%	16.76%	15.19%
CFLP17	obj	Best	2.06E+03	2.08E+03	2.07E+03	2.27E+03	2.33E+03	2.12E+03	2.29E+03	2.32E+03

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
	gap	Mean	2.06E+03	2.09E+03	2.08E+03	2.34E+03	2.42E+03	2.23E+03	2.42E+03	2.37E+03
		Best	0.00%	1.31%	0.68%	9.47%	11.57%	3.04%	10.25%	11.21%
		Mean	0.00%	1.77%	1.11%	12.19%	14.73%	7.42%	14.73%	13.17%
CFLP18	obj	Best	1.96E+03	1.98E+03	1.96E+03	2.22E+03	2.26E+03	2.10E+03	2.37E+03	2.14E+03
		Mean	1.96E+03	1.99E+03	1.96E+03	2.25E+03	2.29E+03	2.19E+03	2.39E+03	2.21E+03
	gap	Best	0.00%	0.83%	0.00%	11.55%	13.31%	6.65%	17.15%	8.29%
		Mean	0.00%	1.35%	0.00%	12.86%	14.53%	10.35%	17.99%	11.39%
CFLP19	obj	Best	2.10E+03	2.13E+03	2.10E+03	2.32E+03	2.28E+03	2.28E+03	2.43E+03	2.49E+03
		Mean	2.10E+03	2.15E+03	2.10E+03	2.48E+03	2.41E+03	2.34E+03	2.47E+03	2.52E+03
	gap	Best	0.00%	1.22%	0.00%	9.30%	7.65%	7.57%	13.27%	15.66%
		Mean	0.00%	1.93%	0.00%	14.95%	12.60%	10.11%	14.84%	16.63%
CFLP20	obj	Best	2.02E+03	2.02E+03	2.02E+03	2.24E+03	2.25E+03	2.13E+03	2.39E+03	2.12E+03
		Mean	2.02E+03	2.05E+03	2.02E+03	2.32E+03	2.33E+03	2.22E+03	2.48E+03	2.24E+03
	gap	Best	0.00%	0.00%	0.00%	9.80%	9.91%	5.06%	15.20%	4.62%
		Mean	0.00%	1.26%	0.00%	12.58%	12.93%	8.67%	18.13%	9.46%
CFLP21	obj	Best	1.98E+03	1.98E+03	1.98E+03	2.15E+03	2.27E+03	2.24E+03	2.30E+03	2.14E+03
		Mean	1.98E+03	2.01E+03	1.99E+03	2.29E+03	2.30E+03	2.31E+03	2.36E+03	2.24E+03
	gap	Best	0.00%	0.00%	0.20%	7.76%	12.94%	11.66%	13.77%	7.50%
		Mean	0.00%	1.40%	0.43%	13.24%	14.08%	14.06%	16.09%	11.40%
CFLP22	obj	Best	1.95E+03	1.95E+03	1.95E+03	2.17E+03	2.15E+03	2.07E+03	2.27E+03	2.15E+03
		Mean	1.95E+03	1.97E+03	1.95E+03	2.22E+03	2.21E+03	2.14E+03	2.34E+03	2.25E+03
	gap	Best	0.00%	0.00%	0.00%	10.28%	9.57%	6.15%	14.12%	9.57%
		Mean	0.00%	1.36%	0.00%	12.26%	12.06%	8.91%	16.71%	13.29%
CFLP23	obj	Best	2.06E+03	2.06E+03	2.06E+03	2.29E+03	2.32E+03	2.18E+03	2.36E+03	2.18E+03
		Mean	2.06E+03	2.07E+03	2.07E+03	2.34E+03	2.39E+03	2.24E+03	2.44E+03	2.26E+03
	gap	Best	0.00%	0.00%	0.00%	9.90%	10.92%	5.46%	12.72%	5.29%
		Mean	0.00%	0.23%	0.19%	11.79%	13.71%	7.75%	15.26%	8.64%
CFLP24	obj	Best	2.03E+03	2.03E+03	2.03E+03	2.26E+03	2.21E+03	2.21E+03	2.36E+03	2.30E+03
		Mean	2.03E+03	2.05E+03	2.03E+03	2.28E+03	2.34E+03	2.25E+03	2.42E+03	2.34E+03
	gap	Best	0.00%	0.00%	0.00%	10.39%	8.13%	8.13%	14.28%	11.77%
		Mean	0.00%	1.01%	0.01%	11.14%	13.14%	10.08%	16.14%	13.46%
CFLP25	obj	Best	1.88E+03	1.88E+03	1.88E+03	2.01E+03	2.18E+03	2.01E+03	2.23E+03	2.14E+03
		Mean	1.88E+03	1.88E+03	1.88E+03	2.15E+03	2.21E+03	2.12E+03	2.29E+03	2.19E+03
	gap	Best	0.00%	0.00%	0.00%	6.25%	13.58%	6.19%	15.53%	12.01%
		Mean	0.00%	0.00%	0.00%	12.07%	14.87%	10.85%	17.79%	14.03%
CFLP26	obj	Best	2.07E+03	2.08E+03	2.08E+03	2.30E+03	2.45E+03	2.27E+03	2.37E+03	2.29E+03
		Mean	2.07E+03	2.09E+03	2.08E+03	2.38E+03	2.49E+03	2.31E+03	2.38E+03	2.37E+03
	gap	Best	0.00%	0.30%	0.30%	9.99%	15.65%	8.71%	12.46%	9.40%
		Mean	0.00%	0.87%	0.30%	13.09%	16.67%	10.25%	13.09%	12.59%
CFLP27	obj	Best	1.94E+03	1.94E+03	1.94E+03	2.19E+03	2.12E+03	2.07E+03	2.14E+03	2.14E+03
		Mean	1.94E+03	1.94E+03	1.94E+03	2.24E+03	2.20E+03	2.10E+03	2.21E+03	2.19E+03
	gap	Best	0.00%	0.00%	0.10%	11.40%	8.45%	6.55%	9.54%	9.71%
		Mean	0.00%	0.00%	0.11%	13.49%	11.83%	7.84%	12.39%	11.51%
CFLP28	obj	Best	1.95E+03	1.95E+03	1.95E+03	2.16E+03	2.22E+03	2.16E+03	2.28E+03	2.16E+03
		Mean	1.95E+03	1.95E+03	1.95E+03	2.21E+03	2.29E+03	2.20E+03	2.33E+03	2.26E+03
	gap	Best	0.00%	0.00%	0.00%	9.75%	12.48%	9.75%	14.65%	9.90%
		Mean	0.00%	0.00%	0.00%	11.77%	14.96%	11.59%	16.50%	13.77%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
CFLP29	obj	Best	1.96E+03	1.96E+03	1.96E+03	2.26E+03	2.26E+03	2.10E+03	2.32E+03	2.10E+03
		Mean	1.96E+03	1.96E+03	1.96E+03	2.31E+03	2.30E+03	2.21E+03	2.39E+03	2.19E+03
	gap	Best	0.00%	0.00%	0.00%	13.34%	13.45%	6.87%	15.66%	6.69%
		Mean	0.00%	0.00%	0.00%	15.29%	14.98%	11.52%	18.07%	10.62%
CFLP30	obj	Best	1.89E+03	1.89E+03	1.89E+03	2.02E+03	2.09E+03	2.02E+03	2.12E+03	2.13E+03
		Mean	1.89E+03	1.89E+03	1.89E+03	2.13E+03	2.13E+03	2.04E+03	2.22E+03	2.16E+03
	gap	Best	0.00%	0.00%	0.00%	6.18%	9.53%	6.18%	10.57%	11.07%
		Mean	0.00%	0.00%	0.00%	10.87%	11.07%	7.39%	14.49%	12.19%
CFLP31	obj	Best	2.04E+03	2.04E+03	2.04E+03	2.28E+03	2.25E+03	2.15E+03	2.32E+03	2.28E+03
		Mean	2.04E+03	2.04E+03	2.05E+03	2.32E+03	2.30E+03	2.23E+03	2.34E+03	2.32E+03
	gap	Best	0.00%	0.00%	0.00%	10.57%	9.05%	4.90%	12.01%	10.22%
		Mean	0.00%	0.11%	0.22%	11.77%	11.12%	8.13%	12.87%	11.84%
CFLP32	obj	Best	1.94E+03	1.94E+03	1.94E+03	2.10E+03	2.29E+03	2.18E+03	2.21E+03	2.09E+03
		Mean	1.94E+03	2.31E+03	1.94E+03	2.22E+03	2.39E+03	2.24E+03	2.29E+03	2.24E+03
	gap	Best	0.00%	0.00%	0.00%	7.45%	15.39%	10.87%	12.00%	7.13%
		Mean	0.00%	9.68%	0.00%	12.33%	18.60%	13.26%	15.10%	12.87%
CFLP33	obj	Best	1.94E+03	1.94E+03	1.94E+03	2.05E+03	2.10E+03	2.10E+03	2.21E+03	2.05E+03
		Mean	1.94E+03	1.94E+03	1.94E+03	2.18E+03	2.17E+03	2.14E+03	2.30E+03	2.17E+03
	gap	Best	0.00%	0.00%	0.00%	5.56%	7.70%	7.59%	12.41%	5.47%
		Mean	0.00%	0.00%	0.00%	10.72%	10.54%	9.34%	15.54%	10.43%
CFLP34	obj	Best	2.00E+03	2.00E+03	2.00E+03	2.16E+03	2.25E+03	2.16E+03	2.28E+03	2.21E+03
		Mean	2.00E+03	2.00E+03	2.00E+03	2.19E+03	2.30E+03	2.23E+03	2.36E+03	2.29E+03
	gap	Best	0.00%	0.00%	0.00%	7.17%	10.98%	7.17%	12.13%	9.22%
		Mean	0.00%	0.00%	0.00%	8.53%	12.87%	10.12%	14.96%	12.45%
CFLP35	obj	Best	2.07E+03	2.07E+03	2.07E+03	2.32E+03	2.23E+03	2.16E+03	2.40E+03	2.34E+03
		Mean	2.07E+03	2.09E+03	2.07E+03	2.43E+03	2.30E+03	2.24E+03	2.43E+03	2.39E+03
	gap	Best	0.00%	0.13%	0.00%	10.92%	7.28%	4.31%	13.88%	11.74%
		Mean	0.00%	1.39%	0.00%	14.89%	10.27%	7.54%	15.01%	13.49%
CFLP36	obj	Best	1.94E+03	1.94E+03	1.94E+03	2.20E+03	2.33E+03	2.19E+03	2.24E+03	2.23E+03
		Mean	1.94E+03	1.94E+03	1.94E+03	2.24E+03	2.36E+03	2.21E+03	2.32E+03	2.34E+03
	gap	Best	0.00%	0.00%	0.00%	12.01%	16.82%	11.45%	13.49%	13.20%
		Mean	0.00%	0.00%	0.00%	13.59%	17.89%	12.41%	16.38%	16.89%
CFLP37	obj	Best	1.95E+03	1.95E+03	1.95E+03	2.17E+03	2.21E+03	2.16E+03	2.27E+03	2.21E+03
		Mean	1.95E+03	1.95E+03	1.95E+03	2.26E+03	2.25E+03	2.22E+03	2.35E+03	2.23E+03
	gap	Best	0.00%	0.00%	0.00%	9.89%	11.50%	9.55%	14.03%	11.50%
		Mean	0.00%	0.00%	0.00%	13.51%	13.32%	12.13%	16.64%	12.50%
CFLP38	obj	Best	2.01E+03	2.01E+03	2.01E+03	2.20E+03	2.28E+03	2.20E+03	2.27E+03	2.20E+03
		Mean	2.01E+03	2.01E+03	2.01E+03	2.26E+03	2.31E+03	2.24E+03	2.34E+03	2.27E+03
	gap	Best	0.00%	0.00%	0.00%	8.56%	11.58%	8.52%	11.43%	8.49%
		Mean	0.00%	0.00%	0.00%	10.93%	12.74%	10.31%	13.73%	11.43%
CFLP39	obj	Best	1.96E+03	1.96E+03	1.96E+03	2.12E+03	2.14E+03	2.09E+03	2.09E+03	2.16E+03
		Mean	1.96E+03	1.96E+03	1.96E+03	2.18E+03	2.30E+03	2.13E+03	2.21E+03	2.24E+03
	gap	Best	0.00%	0.00%	0.00%	7.70%	8.24%	6.11%	6.33%	9.27%
		Mean	0.00%	0.00%	0.00%	9.97%	14.36%	7.89%	11.06%	12.56%
CFLP40	obj	Best	1.99E+03	1.99E+03	1.99E+03	2.17E+03	2.25E+03	2.14E+03	2.27E+03	2.17E+03
		Mean	1.99E+03	1.99E+03	1.99E+03	2.29E+03	2.30E+03	2.19E+03	2.34E+03	2.24E+03
	gap	Best	0.00%	0.00%	0.00%	8.11%	11.31%	6.70%	12.27%	7.97%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	0.00%	0.00%	0.00%	12.77%	13.26%	9.13%	14.65%	10.93%

3.5 Bin packing problem with conflicts (BPPC)

The relevant experimental results on BPPC are presented in Table S-17.

Table S-17 Experimental results on BPPC.

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
BPPC01	obj	Best	NAN	1.06E+02	1.09E+02	1.06E+02	1.06E+02	1.06E+02	1.06E+02	1.07E+02
		Mean	NAN	1.06E+02	1.09E+02	1.07E+02	1.06E+02	1.07E+02	1.07E+02	1.07E+02
	gap	Best	NAN	31.13%	33.03%	31.13%	31.13%	31.13%	31.13%	31.78%
		Mean	NAN	31.26%	33.03%	31.56%	31.13%	31.56%	31.45%	31.78%
BPPC02	obj	Best	NAN	1.05E+02	1.11E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02
		Mean	NAN	1.06E+02	1.11E+02	1.06E+02	1.05E+02	1.06E+02	1.06E+02	1.06E+02
	gap	Best	NAN	2.86%	8.11%	2.86%	2.86%	2.86%	2.86%	2.86%
		Mean	NAN	3.41%	8.11%	3.92%	2.86%	3.32%	3.77%	3.92%
BPPC03	obj	Best	NAN	1.04E+02	1.08E+02	1.04E+02	1.04E+02	1.04E+02	1.04E+02	1.05E+02
		Mean	NAN	1.04E+02	1.08E+02	1.05E+02	1.04E+02	1.04E+02	1.05E+02	1.05E+02
	gap	Best	NAN	6.73%	10.19%	6.73%	6.73%	6.73%	6.73%	7.62%
		Mean	NAN	6.73%	10.19%	7.44%	7.03%	7.03%	7.76%	7.91%
BPPC04	obj	Best	NAN	1.05E+02	1.10E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.07E+02
		Mean	NAN	1.05E+02	1.10E+02	1.06E+02	1.05E+02	1.06E+02	1.06E+02	1.08E+02
	gap	Best	NAN	4.76%	9.09%	4.76%	4.76%	4.76%	4.76%	6.54%
		Mean	NAN	4.76%	9.09%	6.01%	4.94%	5.48%	5.95%	6.97%
BPPC05	obj	Best	NAN	1.18E+02	1.23E+02	1.22E+02	1.19E+02	1.20E+02	1.21E+02	1.21E+02
		Mean	NAN	1.18E+02	1.23E+02	1.22E+02	1.21E+02	1.21E+02	1.23E+02	1.23E+02
	gap	Best	NAN	44.92%	47.15%	46.72%	45.38%	45.83%	46.28%	46.28%
		Mean	NAN	45.10%	47.15%	46.89%	46.10%	46.10%	47.06%	47.06%
BPPC06	obj	Best	NAN	1.32E+02	1.38E+02	1.34E+02	1.33E+02	1.33E+02	1.33E+02	1.35E+02
		Mean	NAN	1.33E+02	1.38E+02	1.35E+02	1.35E+02	1.34E+02	1.34E+02	1.36E+02
	gap	Best	NAN	93.94%	94.20%	94.03%	93.98%	93.98%	93.98%	94.07%
		Mean	NAN	93.98%	94.20%	94.08%	94.08%	94.03%	94.05%	94.12%
BPPC07	obj	Best	NAN	1.66E+02	1.70E+02	1.69E+02	1.67E+02	1.68E+02	1.69E+02	1.71E+02
		Mean	NAN	1.67E+02	1.70E+02	1.69E+02	1.68E+02	1.68E+02	1.71E+02	1.71E+02
	gap	Best	NAN	93.98%	94.12%	94.08%	94.01%	94.05%	94.08%	94.15%
		Mean	NAN	94.00%	94.12%	94.09%	94.06%	94.05%	94.15%	94.16%
BPPC08	obj	Best	NAN	1.78E+02	1.82E+02	1.79E+02	1.79E+02	1.78E+02	1.80E+02	1.80E+02
		Mean	NAN	1.79E+02	1.82E+02	1.81E+02	1.81E+02	1.79E+02	1.81E+02	1.81E+02
	gap	Best	NAN	98.31%	98.35%	98.32%	98.32%	98.31%	98.33%	98.33%
		Mean	NAN	98.33%	98.35%	98.34%	98.34%	98.33%	98.34%	98.35%
BPPC09	obj	Best	NAN	2.05E+02	2.07E+02	2.05E+02	2.05E+02	2.05E+02	2.05E+02	2.05E+02
		Mean	NAN	2.05E+02	2.07E+02	2.05E+02	2.05E+02	2.05E+02	2.05E+02	2.05E+02
	gap	Best	NAN	97.07%	97.10%	97.07%	97.07%	97.07%	97.07%	97.07%
		Mean	NAN	97.08%	97.10%	97.07%	97.07%	97.07%	97.07%	97.08%
BPPC10	obj	Best	NAN	2.29E+02	2.32E+02	2.28E+02	2.28E+02	2.29E+02	2.29E+02	2.29E+02
		Mean	NAN	2.30E+02	2.32E+02	2.29E+02	2.29E+02	2.30E+02	2.30E+02	2.30E+02
	gap	Best	NAN	92.58%	92.67%	92.54%	92.54%	92.58%	92.58%	92.58%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	NAN	92.61%	92.67%	92.57%	92.57%	92.59%	92.61%	92.61%
BPPC11	obj	Best	NAN	2.13E+02	2.19E+02	2.14E+02	2.13E+02	2.14E+02	2.15E+02	2.14E+02
		Mean	NAN	2.15E+02	NAN	2.16E+02	2.14E+02	2.14E+02	2.17E+02	2.15E+02
	gap	Best	NAN	66.20%	67.12%	66.36%	66.20%	66.36%	66.51%	66.36%
		Mean	NAN	66.48%	NAN	66.59%	66.39%	66.42%	66.74%	66.54%
BPPC12	obj	Best	NAN	2.15E+02	2.33E+02	2.14E+02	2.13E+02	2.12E+02	2.12E+02	2.13E+02
		Mean	NAN	2.15E+02	2.39E+02	2.14E+02	2.14E+02	2.13E+02	2.14E+02	2.14E+02
	gap	Best	NAN	52.56%	56.22%	52.34%	52.11%	51.89%	51.89%	52.11%
		Mean	NAN	52.56%	57.39%	52.34%	52.26%	52.00%	52.30%	52.34%
BPPC13	obj	Best	NAN	2.14E+02	2.63E+02	2.16E+02	2.15E+02	2.14E+02	2.16E+02	2.17E+02
		Mean	NAN	2.15E+02	2.63E+02	2.16E+02	2.15E+02	2.15E+02	2.17E+02	2.18E+02
	gap	Best	NAN	99.07%	99.24%	99.07%	99.07%	99.07%	99.07%	99.08%
		Mean	NAN	99.07%	99.24%	99.08%	99.07%	99.07%	99.08%	99.08%
BPPC14	obj	Best	NAN	2.19E+02	2.22E+02	2.19E+02	2.18E+02	2.17E+02	2.19E+02	2.20E+02
		Mean	NAN	2.20E+02	2.22E+02	2.20E+02	2.19E+02	2.17E+02	2.20E+02	2.21E+02
	gap	Best	NAN	95.89%	95.95%	95.89%	95.87%	95.85%	95.89%	95.91%
		Mean	NAN	95.90%	95.95%	95.91%	95.89%	95.86%	95.92%	95.92%
BPPC15	obj	Best	NAN	2.28E+02	2.33E+02	2.29E+02	2.28E+02	2.25E+02	2.27E+02	2.30E+02
		Mean	NAN	2.29E+02	2.33E+02	2.29E+02	2.28E+02	2.26E+02	2.28E+02	2.32E+02
	gap	Best	NAN	78.95%	79.40%	79.04%	78.95%	78.67%	78.85%	79.13%
		Mean	NAN	79.02%	79.40%	79.06%	78.97%	78.76%	78.91%	79.31%
BPPC16	obj	Best	NAN	2.52E+02	2.57E+02	2.54E+02	2.53E+02	2.50E+02	2.50E+02	2.58E+02
		Mean	NAN	2.53E+02	2.57E+02	2.55E+02	2.53E+02	2.50E+02	2.52E+02	2.59E+02
	gap	Best	NAN	94.44%	94.55%	94.49%	94.47%	94.40%	94.40%	94.57%
		Mean	NAN	94.46%	94.55%	94.51%	94.48%	94.41%	94.45%	94.59%
BPPC17	obj	Best	NAN	3.02E+02	3.07E+02	3.00E+02	3.02E+02	2.99E+02	3.03E+02	3.04E+02
		Mean	NAN	3.03E+02	NAN	3.03E+02	3.02E+02	3.00E+02	3.03E+02	3.05E+02
	gap	Best	NAN	97.35%	97.39%	97.33%	97.35%	97.32%	97.36%	97.37%
		Mean	NAN	97.36%	NAN	97.36%	97.35%	97.33%	97.36%	97.37%
BPPC18	obj	Best	NAN	3.43E+02	3.55E+02	3.46E+02	3.46E+02	3.46E+02	3.49E+02	3.51E+02
		Mean	NAN	3.47E+02	3.55E+02	3.47E+02	3.47E+02	3.47E+02	3.49E+02	3.53E+02
	gap	Best	NAN	95.34%	95.49%	95.38%	95.38%	95.38%	95.42%	95.44%
		Mean	NAN	95.39%	95.49%	95.39%	95.39%	95.39%	95.42%	95.47%
BPPC19	obj	Best	NAN	4.04E+02	4.10E+02	4.04E+02	4.05E+02	4.04E+02	4.04E+02	4.05E+02
		Mean	NAN	4.04E+02	4.10E+02	4.05E+02	4.05E+02	4.05E+02	4.06E+02	4.08E+02
	gap	Best	NAN	99.26%	99.27%	99.26%	99.26%	99.26%	99.26%	99.26%
		Mean	NAN	99.26%	99.27%	99.26%	99.26%	99.26%	99.26%	99.26%
BPPC20	obj	Best	NAN	4.59E+02	NAN	4.59E+02	4.59E+02	4.59E+02	4.59E+02	4.60E+02
		Mean	NAN	4.60E+02	NAN	4.60E+02	4.59E+02	4.60E+02	4.60E+02	4.61E+02
	gap	Best	NAN	91.94%	NAN	91.94%	91.94%	91.94%	91.94%	91.96%
		Mean	NAN	91.96%	NAN	91.95%	91.94%	91.95%	91.96%	91.97%
BPPC21	obj	Best	2.10E+01	2.00E+01	2.00E+01	2.10E+01	2.10E+01	2.10E+01	2.20E+01	2.10E+01
		Mean	2.10E+01	2.00E+01	2.00E+01	2.15E+01	2.10E+01	2.10E+01	2.20E+01	2.18E+01
	gap	Best	4.76%	0.00%	0.00%	4.76%	4.76%	4.76%	9.09%	4.76%
		Mean	4.76%	0.00%	0.00%	6.93%	4.76%	4.76%	9.09%	8.37%
BPPC22	obj	Best	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01

Pro.	Metric	Status	GUROBI	OR- TOOLS	SCIP	SA	VNS	LNS	TS	GA
	gap	Mean	2.10E+01	2.10E+01	2.10E+01	2.17E+01	2.13E+01	2.10E+01	2.15E+01	2.17E+01
		Best	4.76%	4.76%	4.76%	4.76%	4.76%	4.76%	4.76%	4.76%
		Mean	4.76%	4.76%	4.76%	7.65%	6.20%	4.76%	6.93%	7.65%
BPPC23	obj	Best	2.10E+01	2.10E+01	2.20E+01	2.10E+01	2.10E+01	2.10E+01	2.20E+01	2.10E+01
		Mean	2.10E+01	2.10E+01	2.22E+01	2.17E+01	2.15E+01	2.10E+01	2.20E+01	2.17E+01
	gap	Best	4.76%	4.76%	9.09%	4.76%	4.76%	4.76%	9.09%	4.76%
		Mean	4.76%	4.76%	9.88%	7.65%	6.93%	4.76%	9.09%	7.65%
BPPC24	obj	Best	2.10E+01	2.10E+01	2.20E+01	2.20E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01
		Mean	2.10E+01	2.10E+01	2.20E+01	2.20E+01	2.10E+01	2.10E+01	2.18E+01	2.17E+01
	gap	Best	4.76%	4.76%	9.09%	9.09%	4.76%	4.76%	4.76%	4.76%
		Mean	4.76%	4.76%	9.09%	9.09%	4.76%	4.76%	8.37%	7.65%
BPPC25	obj	Best	2.20E+01	2.20E+01	2.30E+01	2.20E+01	2.20E+01	2.20E+01	2.20E+01	2.20E+01
		Mean	2.20E+01	2.20E+01	2.30E+01	2.25E+01	2.23E+01	2.20E+01	2.25E+01	2.25E+01
	gap	Best	0.00%	0.00%	4.35%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	4.35%	2.17%	1.45%	0.00%	2.17%	2.17%
BPPC26	obj	Best	NAN	2.70E+01	2.80E+01	2.70E+01	2.70E+01	2.70E+01	2.70E+01	2.70E+01
		Mean	NAN	2.70E+01	2.80E+01	2.70E+01	2.70E+01	2.73E+01	2.70E+01	2.77E+01
	gap	Best	NAN	3.70%	7.14%	3.70%	3.70%	3.70%	3.70%	3.70%
		Mean	NAN	3.70%	7.14%	3.70%	3.70%	4.85%	3.70%	6.00%
BPPC27	obj	Best	NAN	4.30E+01	4.40E+01	4.30E+01	4.30E+01	4.30E+01	4.30E+01	4.30E+01
		Mean	NAN	4.30E+01	4.40E+01	4.30E+01	4.30E+01	4.30E+01	4.30E+01	4.30E+01
	gap	Best	NAN	2.33%	4.55%	2.33%	2.33%	2.33%	2.33%	2.33%
		Mean	NAN	2.33%	4.55%	2.33%	2.33%	2.33%	2.33%	2.33%
BPPC28	obj	Best	NAN	4.10E+01	4.20E+01	4.10E+01	4.10E+01	4.10E+01	4.10E+01	4.10E+01
		Mean	NAN	4.10E+01	4.20E+01	4.10E+01	4.10E+01	4.10E+01	4.10E+01	4.10E+01
	gap	Best	NAN	0.00%	2.38%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	NAN	0.00%	2.38%	0.00%	0.00%	0.00%	0.00%	0.00%
BPPC29	obj	Best	NAN	4.60E+01	4.70E+01	4.60E+01	4.60E+01	4.60E+01	4.60E+01	4.60E+01
		Mean	NAN	4.60E+01	4.70E+01	4.60E+01	4.60E+01	4.60E+01	4.60E+01	4.60E+01
	gap	Best	NAN	0.00%	2.13%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	NAN	0.00%	2.13%	0.00%	0.00%	0.00%	0.00%	0.00%
BPPC30	obj	Best	NAN	5.60E+01	5.60E+01	5.60E+01	5.60E+01	5.60E+01	5.60E+01	5.60E+01
		Mean	NAN	5.60E+01	5.60E+01	5.60E+01	5.60E+01	5.60E+01	5.60E+01	5.60E+01
	gap	Best	NAN	7.14%	7.14%	7.14%	7.14%	7.14%	7.14%	7.14%
		Mean	NAN	7.14%	7.14%	7.14%	7.14%	7.14%	7.14%	7.14%
BPPC31	obj	Best	4.10E+01	4.00E+01	4.00E+01	4.30E+01	4.20E+01	4.20E+01	4.20E+01	4.20E+01
		Mean	NAN	4.00E+01	4.00E+01	4.30E+01	4.27E+01	4.23E+01	4.32E+01	4.28E+01
	gap	Best	2.44%	0.00%	0.00%	6.98%	4.76%	4.76%	4.76%	4.76%
		Mean	NAN	0.00%	0.00%	6.98%	6.24%	5.50%	7.30%	6.61%
BPPC32	obj	Best	4.10E+01	4.10E+01	4.50E+01	4.20E+01	4.30E+01	4.20E+01	4.30E+01	4.30E+01
		Mean	4.16E+01	4.10E+01	4.50E+01	4.32E+01	4.30E+01	4.25E+01	4.30E+01	4.35E+01
	gap	Best	2.44%	2.44%	11.11%	4.76%	6.98%	4.76%	6.98%	6.98%
		Mean	3.83%	2.44%	11.11%	7.31%	6.98%	5.87%	6.98%	8.03%
BPPC33	obj	Best	NAN	4.10E+01	4.40E+01	4.30E+01	4.30E+01	4.20E+01	4.20E+01	4.30E+01
		Mean	NAN	4.16E+01	4.40E+01	4.30E+01	4.30E+01	4.23E+01	4.32E+01	4.30E+01
	gap	Best	NAN	2.44%	9.09%	6.98%	6.98%	4.76%	4.76%	6.98%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	NAN	3.83%	9.09%	6.98%	6.98%	5.50%	7.31%	6.98%
BPPC34	obj	Best	NAN	4.20E+01	4.50E+01	4.30E+01	4.30E+01	4.30E+01	4.30E+01	4.30E+01
		Mean	NAN	4.20E+01	4.50E+01	4.38E+01	4.30E+01	4.30E+01	4.35E+01	4.36E+01
	gap	Best	NAN	4.76%	11.11%	6.98%	6.98%	6.98%	6.98%	6.98%
		Mean	NAN	4.76%	11.11%	8.74%	6.98%	6.98%	8.03%	8.25%
BPPC35	obj	Best	NAN	5.10E+01	5.30E+01	5.10E+01	5.10E+01	5.10E+01	5.10E+01	5.10E+01
		Mean	NAN	5.10E+01	5.30E+01	5.10E+01	5.13E+01	5.10E+01	5.12E+01	5.15E+01
	gap	Best	NAN	21.57%	24.53%	21.57%	21.57%	21.57%	21.57%	21.57%
		Mean	NAN	21.57%	24.53%	21.57%	22.07%	21.57%	21.87%	22.32%
BPPC36	obj	Best	6.30E+01	5.80E+01	6.30E+01	5.80E+01	5.80E+01	5.80E+01	5.80E+01	5.80E+01
		Mean	6.30E+01	5.80E+01	6.30E+01	5.87E+01	5.92E+01	5.83E+01	5.92E+01	5.90E+01
	gap	Best	36.51%	31.03%	36.51%	31.03%	31.03%	31.03%	31.03%	31.03%
		Mean	36.51%	31.03%	36.51%	31.81%	32.38%	31.42%	32.39%	32.19%
BPPC37	obj	Best	NAN	7.70E+01	7.90E+01	7.70E+01	7.70E+01	7.70E+01	7.70E+01	7.70E+01
		Mean	NAN	7.70E+01	7.90E+01	7.70E+01	7.70E+01	7.70E+01	7.77E+01	7.70E+01
	gap	Best	NAN	48.05%	49.37%	48.05%	48.05%	48.05%	48.05%	48.05%
		Mean	NAN	48.05%	49.37%	48.05%	48.05%	48.05%	48.50%	48.05%
BPPC38	obj	Best	NAN	8.20E+01	8.50E+01	8.30E+01	8.30E+01	8.20E+01	8.30E+01	8.30E+01
		Mean	NAN	8.26E+01	8.50E+01	8.30E+01	8.30E+01	8.28E+01	8.30E+01	8.38E+01
	gap	Best	NAN	52.44%	54.12%	53.01%	53.01%	52.44%	53.01%	53.01%
		Mean	NAN	52.78%	54.12%	53.01%	53.01%	52.90%	53.01%	53.48%
BPPC39	obj	Best	NAN	1.02E+02	1.04E+02	1.02E+02	1.02E+02	1.02E+02	1.02E+02	1.03E+02
		Mean	NAN	1.02E+02	1.04E+02	1.02E+02	1.02E+02	1.02E+02	1.02E+02	1.03E+02
	gap	Best	NAN	59.80%	60.58%	59.80%	59.80%	59.80%	59.80%	60.19%
		Mean	NAN	59.80%	60.58%	59.80%	59.80%	59.80%	59.80%	60.19%
BPPC40	obj	Best	NAN	1.11E+02	1.12E+02	1.11E+02	1.11E+02	1.11E+02	1.11E+02	1.12E+02
		Mean	NAN	1.11E+02	1.12E+02	1.11E+02	1.11E+02	1.11E+02	1.11E+02	1.12E+02
	gap	Best	NAN	59.46%	59.82%	59.46%	59.46%	59.46%	59.46%	59.82%
		Mean	NAN	59.46%	59.82%	59.46%	59.46%	59.46%	59.58%	59.82%
BPPC41	obj	Best	NAN	8.30E+01	8.30E+01	8.90E+01	8.70E+01	8.50E+01	8.80E+01	9.00E+01
		Mean	NAN	8.30E+01	8.30E+01	8.98E+01	8.84E+01	8.60E+01	8.95E+01	9.00E+01
	gap	Best	NAN	0.00%	NAN	6.74%	4.60%	2.35%	5.68%	7.78%
		Mean	NAN	0.00%	NAN	7.57%	6.10%	3.48%	7.26%	7.78%
BPPC42	obj	Best	NAN	8.50E+01	8.50E+01	8.80E+01	8.90E+01	8.80E+01	8.80E+01	8.90E+01
		Mean	NAN	8.50E+01	8.50E+01	8.98E+01	8.90E+01	8.80E+01	8.96E+01	8.96E+01
	gap	Best	NAN	3.53%	3.53%	6.82%	7.87%	6.82%	6.82%	7.87%
		Mean	NAN	3.53%	3.53%	8.71%	7.87%	6.82%	8.47%	8.48%
BPPC43	obj	Best	NAN	8.60E+01	9.40E+01	8.80E+01	8.90E+01	8.70E+01	8.90E+01	9.00E+01
		Mean	NAN	8.68E+01	9.96E+01	8.94E+01	8.93E+01	8.77E+01	9.03E+01	9.00E+01
	gap	Best	NAN	3.49%	11.70%	5.68%	6.74%	4.60%	6.74%	7.78%
		Mean	NAN	4.38%	16.60%	7.15%	7.09%	5.32%	8.11%	7.78%
BPPC44	obj	Best	NAN	8.80E+01	9.10E+01	8.90E+01	9.00E+01	8.80E+01	9.00E+01	9.10E+01
		Mean	NAN	8.82E+01	9.10E+01	8.98E+01	9.03E+01	8.87E+01	9.12E+01	9.10E+01
	gap	Best	NAN	6.82%	9.89%	7.87%	8.89%	6.82%	8.89%	9.89%
		Mean	NAN	7.03%	9.89%	8.72%	9.22%	7.52%	10.05%	9.89%
BPPC45	obj	Best	NAN	9.90E+01	1.03E+02	1.01E+02	1.01E+02	1.01E+02	1.01E+02	1.02E+02

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
	gap	Mean	NAN	1.00E+02	1.03E+02	1.02E+02	1.02E+02	1.02E+02	1.02E+02	1.03E+02
		Best	NAN	87.88%	88.35%	88.12%	88.12%	88.12%	88.12%	88.24%
		Mean	NAN	88.00%	88.35%	88.27%	88.23%	88.18%	88.23%	88.31%
BPPC46	obj	Best	NAN	1.34E+02	1.39E+02	1.34E+02	1.34E+02	1.34E+02	1.34E+02	1.34E+02
		Mean	NAN	1.34E+02	1.39E+02	1.35E+02	1.34E+02	1.34E+02	1.34E+02	1.35E+02
	gap	Best	NAN	71.64%	72.66%	71.64%	71.64%	71.64%	71.64%	71.64%
		Mean	NAN	71.68%	72.66%	71.78%	71.64%	71.64%	71.64%	71.89%
BPPC47	obj	Best	NAN	1.58E+02	1.59E+02	1.58E+02	1.59E+02	1.58E+02	1.58E+02	1.59E+02
		Mean	NAN	1.58E+02	1.59E+02	1.59E+02	1.60E+02	1.59E+02	1.60E+02	1.60E+02
	gap	Best	NAN	89.87%	89.94%	89.87%	89.94%	89.87%	89.87%	89.94%
		Mean	NAN	89.87%	89.94%	89.96%	89.97%	89.92%	90.00%	90.01%
BPPC48	obj	Best	NAN	1.73E+02	1.77E+02	1.74E+02	1.75E+02	1.74E+02	1.74E+02	1.75E+02
		Mean	NAN	1.74E+02	1.77E+02	1.75E+02	1.75E+02	1.75E+02	1.76E+02	1.77E+02
	gap	Best	NAN	90.17%	90.40%	90.23%	90.29%	90.23%	90.23%	90.29%
		Mean	NAN	90.23%	90.40%	90.30%	90.31%	90.29%	90.31%	90.40%
BPPC49	obj	Best	NAN	1.97E+02	2.00E+02	1.98E+02	1.98E+02	1.98E+02	1.98E+02	1.99E+02
		Mean	NAN	1.98E+02	2.00E+02	1.98E+02	1.99E+02	1.98E+02	1.99E+02	1.99E+02
	gap	Best	NAN	87.82%	88.00%	87.88%	87.88%	87.88%	87.88%	87.94%
		Mean	NAN	87.87%	88.00%	87.90%	87.91%	87.88%	87.95%	87.95%
BPPC50	obj	Best	NAN	2.28E+02	2.28E+02	2.28E+02	2.28E+02	2.28E+02	2.28E+02	2.28E+02
		Mean	NAN	2.28E+02	2.28E+02	2.28E+02	2.28E+02	2.28E+02	2.28E+02	2.28E+02
	gap	Best	NAN	90.35%	90.35%	90.35%	90.35%	90.35%	90.35%	90.35%
		Mean	NAN	90.35%	90.35%	90.35%	90.35%	90.35%	90.35%	90.35%
BPPC51	obj	Best	NAN	1.67E+02	1.67E+02	1.79E+02	1.79E+02	1.76E+02	1.80E+02	1.81E+02
		Mean	NAN	1.67E+02	NAN	1.80E+02	1.80E+02	1.76E+02	1.81E+02	1.81E+02
	gap	Best	NAN	0.60%	0.60%	7.26%	7.26%	5.68%	7.78%	8.29%
		Mean	NAN	0.60%	NAN	7.78%	7.78%	5.86%	8.29%	8.46%
BPPC52	obj	Best	NAN	1.71E+02	2.02E+02	1.80E+02	1.78E+02	1.76E+02	1.81E+02	1.81E+02
		Mean	NAN	1.71E+02	2.02E+02	1.82E+02	1.79E+02	1.76E+02	1.82E+02	1.82E+02
	gap	Best	NAN	21.64%	33.66%	25.56%	24.72%	23.86%	25.97%	25.97%
		Mean	NAN	21.82%	33.66%	26.30%	25.22%	24.04%	26.51%	26.21%
BPPC53	obj	Best	NAN	1.75E+02	2.21E+02	1.80E+02	1.79E+02	1.75E+02	1.82E+02	1.80E+02
		Mean	NAN	1.75E+02	2.21E+02	1.81E+02	1.79E+02	1.76E+02	1.83E+02	1.81E+02
	gap	Best	NAN	46.86%	57.92%	48.33%	48.04%	46.86%	48.90%	48.33%
		Mean	NAN	46.92%	57.92%	48.71%	48.16%	47.10%	49.07%	48.73%
BPPC54	obj	Best	NAN	1.77E+02	1.84E+02	1.81E+02	1.82E+02	1.77E+02	1.84E+02	1.82E+02
		Mean	NAN	1.79E+02	1.84E+02	1.83E+02	1.83E+02	1.78E+02	1.84E+02	1.83E+02
	gap	Best	NAN	47.46%	49.46%	48.62%	48.90%	47.46%	49.46%	48.90%
		Mean	NAN	47.93%	49.46%	49.07%	49.04%	47.75%	49.51%	49.29%
BPPC55	obj	Best	NAN	2.29E+02	2.31E+02	2.28E+02	2.28E+02	2.28E+02	2.28E+02	2.30E+02
		Mean	NAN	2.29E+02	2.31E+02	2.29E+02	2.29E+02	2.28E+02	2.29E+02	2.30E+02
	gap	Best	NAN	91.70%	91.77%	91.67%	91.67%	91.67%	91.67%	91.74%
		Mean	NAN	91.70%	91.77%	91.70%	91.70%	91.68%	91.70%	91.75%
BPPC56	obj	Best	NAN	2.36E+02	2.42E+02	2.39E+02	2.40E+02	2.37E+02	2.38E+02	2.40E+02
		Mean	NAN	2.37E+02	NAN	2.40E+02	2.40E+02	2.38E+02	2.39E+02	2.41E+02
	gap	Best	NAN	99.15%	99.17%	99.16%	99.17%	99.16%	99.16%	99.17%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	NAN	99.15%	NAN	99.17%	99.17%	99.16%	99.16%	99.17%
BPPC57	obj	Best	NAN	3.04E+02	NAN	3.05E+02	3.04E+02	3.04E+02	3.04E+02	3.05E+02
		Mean	NAN	3.05E+02	NAN	3.06E+02	3.05E+02	3.05E+02	3.05E+02	3.07E+02
	gap	Best	NAN	99.34%	NAN	99.34%	99.34%	99.34%	99.34%	99.34%
		Mean	NAN	99.34%	NAN	99.35%	99.34%	99.34%	99.34%	99.35%
BPPC58	obj	Best	NAN	3.69E+02	NAN	3.68E+02	3.69E+02	3.68E+02	3.70E+02	3.70E+02
		Mean	NAN	3.70E+02	NAN	3.70E+02	3.70E+02	3.68E+02	3.70E+02	3.72E+02
	gap	Best	NAN	99.19%	NAN	99.18%	99.19%	99.18%	99.19%	99.19%
		Mean	NAN	99.19%	NAN	99.19%	99.19%	99.19%	99.19%	99.19%
BPPC59	obj	Best	NAN	4.14E+02	NAN	4.13E+02	4.13E+02	4.13E+02	4.13E+02	4.14E+02
		Mean	NAN	4.15E+02	NAN	4.14E+02	4.13E+02	4.14E+02	4.15E+02	4.15E+02
	gap	Best	NAN	99.03%	NAN	99.03%	99.03%	99.03%	99.03%	99.03%
		Mean	NAN	99.04%	NAN	99.03%	99.03%	99.03%	99.04%	99.04%
BPPC60	obj	Best	NAN	4.52E+02	NAN	4.51E+02	4.51E+02	4.51E+02	4.51E+02	4.52E+02
		Mean	NAN	4.53E+02	NAN	4.51E+02	4.52E+02	4.52E+02	4.53E+02	4.53E+02
	gap	Best	NAN	98.01%	NAN	98.00%	98.00%	98.00%	98.00%	98.01%
		Mean	NAN	98.01%	NAN	98.01%	98.01%	98.01%	98.01%	98.01%

3.6 Generalized bin packing problem (GBPPI)

Table S-16 provides the experimental results on 50 GBPPI problems.

Table S-18 Experimental results on GBPPI

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
GBP PI01	obj	Best	2.84E+02	2.83E+02	3.14E+02	3.14E+02	3.40E+02	3.91E+02	3.86E+02	2.94E+02
		Mean	2.89E+02	2.88E+02	3.14E+02	3.52E+02	3.61E+02	4.17E+02	4.10E+02	3.30E+02
	gap	Best	0.35%	0.00%	9.87%	9.87%	16.76%	27.62%	26.68%	3.74%
		Mean	2.00%	1.80%	9.87%	19.05%	21.55%	32.07%	30.78%	13.84%
GBP PI02	obj	Best	6.78E+02	6.78E+02	6.78E+02	7.67E+02	8.35E+02	9.05E+02	8.77E+02	7.23E+02
		Mean	6.78E+02	6.80E+02	6.78E+02	8.81E+02	8.98E+02	9.76E+02	9.05E+02	7.67E+02
	gap	Best	0.00%	0.00%	0.00%	11.60%	18.80%	25.08%	22.69%	6.22%
		Mean	0.00%	0.26%	0.00%	22.60%	24.28%	30.32%	24.95%	11.36%
GBP PI03	obj	Best	4.77E+02	4.77E+02	5.39E+02	5.22E+02	5.44E+02	6.54E+02	5.76E+02	5.16E+02
		Mean	4.77E+02	4.79E+02	5.39E+02	5.40E+02	5.60E+02	6.57E+02	6.02E+02	5.37E+02
	gap	Best	0.00%	0.00%	11.50%	8.62%	12.32%	27.06%	17.19%	7.56%
		Mean	0.00%	0.49%	11.50%	11.57%	14.77%	27.42%	20.57%	11.07%
GBP PI04	obj	Best	8.21E+02	8.00E+02	9.03E+02	8.84E+02	9.04E+02	9.96E+02	9.51E+02	8.22E+02
		Mean	8.28E+02	8.14E+02	9.03E+02	9.19E+02	9.39E+02	1.01E+03	9.97E+02	8.51E+02
	gap	Best	5.48%	3.00%	14.06%	12.22%	14.16%	22.09%	18.40%	5.60%
		Mean	6.30%	4.70%	14.06%	15.54%	17.31%	23.21%	22.01%	8.75%
GBP PI05	obj	Best	1.13E+03	1.16E+03	1.28E+03	1.35E+03	1.45E+03	1.44E+03	1.45E+03	1.19E+03
		Mean	1.21E+03	1.17E+03	1.28E+03	1.40E+03	1.48E+03	1.46E+03	1.48E+03	1.26E+03
	gap	Best	0.00%	2.68%	11.83%	16.79%	22.20%	21.66%	22.57%	5.30%
		Mean	7.18%	3.97%	11.83%	19.71%	23.91%	22.82%	24.04%	10.68%
GBP PI06	obj	Best	1.65E+03	1.66E+03	1.76E+03	1.91E+03	2.04E+03	2.19E+03	2.00E+03	1.72E+03
		Mean	1.65E+03	1.68E+03	1.76E+03	2.03E+03	2.08E+03	2.25E+03	2.07E+03	1.81E+03
	gap	Best	0.00%	0.18%	5.87%	13.64%	24.53%	24.53%	17.48%	4.18%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	0.00%	1.54%	5.87%	18.68%	20.69%	26.52%	20.24%	8.76%
GBP PI07	obj	Best	1.77E+03	1.57E+03	1.82E+03	1.90E+03	1.83E+03	1.93E+03	2.01E+03	1.68E+03
		Mean	1.77E+03	1.59E+03	1.82E+03	1.91E+03	1.87E+03	1.98E+03	2.07E+03	1.75E+03
	gap	Best	11.76%	0.45%	14.14%	17.72%	14.61%	19.30%	22.50%	7.03%
		Mean	11.76%	1.68%	14.14%	18.28%	16.75%	21.13%	24.58%	10.99%
GBP PI08	obj	Best	2.11E+03	2.10E+03	2.38E+03	2.40E+03	2.58E+03	2.79E+03	2.58E+03	2.28E+03
		Mean	2.16E+03	2.12E+03	2.38E+03	2.48E+03	2.58E+03	2.83E+03	2.65E+03	2.35E+03
	gap	Best	3.51%	3.28%	14.65%	15.29%	18.12%	27.21%	21.05%	10.91%
		Mean	5.86%	3.88%	14.65%	17.94%	21.28%	28.15%	23.24%	13.37%
GBP PI09	obj	Best	2.84E+03	2.86E+03	3.19E+03	3.52E+03	3.40E+03	4.08E+03	3.82E+03	3.25E+03
		Mean	2.84E+03	2.87E+03	3.19E+03	3.74E+03	3.58E+03	4.39E+03	3.92E+03	3.33E+03
	gap	Best	0.00%	0.87%	11.01%	19.44%	16.46%	30.46%	25.75%	12.60%
		Mean	0.00%	1.19%	11.01%	23.99%	20.51%	35.22%	27.52%	14.69%
GBP PI10	obj	Best	NAN	2.67E+03	3.09E+03	3.24E+03	3.11E+03	3.67E+03	3.35E+03	2.89E+03
		Mean	NAN	2.68E+03	3.09E+03	3.29E+03	3.15E+03	3.76E+03	3.61E+03	2.98E+03
	gap	Best	NAN	2.13%	15.41%	19.23%	16.03%	28.86%	22.00%	9.58%
		Mean	NAN	2.55%	15.41%	20.62%	17.16%	30.53%	27.44%	12.28%
GBP PI11	obj	Best	NAN	4.57E+03	5.28E+03	5.34E+03	5.27E+03	5.84E+03	5.58E+03	5.21E+03
		Mean	NAN	4.60E+03	5.28E+03	5.44E+03	5.33E+03	5.89E+03	5.74E+03	5.29E+03
	gap	Best	NAN	1.49%	14.83%	15.83%	14.59%	23.00%	19.38%	13.60%
		Mean	NAN	2.30%	14.83%	17.27%	15.64%	23.70%	21.64%	15.04%
GBP PI12	obj	Best	NAN	6.04E+03	6.70E+03	7.71E+03	7.47E+03	8.55E+03	8.18E+03	7.43E+03
		Mean	NAN	6.06E+03	6.70E+03	7.96E+03	7.76E+03	8.95E+03	8.32E+03	7.83E+03
	gap	Best	NAN	1.49%	11.16%	22.89%	20.39%	30.40%	27.25%	19.96%
		Mean	NAN	1.82%	11.16%	25.22%	23.32%	33.48%	28.46%	23.89%
GBP PI13	obj	Best	NAN	6.85E+03	8.35E+03	8.08E+03	7.66E+03	8.61E+03	9.40E+03	8.42E+03
		Mean	NAN	6.88E+03	8.35E+03	8.32E+03	7.75E+03	9.22E+03	9.44E+03	8.48E+03
	gap	Best	NAN	0.60%	18.49%	15.83%	11.15%	20.99%	27.59%	19.21%
		Mean	NAN	1.15%	18.49%	18.16%	12.18%	26.13%	27.90%	19.78%
GBP PI14	obj	Best	NAN	1.07E+04	1.29E+04	1.29E+04	1.24E+04	1.34E+04	1.38E+04	1.40E+04
		Mean	NAN	1.18E+04	1.29E+04	1.31E+04	1.26E+04	1.37E+04	1.38E+04	1.41E+04
	gap	Best	NAN	3.80%	11.43%	11.19%	8.11%	14.49%	17.25%	18.55%
		Mean	NAN	9.41%	11.43%	12.75%	9.50%	16.95%	17.57%	19.18%
GBP PI15	obj	Best	NAN	1.53E+04	1.72E+04	2.17E+04	2.11E+04	2.21E+04	2.13E+04	2.11E+04
		Mean	NAN	1.54E+04	1.72E+04	2.19E+04	2.12E+04	2.23E+04	2.16E+04	2.15E+04
	gap	Best	NAN	2.75%	13.58%	31.64%	29.58%	32.76%	30.43%	29.75%
		Mean	NAN	3.47%	13.58%	32.36%	30.11%	33.42%	31.28%	31.07%
GBP PI16	obj	Best	3.40E+02	3.40E+02	3.90E+02	3.98E+02	4.22E+02	3.86E+02	4.25E+02	3.86E+02
		Mean	3.40E+02	3.47E+02	3.90E+02	4.21E+02	4.31E+02	4.14E+02	4.37E+02	4.06E+02
	gap	Best	0.00%	0.00%	12.82%	14.57%	19.43%	11.92%	20.00%	11.92%
		Mean	0.00%	2.12%	12.82%	19.13%	21.13%	17.79%	22.24%	16.19%
GBP PI17	obj	Best	4.79E+02	4.89E+02	4.89E+02	5.50E+02	5.97E+02	6.45E+02	6.05E+02	4.88E+02
		Mean	4.79E+02	4.97E+02	4.89E+02	5.95E+02	6.21E+02	6.61E+02	6.21E+02	5.21E+02
	gap	Best	0.00%	2.04%	2.04%	12.91%	19.77%	25.74%	20.83%	1.84%
		Mean	0.00%	3.54%	2.04%	19.36%	22.77%	27.51%	22.88%	7.98%
	obj	Best	7.86E+02	7.94E+02	8.64E+02	9.07E+02	8.76E+02	9.49E+02	9.55E+02	8.52E+02

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
GBP PI18	gap	Mean	7.96E+02	7.96E+02	8.64E+02	9.28E+02	9.06E+02	9.55E+02	9.71E+02	8.89E+02
		Best	0.25%	1.26%	9.26%	13.56%	10.50%	17.39%	17.91%	7.98%
		Mean	1.45%	1.55%	9.26%	15.52%	13.41%	17.94%	19.20%	11.73%
GBP PI19	obj	Best	1.28E+03	1.28E+03	1.41E+03	1.50E+03	1.50E+03	1.54E+03	1.58E+03	1.44E+03
		Mean	1.28E+03	1.29E+03	1.41E+03	1.53E+03	1.54E+03	1.56E+03	1.60E+03	1.50E+03
	gap	Best	0.00%	0.16%	9.50%	14.99%	14.93%	17.36%	19.19%	11.57%
		Mean	0.00%	0.84%	9.50%	16.61%	17.32%	18.17%	20.18%	14.84%
GBP PI20	obj	Best	2.01E+03	1.97E+03	2.18E+03	2.30E+03	2.23E+03	2.38E+03	2.44E+03	2.16E+03
		Mean	2.02E+03	1.98E+03	2.18E+03	2.34E+03	2.28E+03	2.42E+03	2.46E+03	2.22E+03
	gap	Best	3.83%	2.03%	11.42%	16.00%	13.52%	18.86%	20.95%	10.72%
		Mean	4.55%	2.36%	11.42%	17.58%	15.14%	20.18%	21.46%	12.77%
GBP PI21	obj	Best	2.26E+03	2.19E+03	2.44E+03	2.56E+03	2.46E+03	2.57E+03	2.68E+03	2.34E+03
		Mean	2.29E+03	2.20E+03	2.44E+03	2.62E+03	2.51E+03	2.66E+03	2.70E+03	2.45E+03
	gap	Best	3.94%	1.00%	10.97%	15.21%	11.76%	15.77%	19.19%	7.47%
		Mean	5.15%	1.33%	10.97%	17.07%	13.55%	18.58%	19.77%	11.58%
GBP PI22	obj	Best	NAN	4.84E+03	5.53E+03	5.62E+03	5.44E+03	6.05E+03	5.82E+03	5.63E+03
		Mean	NAN	4.85E+03	5.53E+03	5.70E+03	5.49E+03	6.08E+03	5.94E+03	5.70E+03
	gap	Best	NAN	2.37%	14.44%	15.83%	13.12%	21.88%	18.71%	16.08%
		Mean	NAN	2.44%	14.44%	17.06%	13.87%	22.21%	20.43%	17.06%
GBP PI23	obj	Best	4.08E+03	3.47E+03	4.22E+03	4.05E+03	3.92E+03	4.48E+03	4.26E+03	3.84E+03
		Mean	8.00E+19	3.50E+03	4.22E+03	4.12E+03	3.95E+03	4.52E+03	4.46E+03	3.97E+03
	gap	Best	17.61%	3.14%	20.27%	16.88%	14.27%	24.89%	21.11%	12.33%
		Mean	83.52%	3.89%	20.27%	18.26%	14.93%	25.62%	24.50%	15.24%
GBP PI24	obj	Best	NAN	8.55E+03	1.21E+04	1.04E+04	1.03E+04	1.05E+04	1.08E+04	1.13E+04
		Mean	NAN	8.63E+03	1.21E+04	1.07E+04	1.04E+04	1.06E+04	1.10E+04	1.14E+04
	gap	Best	NAN	0.02%	28.17%	16.12%	15.79%	16.89%	19.13%	22.66%
		Mean	NAN	0.96%	28.17%	18.26%	16.57%	18.06%	20.83%	23.51%
GBP PI25	obj	Best	NAN	1.39E+04	1.52E+04	1.57E+04	1.49E+04	1.52E+04	1.53E+04	1.55E+04
		Mean	NAN	1.39E+04	1.52E+04	1.58E+04	1.51E+04	1.53E+04	1.56E+04	1.57E+04
	gap	Best	NAN	7.12%	15.03%	17.65%	13.75%	15.21%	15.84%	17.08%
		Mean	NAN	7.46%	15.03%	18.24%	14.71%	15.86%	17.18%	17.71%
GBP PI26	obj	Best	3.42E+02	3.50E+02	3.66E+02	4.06E+02	3.57E+02	4.87E+02	4.09E+02	4.17E+02
		Mean	3.42E+02	3.52E+02	3.66E+02	4.28E+02	4.16E+02	6.72E+02	4.38E+02	4.31E+02
	gap	Best	0.00%	2.29%	6.56%	15.76%	4.20%	29.77%	16.38%	17.99%
		Mean	0.00%	2.78%	6.56%	19.87%	17.27%	47.86%	21.69%	20.57%
GBP PI27	obj	Best	7.45E+02	7.45E+02	7.45E+02	7.96E+02	8.97E+02	9.90E+02	9.17E+02	7.45E+02
		Mean	7.45E+02	7.45E+02	7.45E+02	8.46E+02	9.39E+02	1.08E+03	9.69E+02	8.32E+02
	gap	Best	0.00%	0.00%	0.00%	6.41%	16.95%	24.75%	18.76%	0.00%
		Mean	0.00%	0.00%	0.00%	11.83%	20.59%	30.78%	22.97%	10.02%
GBP PI28	obj	Best	5.39E+02	5.39E+02	6.74E+02	5.88E+02	6.18E+02	7.21E+02	6.63E+02	6.18E+02
		Mean	5.39E+02	5.53E+02	6.74E+02	6.27E+02	6.46E+02	8.49E+02	6.76E+02	6.36E+02
	gap	Best	0.00%	0.00%	20.03%	8.33%	12.78%	25.24%	18.70%	12.78%
		Mean	0.00%	2.58%	20.03%	13.88%	16.47%	36.18%	20.29%	15.16%
GBP PI29	obj	Best	7.42E+02	7.51E+02	8.86E+02	8.47E+02	9.07E+02	1.03E+03	9.48E+02	7.63E+02
		Mean	7.84E+02	7.58E+02	8.86E+02	8.81E+02	9.40E+02	1.22E+03	9.80E+02	8.32E+02
	gap	Best	2.83%	3.99%	18.62%	14.88%	20.51%	30.07%	23.95%	5.50%
		Mean	8.01%	4.87%	18.62%	18.12%	23.27%	40.51%	26.40%	13.14%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
GBP PI30	obj	Best	9.57E+02	9.74E+02	1.14E+03	1.10E+03	1.06E+03	1.22E+03	1.15E+03	9.86E+02
		Mean	1.02E+03	9.85E+02	1.14E+03	1.12E+03	1.08E+03	1.47E+03	1.17E+03	1.03E+03
	gap	Best	1.36%	3.08%	16.83%	14.03%	10.52%	22.30%	17.77%	4.26%
		Mean	7.16%	4.17%	16.83%	15.96%	12.75%	35.01%	19.61%	8.23%
GBP PI31	obj	Best	1.66E+03	1.66E+03	1.76E+03	1.92E+03	1.84E+03	2.11E+03	1.90E+03	1.76E+03
		Mean	1.66E+03	1.67E+03	1.76E+03	1.98E+03	1.97E+03	2.19E+03	1.99E+03	1.80E+03
	gap	Best	0.00%	0.12%	5.46%	13.53%	9.83%	21.28%	12.39%	5.79%
		Mean	0.00%	0.45%	5.46%	15.90%	15.57%	24.10%	16.32%	7.80%
GBP PI32	obj	Best	1.31E+03	1.19E+03	1.41E+03	1.50E+03	1.37E+03	1.73E+03	1.55E+03	1.33E+03
		Mean	1.31E+03	1.19E+03	1.41E+03	1.53E+03	1.45E+03	2.28E+03	1.63E+03	1.41E+03
	gap	Best	10.81%	1.43%	17.13%	21.99%	14.53%	32.39%	24.60%	11.62%
		Mean	10.81%	1.76%	17.13%	23.63%	18.88%	47.81%	28.19%	16.61%
GBP PI33	obj	Best	2.78E+03	2.55E+03	2.97E+03	2.98E+03	2.74E+03	3.26E+03	3.07E+03	2.81E+03
		Mean	2.93E+03	2.58E+03	2.97E+03	3.02E+03	2.91E+03	3.70E+03	3.16E+03	2.86E+03
	gap	Best	9.59%	1.76%	15.38%	15.86%	8.40%	23.11%	18.30%	10.78%
		Mean	14.09%	2.78%	15.38%	16.85%	13.75%	32.00%	20.64%	12.38%
GBP PI34	obj	Best	2.80E+03	2.80E+03	3.18E+03	3.36E+03	3.50E+03	3.93E+03	3.64E+03	3.19E+03
		Mean	2.80E+03	2.82E+03	3.18E+03	3.54E+03	3.62E+03	4.37E+03	3.76E+03	3.25E+03
	gap	Best	0.00%	0.14%	12.09%	16.60%	19.96%	28.71%	23.08%	12.20%
		Mean	0.00%	0.71%	12.09%	20.90%	22.64%	35.81%	25.58%	13.85%
GBP PI35	obj	Best	NAN	3.50E+03	4.01E+03	4.16E+03	3.94E+03	4.57E+03	4.32E+03	4.02E+03
		Mean	NAN	3.52E+03	4.01E+03	4.20E+03	4.08E+03	5.52E+03	4.39E+03	4.09E+03
	gap	Best	NAN	1.63%	14.18%	17.20%	12.57%	24.69%	20.21%	14.31%
		Mean	NAN	2.15%	14.18%	18.06%	15.47%	37.11%	21.56%	15.89%
GBP PI36	obj	Best	NAN	4.14E+03	5.00E+03	4.83E+03	4.92E+03	5.48E+03	5.15E+03	4.49E+03
		Mean	NAN	4.16E+03	5.00E+03	4.96E+03	5.12E+03	6.17E+03	5.36E+03	4.62E+03
	gap	Best	NAN	2.42%	19.20%	16.40%	17.98%	26.32%	21.63%	10.03%
		Mean	NAN	2.90%	19.20%	18.67%	21.18%	34.30%	24.71%	12.60%
GBP PI37	obj	Best	NAN	6.20E+03	6.84E+03	7.53E+03	7.80E+03	8.57E+03	7.91E+03	7.49E+03
		Mean	NAN	6.22E+03	6.84E+03	7.87E+03	7.95E+03	8.86E+03	8.04E+03	7.81E+03
	gap	Best	NAN	2.45%	11.54%	19.72%	22.46%	29.42%	23.54%	19.28%
		Mean	NAN	2.81%	11.54%	23.15%	23.89%	31.71%	24.79%	22.51%
GBP PI38	obj	Best	NAN	7.80E+03	9.98E+03	9.45E+03	9.05E+03	1.07E+04	1.00E+04	9.55E+03
		Mean	NAN	7.86E+03	9.98E+03	9.66E+03	9.65E+03	1.33E+04	1.04E+04	9.73E+03
	gap	Best	NAN	10.14%	29.77%	25.83%	22.55%	34.49%	29.91%	26.61%
		Mean	NAN	10.61%	29.77%	27.44%	27.37%	47.30%	32.61%	27.96%
GBP PI39	obj	Best	NAN	1.10E+04	1.32E+04	1.20E+04	1.30E+04	1.45E+04	1.38E+04	1.36E+04
		Mean	NAN	1.11E+04	1.32E+04	1.31E+04	1.32E+04	1.61E+04	1.41E+04	1.39E+04
	gap	Best	NAN	9.03%	24.19%	16.83%	23.11%	30.98%	27.72%	26.19%
		Mean	NAN	9.60%	24.19%	23.33%	24.12%	37.87%	29.04%	28.18%
GBP PI40	obj	Best	NAN	1.58E+04	1.69E+04	2.03E+04	2.01E+04	2.16E+04	2.09E+04	2.07E+04
		Mean	NAN	1.61E+04	1.69E+04	2.07E+04	2.03E+04	2.23E+04	2.10E+04	2.08E+04
	gap	Best	NAN	3.18%	9.42%	24.84%	23.77%	29.19%	26.78%	26.01%
		Mean	NAN	4.71%	9.42%	26.03%	24.70%	31.32%	27.30%	26.50%
GBP PI41	obj	Best	3.82E+02	3.82E+02	3.88E+02	4.02E+02	4.02E+02	4.63E+02	4.02E+02	4.02E+02
		Mean	3.82E+02	3.83E+02	3.88E+02	4.18E+02	4.12E+02	6.41E+02	4.21E+02	4.11E+02
	gap	Best	0.00%	0.00%	1.55%	4.98%	4.98%	17.49%	4.98%	4.98%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	0.00%	0.21%	1.55%	8.64%	7.18%	39.09%	9.22%	7.02%
GBP PI42	obj	Best	5.18E+02	5.18E+02	5.34E+02	5.82E+02	5.43E+02	6.69E+02	6.11E+02	5.83E+02
		Mean	5.18E+02	5.23E+02	5.34E+02	5.98E+02	5.77E+02	7.64E+02	6.36E+02	5.94E+02
	gap	Best	0.00%	0.00%	3.00%	11.00%	4.60%	22.57%	15.22%	11.15%
		Mean	0.00%	1.02%	3.00%	13.26%	10.14%	31.90%	18.45%	12.72%
GBP PI43	obj	Best	9.87E+02	9.89E+02	1.07E+03	1.15E+03	1.10E+03	1.25E+03	1.22E+03	1.02E+03
		Mean	1.10E+03	1.01E+03	1.07E+03	1.18E+03	1.12E+03	1.32E+03	1.23E+03	1.10E+03
	gap	Best	2.53%	2.73%	10.18%	16.42%	12.62%	23.22%	20.89%	5.41%
		Mean	12.58%	4.32%	10.18%	18.17%	14.24%	27.22%	21.67%	12.49%
GBP PI44	obj	Best	1.12E+03	1.16E+03	1.21E+03	1.17E+03	1.31E+03	1.43E+03	1.33E+03	1.26E+03
		Mean	1.15E+03	1.18E+03	1.21E+03	1.28E+03	1.35E+03	1.50E+03	1.36E+03	1.30E+03
	gap	Best	0.27%	3.95%	7.37%	4.28%	14.53%	21.60%	15.81%	10.92%
		Mean	3.02%	5.01%	7.37%	12.53%	16.92%	25.18%	17.86%	13.70%
GBP PI45	obj	Best	1.60E+03	1.52E+03	1.72E+03	1.76E+03	1.72E+03	1.99E+03	1.80E+03	1.68E+03
		Mean	1.71E+03	1.54E+03	1.72E+03	1.78E+03	1.76E+03	2.46E+03	1.89E+03	1.75E+03
	gap	Best	8.82%	3.76%	15.33%	17.21%	15.13%	26.59%	18.86%	13.06%
		Mean	14.68%	5.33%	15.33%	18.25%	17.29%	40.10%	22.64%	16.50%
GBP PI46	obj	Best	2.71E+03	2.57E+03	2.86E+03	2.90E+03	2.87E+03	3.13E+03	3.02E+03	2.83E+03
		Mean	2.97E+03	2.59E+03	2.86E+03	2.97E+03	2.94E+03	3.34E+03	3.05E+03	2.94E+03
	gap	Best	6.60%	1.40%	11.31%	12.59%	11.71%	19.02%	16.20%	10.46%
		Mean	14.25%	1.99%	11.31%	14.56%	13.83%	24.04%	16.78%	13.70%
GBP PI47	obj	Best	NAN	4.55E+03	5.28E+03	5.33E+03	5.17E+03	5.75E+03	5.46E+03	5.25E+03
		Mean	NAN	4.58E+03	5.28E+03	5.39E+03	5.24E+03	6.09E+03	5.52E+03	5.31E+03
	gap	Best	NAN	1.43%	14.97%	15.84%	13.12%	21.95%	17.77%	14.51%
		Mean	NAN	1.99%	14.97%	16.68%	14.36%	26.27%	18.63%	15.48%
GBP PI48	obj	Best	NAN	3.24E+03	3.78E+03	3.78E+03	3.60E+03	4.33E+03	4.00E+03	3.63E+03
		Mean	NAN	3.26E+03	3.78E+03	3.86E+03	3.71E+03	5.22E+03	4.20E+03	3.72E+03
	gap	Best	NAN	2.34%	16.22%	16.22%	12.10%	26.88%	20.87%	12.76%
		Mean	NAN	2.78%	16.22%	17.91%	14.59%	38.83%	24.51%	14.84%
GBP PI49	obj	Best	NAN	1.31E+04	1.41E+04	1.44E+04	1.40E+04	1.56E+04	1.47E+04	1.49E+04
		Mean	NAN	1.33E+04	1.41E+04	1.45E+04	1.42E+04	1.64E+04	1.48E+04	1.52E+04
	gap	Best	NAN	4.12%	10.90%	12.70%	10.50%	19.62%	14.26%	15.89%
		Mean	NAN	5.64%	10.90%	13.22%	11.52%	23.25%	15.03%	17.32%
GBP PI50	obj	Best	NAN	1.25E+04	1.45E+04	1.34E+04	1.34E+04	1.47E+04	1.39E+04	1.42E+04
		Mean	NAN	1.28E+04	1.45E+04	1.36E+04	1.36E+04	1.56E+04	1.41E+04	1.43E+04
	gap	Best	NAN	3.38%	16.65%	10.19%	10.19%	18.06%	13.20%	15.10%
		Mean	NAN	5.44%	16.65%	11.45%	11.13%	22.68%	14.30%	15.63%

3.7 Quadratic multiple knapsack problem (QMKP)

The experimental results of QMKP are shown in Table S-19.

Table S-19 Experimental results on QMKP.

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
QMKP01	obj	Best	9.98E+03	9.98E+03	9.32E+03	9.98E+03	9.97E+03	9.98E+03	9.98E+03	9.98E+03
		Mean	9.98E+03	9.97E+03	9.32E+03	9.95E+03	9.91E+03	9.98E+03	9.94E+03	9.96E+03
	gap	Best	0.00%	0.00%	7.07%	0.00%	0.11%	0.00%	0.00%	0.00%
		Mean	0.00%	0.11%	7.07%	0.29%	0.71%	0.00%	0.44%	0.17%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
QMKP02	obj	Best	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.05E+04
		Mean	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.05E+04	1.05E+04
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
QMKP03	obj	Best	8.74E+03	8.74E+03	8.46E+03	8.65E+03	8.59E+03	8.74E+03	8.47E+03	8.74E+03
		Mean	8.74E+03	8.72E+03	8.46E+03	8.56E+03	8.52E+03	8.65E+03	8.37E+03	8.57E+03
	gap	Best	0.00%	0.00%	3.37%	1.11%	1.77%	0.00%	3.26%	0.00%
		Mean	0.00%	0.24%	3.37%	2.14%	2.65%	1.04%	4.48%	1.99%
QMKP04	obj	Best	4.81E+03	8.07E+03	3.86E+03	5.82E+03	6.23E+03	8.88E+03	9.14E+03	7.43E+03
		Mean	4.86E+03	7.44E+03	3.86E+03	5.71E+03	6.04E+03	7.52E+03	7.71E+03	6.91E+03
	gap	Best	120.08%	33.67%	179.36%	85.20%	73.13%	21.46%	18.02%	45.09%
		Mean	121.82%	46.09%	179.36%	89.01%	78.62%	46.66%	44.53%	56.53%
QMKP05	obj	Best	4.97E+03	5.48E+03	3.68E+03	5.68E+03	5.47E+03	5.69E+03	5.31E+03	6.12E+03
		Mean	4.97E+03	5.35E+03	3.68E+03	5.48E+03	5.47E+03	5.62E+03	5.24E+03	5.63E+03
	gap	Best	66.85%	51.34%	125.00%	46.06%	51.48%	45.57%	56.25%	35.35%
		Mean	66.85%	54.99%	125.00%	51.39%	51.51%	47.48%	58.07%	47.47%
QMKP06	obj	Best	1.99E+04	1.99E+04	1.99E+04	1.99E+04	1.99E+04	1.99E+04	1.99E+04	1.99E+04
		Mean	1.99E+04	1.99E+04	1.99E+04	1.99E+04	1.99E+04	1.99E+04	1.99E+04	1.99E+04
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
QMKP07	obj	Best	1.50E+04	1.71E+04	1.23E+04	1.71E+04	1.71E+04	1.73E+04	1.69E+04	1.73E+04
		Mean	1.50E+04	1.69E+04	1.23E+04	1.69E+04	1.69E+04	1.72E+04	1.66E+04	1.72E+04
	gap	Best	33.73%	17.13%	62.76%	16.95%	17.16%	15.82%	18.79%	15.63%
		Mean	33.73%	18.23%	62.76%	18.67%	18.38%	16.55%	20.71%	16.75%
QMKP08	obj	Best	2.68E+04	2.68E+04	2.68E+04	2.68E+04	2.68E+04	2.68E+04	2.68E+04	2.68E+04
		Mean	2.68E+04	2.68E+04	2.68E+04	2.68E+04	2.68E+04	2.68E+04	2.68E+04	2.68E+04
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
QMKP09	obj	Best	3.91E+03	7.38E+03	3.59E+03	7.14E+03	6.77E+03	7.07E+03	6.92E+03	7.05E+03
		Mean	3.91E+03	6.99E+03	3.59E+03	6.46E+03	6.60E+03	6.76E+03	6.66E+03	6.65E+03
	gap	Best	259.33%	90.18%	290.95%	96.60%	107.34%	98.52%	102.85%	99.05%
		Mean	259.33%	100.96%	290.95%	119.17%	112.84%	107.83%	111.20%	111.65%
QMKP10	obj	Best	4.86E+03	5.28E+03	4.39E+03	5.22E+03	5.32E+03	5.53E+03	5.16E+03	5.63E+03
		Mean	4.86E+03	5.15E+03	4.31E+03	5.10E+03	5.19E+03	5.43E+03	5.01E+03	5.27E+03
	gap	Best	28.51%	18.38%	42.43%	19.65%	17.49%	12.95%	21.18%	10.92%
		Mean	28.51%	21.46%	45.17%	22.45%	20.37%	15.16%	24.74%	18.90%
QMKP11	obj	Best	1.22E+04	1.22E+04	1.10E+04	1.20E+04	1.22E+04	1.22E+04	1.21E+04	1.22E+04
		Mean	1.22E+04	1.22E+04	1.10E+04	1.20E+04	1.21E+04	1.22E+04	1.21E+04	1.21E+04
	gap	Best	0.00%	0.00%	10.53%	1.24%	0.05%	0.00%	0.53%	0.05%
		Mean	0.00%	0.03%	10.63%	1.51%	0.37%	0.28%	0.93%	0.35%
QMKP12	obj	Best	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04
		Mean	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
QMKP13	obj	Best	5.84E+03	9.95E+03	4.85E+03	9.84E+03	1.02E+04	1.08E+04	9.10E+03	1.07E+04
		Mean	6.48E+03	9.48E+03	4.85E+03	9.38E+03	9.45E+03	1.01E+04	8.79E+03	9.92E+03
	gap	Best	102.82%	40.84%	189.27%	42.37%	37.94%	29.91%	54.10%	31.39%
		Mean	117.77%	47.94%	189.27%	49.96%	48.60%	39.11%	59.77%	41.77%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
QMKP14	obj	Best	1.93E+04	1.95E+04	1.93E+04	1.95E+04	1.95E+04	1.95E+04	1.94E+04	1.95E+04
		Mean	1.93E+04	1.95E+04	1.93E+04	1.93E+04	1.94E+04	1.95E+04	1.91E+04	1.93E+04
	gap	Best	1.23%	0.00%	1.26%	0.36%	0.11%	0.00%	0.60%	0.21%
		Mean	1.23%	0.32%	1.26%	1.24%	0.55%	0.16%	2.25%	1.52%
QMKP15	obj	Best	8.97E+03	1.33E+04	8.48E+03	1.30E+04	1.26E+04	1.34E+04	1.26E+04	1.34E+04
		Mean	8.97E+03	1.26E+04	8.33E+03	1.24E+04	1.24E+04	1.30E+04	1.18E+04	1.26E+04
	gap	Best	88.08%	26.93%	98.95%	29.33%	33.99%	26.04%	33.39%	26.04%
		Mean	88.08%	34.21%	102.72%	35.85%	35.47%	29.35%	43.89%	34.02%
QMKP16	obj	Best	9.84E+03	1.46E+04	1.01E+04	1.52E+04	1.43E+04	1.49E+04	1.33E+04	1.52E+04
		Mean	9.84E+03	1.44E+04	1.01E+04	1.40E+04	1.42E+04	1.45E+04	1.29E+04	1.42E+04
	gap	Best	134.14%	58.04%	128.68%	51.24%	61.28%	54.65%	72.92%	51.24%
		Mean	134.14%	60.51%	128.68%	65.79%	62.78%	58.49%	78.52%	62.88%
QMKP17	obj	Best	3.35E+04	3.35E+04	3.32E+04	3.35E+04	3.35E+04	3.35E+04	3.35E+04	3.35E+04
		Mean	3.35E+04	3.35E+04	3.32E+04	3.35E+04	3.35E+04	3.35E+04	3.35E+04	3.35E+04
	gap	Best	0.00%	0.00%	0.82%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.82%	0.00%	0.00%	0.00%	0.00%	0.00%
QMKP18	obj	Best	3.16E+04	3.16E+04	3.11E+04	3.16E+04	3.16E+04	3.16E+04	3.16E+04	3.16E+04
		Mean	3.16E+04	3.15E+04	3.11E+04	3.14E+04	3.13E+04	3.16E+04	3.12E+04	3.13E+04
	gap	Best	0.00%	0.00%	1.36%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.20%	1.36%	0.54%	0.76%	0.00%	1.10%	0.87%
QMKP19	obj	Best	1.55E+04	1.55E+04	1.55E+04	1.55E+04	1.55E+04	1.55E+04	1.55E+04	1.55E+04
		Mean	1.55E+04	1.55E+04	1.55E+04	1.55E+04	1.55E+04	1.55E+04	1.55E+04	1.55E+04
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%
QMKP20	obj	Best	1.05E+04	1.15E+04	8.42E+03	1.13E+04	1.12E+04	1.13E+04	1.10E+04	1.16E+04
		Mean	1.05E+04	1.11E+04	8.42E+03	1.12E+04	1.12E+04	1.12E+04	1.07E+04	1.13E+04
	gap	Best	27.50%	16.31%	58.78%	18.16%	19.34%	18.20%	21.80%	14.86%
		Mean	27.50%	20.10%	58.86%	19.27%	19.81%	18.96%	25.15%	18.08%
QMKP21	obj	Best	1.00E+04	1.07E+04	8.25E+03	1.06E+04	1.04E+04	1.01E+04	1.02E+04	1.09E+04
		Mean	1.00E+04	1.02E+04	8.16E+03	1.05E+04	1.03E+04	1.00E+04	1.01E+04	1.07E+04
	gap	Best	17.87%	10.21%	43.07%	11.01%	13.48%	16.30%	15.24%	7.89%
		Mean	17.87%	15.97%	44.64%	12.07%	14.28%	17.53%	17.22%	10.31%
QMKP22	obj	Best	1.03E+04	1.45E+04	9.69E+03	1.56E+04	1.48E+04	1.53E+04	1.43E+04	1.51E+04
		Mean	1.03E+04	1.40E+04	9.57E+03	1.45E+04	1.44E+04	1.48E+04	1.36E+04	1.47E+04
	gap	Best	121.29%	57.12%	135.37%	46.56%	54.26%	49.05%	59.59%	51.33%
		Mean	121.29%	62.73%	138.52%	57.98%	58.55%	53.87%	67.66%	55.33%
QMKP23	obj	Best	3.73E+03	6.90E+03	3.87E+03	6.76E+03	6.75E+03	7.71E+03	7.01E+03	6.82E+03
		Mean	3.73E+03	6.35E+03	3.87E+03	6.42E+03	6.56E+03	7.37E+03	6.68E+03	6.66E+03
	gap	Best	308.57%	121.02%	294.21%	125.46%	125.80%	97.72%	117.39%	123.58%
		Mean	308.57%	140.64%	294.21%	138.29%	132.35%	107.26%	128.73%	129.23%
QMKP24	obj	Best	1.68E+04	1.80E+04	1.45E+04	1.79E+04	1.75E+04	1.83E+04	1.72E+04	1.85E+04
		Mean	1.68E+04	1.78E+04	1.45E+04	1.76E+04	1.74E+04	1.79E+04	1.67E+04	1.80E+04
	gap	Best	49.56%	39.39%	73.17%	40.01%	43.42%	37.26%	46.10%	35.68%
		Mean	49.56%	40.77%	73.17%	42.96%	43.82%	39.98%	50.25%	39.18%
QMKP25	obj	Best	4.77E+04	4.77E+04	4.77E+04	4.77E+04	4.77E+04	4.77E+04	4.77E+04	4.77E+04
		Mean	4.77E+04	4.77E+04	4.77E+04	4.77E+04	4.77E+04	4.77E+04	4.77E+04	4.77E+04
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
QMKP26	obj	Best	2.88E+04	2.98E+04	2.16E+04	2.96E+04	2.94E+04	3.01E+04	2.87E+04	3.05E+04
		Mean	2.88E+04	2.97E+04	2.16E+04	2.93E+04	2.92E+04	2.98E+04	2.80E+04	2.99E+04
	gap	Best	18.41%	14.30%	57.71%	15.08%	16.01%	13.39%	18.88%	12.00%
		Mean	18.41%	15.04%	57.71%	16.42%	16.88%	14.45%	21.79%	14.26%
QMKP27	obj	Best	2.94E+04	2.99E+04	2.89E+04	2.97E+04	2.96E+04	3.10E+04	2.95E+04	3.00E+04
		Mean	2.94E+04	2.97E+04	2.88E+04	2.95E+04	2.95E+04	3.02E+04	2.90E+04	2.99E+04
	gap	Best	22.37%	20.40%	24.42%	20.99%	21.51%	16.10%	22.17%	19.81%
		Mean	22.37%	21.06%	24.99%	21.83%	21.88%	19.27%	23.95%	20.36%
QMKP28	obj	Best	1.15E+04	1.22E+04	8.59E+03	1.20E+04	1.18E+04	1.21E+04	1.19E+04	1.24E+04
		Mean	1.15E+04	1.15E+04	8.59E+03	1.14E+04	1.17E+04	1.18E+04	1.10E+04	1.22E+04
	gap	Best	25.83%	19.09%	68.94%	21.23%	22.45%	20.12%	21.81%	17.16%
		Mean	25.83%	25.87%	68.94%	27.83%	23.64%	23.28%	32.61%	19.30%
QMKP29	obj	Best	1.97E+04	1.97E+04	1.95E+04	1.97E+04	1.97E+04	1.97E+04	1.97E+04	1.97E+04
		Mean	1.97E+04	1.97E+04	1.94E+04	1.97E+04	1.97E+04	1.97E+04	1.97E+04	1.97E+04
	gap	Best	0.00%	0.00%	1.24%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	1.34%	0.00%	0.03%	0.00%	0.14%	0.00%
QMKP30	obj	Best	1.44E+04	1.47E+04	1.30E+04	1.45E+04	1.45E+04	1.50E+04	1.44E+04	1.47E+04
		Mean	1.44E+04	1.44E+04	1.30E+04	1.43E+04	1.44E+04	1.47E+04	1.40E+04	1.46E+04
	gap	Best	6.96%	5.31%	19.01%	6.16%	6.60%	2.66%	7.31%	4.94%
		Mean	6.96%	7.01%	19.01%	8.15%	7.24%	5.20%	10.66%	5.76%
QMKP31	obj	Best	2.14E+04	2.26E+04	2.05E+04	2.32E+04	2.30E+04	2.33E+04	2.28E+04	2.39E+04
		Mean	2.14E+04	2.22E+04	1.99E+04	2.30E+04	2.29E+04	2.31E+04	2.23E+04	2.33E+04
	gap	Best	35.48%	28.58%	41.83%	25.36%	26.36%	24.69%	27.59%	21.64%
		Mean	35.48%	30.96%	46.52%	26.32%	26.64%	25.89%	30.08%	24.86%
QMKP32	obj	Best	2.61E+04	2.68E+04	2.52E+04	2.72E+04	2.69E+04	2.72E+04	2.65E+04	2.80E+04
		Mean	2.61E+04	2.65E+04	2.52E+04	2.66E+04	2.68E+04	2.70E+04	2.63E+04	2.72E+04
	gap	Best	13.17%	10.08%	17.45%	8.63%	9.82%	8.71%	11.40%	5.57%
		Mean	13.17%	11.58%	17.45%	10.88%	10.05%	9.47%	12.25%	8.44%
QMKP33	obj	Best	2.50E+04	2.58E+04	2.20E+04	2.56E+04	2.56E+04	2.66E+04	2.56E+04	2.58E+04
		Mean	2.50E+04	2.56E+04	2.20E+04	2.54E+04	2.55E+04	2.60E+04	2.49E+04	2.57E+04
	gap	Best	22.20%	18.19%	38.50%	19.09%	19.00%	14.76%	19.01%	18.44%
		Mean	22.20%	18.95%	38.50%	20.13%	19.46%	17.19%	22.69%	18.84%
QMKP34	obj	Best	5.13E+04	5.13E+04	5.11E+04	5.13E+04	5.13E+04	5.13E+04	5.13E+04	5.13E+04
		Mean	5.13E+04	5.13E+04	5.01E+04	5.13E+04	5.13E+04	5.13E+04	5.13E+04	5.13E+04
	gap	Best	0.00%	0.00%	0.33%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	2.37%	0.00%	0.00%	0.00%	0.00%	0.00%
QMKP35	obj	Best	7.24E+03	1.61E+04	7.38E+03	1.56E+04	1.49E+04	2.60E+04	1.82E+04	1.62E+04
		Mean	7.24E+03	1.45E+04	7.38E+03	1.44E+04	1.43E+04	1.83E+04	1.60E+04	1.56E+04
	gap	Best	458.11%	151.10%	447.45%	159.43%	171.04%	55.48%	121.70%	148.73%
		Mean	458.11%	180.15%	447.45%	182.65%	183.33%	129.61%	154.84%	159.27%
QMKP36	obj	Best	5.07E+04	5.07E+04	5.06E+04	5.07E+04	5.07E+04	5.07E+04	5.07E+04	5.07E+04
		Mean	5.07E+04	5.07E+04	5.06E+04	5.07E+04	5.07E+04	5.07E+04	5.07E+04	5.07E+04
	gap	Best	0.00%	0.00%	0.16%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.16%	0.00%	0.00%	0.00%	0.05%	0.00%
QMKP37	obj	Best	2.10E+04	2.10E+04	2.08E+04	2.10E+04	2.10E+04	2.10E+04	2.10E+04	2.10E+04
		Mean	2.10E+04	2.10E+04	2.08E+04	2.10E+04	2.10E+04	2.10E+04	2.09E+04	2.10E+04

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
	gap	Best	0.00%	0.00%	0.92%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.92%	0.00%	0.00%	0.00%	0.36%	0.00%
QMKP38	obj	Best	1.95E+04	1.97E+04	1.83E+04	1.97E+04	1.97E+04	1.97E+04	1.92E+04	1.97E+04
		Mean	1.95E+04	1.96E+04	1.82E+04	1.96E+04	1.94E+04	1.96E+04	1.89E+04	1.96E+04
	gap	Best	0.64%	0.00%	7.14%	0.00%	0.00%	0.00%	2.58%	0.00%
		Mean	0.64%	0.24%	7.93%	0.42%	1.14%	0.06%	4.18%	0.27%
QMKP39	obj	Best	8.37E+03	8.89E+03	5.30E+03	8.89E+03	8.29E+03	8.64E+03	8.62E+03	8.85E+03
		Mean	8.37E+03	7.87E+03	5.30E+03	8.05E+03	8.00E+03	8.42E+03	7.64E+03	8.67E+03
	gap	Best	72.01%	61.81%	171.77%	61.83%	73.56%	66.47%	66.86%	62.67%
		Mean	72.01%	84.32%	171.77%	80.67%	80.05%	70.90%	90.22%	66.09%
QMKP40	obj	Best	NaN	9.84E+03	5.60E+03	1.06E+04	1.02E+04	1.26E+04	1.13E+04	1.13E+04
		Mean	NaN	8.86E+03	5.60E+03	1.03E+04	9.99E+03	1.07E+04	1.01E+04	1.07E+04
	gap	Best	NaN	198.10%	423.75%	177.09%	187.01%	133.46%	159.17%	158.94%
		Mean	NaN	232.63%	423.75%	184.51%	193.58%	175.52%	192.50%	175.74%
QMKP41	obj	Best	3.92E+04	3.92E+04	3.92E+04	3.92E+04	3.92E+04	3.92E+04	3.92E+04	3.92E+04
		Mean	3.92E+04	3.92E+04	3.90E+04	3.92E+04	3.92E+04	3.92E+04	3.91E+04	3.92E+04
	gap	Best	0.00%	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.44%	0.00%	0.00%	0.00%	0.20%	0.00%
QMKP42	obj	Best	2.30E+04	2.55E+04	1.69E+04	2.50E+04	2.53E+04	2.56E+04	2.45E+04	2.67E+04
		Mean	2.30E+04	2.51E+04	1.69E+04	2.49E+04	2.48E+04	2.56E+04	2.38E+04	2.57E+04
	gap	Best	53.94%	38.73%	109.05%	41.20%	39.57%	37.87%	44.31%	32.18%
		Mean	53.94%	40.93%	109.54%	41.91%	42.65%	38.13%	48.74%	37.39%
QMKP43	obj	Best	6.76E+04	6.76E+04	6.76E+04	6.76E+04	6.76E+04	6.76E+04	6.76E+04	6.76E+04
		Mean	6.76E+04	6.76E+04	6.76E+04	6.76E+04	6.76E+04	6.76E+04	6.76E+04	6.76E+04
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
QMKP44	obj	Best	6.28E+04	6.28E+04	6.28E+04	6.28E+04	6.28E+04	6.28E+04	6.28E+04	6.28E+04
		Mean	6.28E+04	6.28E+04	6.28E+04	6.28E+04	6.28E+04	6.28E+04	6.28E+04	6.28E+04
	gap	Best	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.00%	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%
QMKP45	obj	Best	4.19E+04	4.38E+04	4.28E+04	4.41E+04	4.41E+04	4.42E+04	4.33E+04	4.42E+04
		Mean	4.19E+04	4.37E+04	4.17E+04	4.38E+04	4.40E+04	4.41E+04	4.25E+04	4.41E+04
	gap	Best	34.12%	28.34%	31.30%	27.57%	27.39%	27.08%	29.76%	27.32%
		Mean	34.12%	28.75%	35.17%	28.33%	27.82%	27.38%	32.33%	27.64%

3.8 High school timetabling problem (HTS)

Table S-20 shows the experimental results of the HTS problems.

Table S-20 Experimental results on HTS.

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
HTS01	obj	Best	7.11E+02	7.73E+02	NAN	7.19E+02	7.14E+02	7.04E+02	7.21E+02	7.04E+02
		Mean	7.44E+02	7.84E+02	NAN	7.25E+02	7.27E+02	7.11E+02	7.35E+02	7.15E+02
	gap	Best	8.16%	15.52%	NAN	9.18%	8.54%	7.24%	9.43%	7.24%
		Mean	12.06%	16.68%	NAN	9.92%	10.14%	8.10%	11.12%	8.71%
HTS02	obj	Best	7.34E+02	7.84E+02	NAN	7.26E+02	7.28E+02	7.14E+02	7.29E+02	7.15E+02
		Mean	7.34E+02	8.09E+02	NAN	7.31E+02	7.36E+02	7.20E+02	7.35E+02	7.16E+02
	gap	Best	7.77%	13.65%	NAN	6.75%	7.01%	5.18%	7.13%	5.31%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	7.77%	16.27%	NAN	7.43%	8.04%	5.99%	7.94%	5.38%
HTS03	obj	Best	8.37E+02	8.79E+02	NAN	7.32E+02	7.32E+02	7.24E+02	7.33E+02	7.22E+02
		Mean	8.37E+02	9.17E+02	NAN	7.34E+02	7.36E+02	7.29E+02	7.35E+02	7.23E+02
	gap	Best	14.70%	18.77%	NAN	2.46%	2.46%	1.38%	2.59%	1.11%
		Mean	14.70%	22.10%	NAN	2.75%	2.94%	2.03%	2.83%	1.30%
HTS04	obj	Best	8.68E+02	8.73E+02	NAN	7.36E+02	7.42E+02	7.34E+02	7.49E+02	7.38E+02
		Mean	NAN	9.26E+02	NAN	7.44E+02	7.47E+02	7.39E+02	7.51E+02	7.40E+02
	gap	Best	16.59%	17.07%	NAN	1.63%	2.43%	1.36%	3.34%	1.90%
		Mean	NAN	21.73%	NAN	2.63%	3.08%	1.97%	3.65%	2.11%
HTS05	obj	Best	6.82E+02	6.86E+02	NAN	6.20E+02	6.28E+02	6.18E+02	6.30E+02	6.18E+02
		Mean	6.82E+02	6.94E+02	NAN	6.26E+02	6.30E+02	6.24E+02	6.32E+02	6.23E+02
	gap	Best	10.12%	10.64%	NAN	1.13%	2.39%	0.81%	2.70%	0.81%
		Mean	10.12%	11.69%	NAN	2.10%	2.67%	1.82%	3.07%	1.66%
HTS06	obj	Best	8.70E+02	9.22E+02	NAN	8.16E+02	8.17E+02	7.84E+02	8.24E+02	8.06E+02
		Mean	8.70E+02	9.43E+02	NAN	8.24E+02	8.21E+02	8.03E+02	8.27E+02	8.09E+02
	gap	Best	13.68%	18.55%	NAN	7.97%	8.08%	4.21%	8.86%	6.82%
		Mean	13.68%	20.38%	NAN	8.90%	8.51%	6.43%	9.23%	7.21%
HTS07	obj	Best	1.30E+03	1.35E+03	NAN	1.22E+03	1.22E+03	1.21E+03	1.23E+03	1.23E+03
		Mean	1.30E+03	1.38E+03	NAN	1.22E+03	1.23E+03	1.21E+03	1.23E+03	1.23E+03
	gap	Best	7.99%	11.19%	NAN	0.00%	0.49%	0.00%	0.90%	0.81%
		Mean	7.99%	13.07%	NAN	0.47%	0.86%	0.48%	1.10%	0.91%
HTS08	obj	Best	6.79E+02	6.93E+02	7.26E+02	6.53E+02	6.60E+02	6.38E+02	6.75E+02	6.40E+02
		Mean	6.79E+02	7.07E+02	7.31E+02	6.63E+02	6.78E+02	6.39E+02	6.80E+02	6.58E+02
	gap	Best	8.84%	10.68%	14.74%	5.21%	6.21%	2.98%	8.30%	3.28%
		Mean	8.84%	12.38%	15.34%	6.60%	8.69%	3.13%	8.91%	5.90%
HTS09	obj	Best	8.65E+02	9.05E+02	NAN	8.18E+02	8.15E+02	8.14E+02	8.23E+02	8.03E+02
		Mean	8.65E+02	9.27E+02	NAN	8.20E+02	8.18E+02	8.20E+02	8.26E+02	8.12E+02
	gap	Best	9.25%	13.26%	NAN	4.03%	3.68%	3.56%	4.62%	2.24%
		Mean	9.25%	15.27%	NAN	4.27%	3.99%	4.26%	4.91%	3.32%
HTS10	obj	Best	3.06E+02	3.15E+02	NAN	3.10E+02	3.12E+02	3.00E+02	3.11E+02	3.01E+02
		Mean	3.06E+02	3.32E+02	NAN	3.12E+02	3.13E+02	3.03E+02	3.14E+02	3.08E+02
	gap	Best	2.61%	5.40%	NAN	3.87%	4.49%	0.67%	4.18%	1.00%
		Mean	2.61%	10.13%	NAN	4.55%	4.73%	1.76%	5.21%	3.22%
HTS11	obj	Best	NAN	1.13E+03	NAN	9.78E+02	9.97E+02	9.76E+02	1.01E+03	9.87E+02
		Mean	NAN	1.21E+03	NAN	9.96E+02	1.00E+03	9.82E+02	1.02E+03	9.92E+02
	gap	Best	NAN	15.78%	NAN	2.35%	4.21%	2.15%	5.45%	3.24%
		Mean	NAN	20.91%	NAN	4.10%	4.95%	2.78%	5.91%	3.75%
HTS12	obj	Best	1.05E+03	1.08E+03	NAN	1.01E+03	1.02E+03	9.86E+02	1.03E+03	9.98E+02
		Mean	1.06E+03	1.09E+03	NAN	1.02E+03	1.03E+03	1.01E+03	1.04E+03	1.01E+03
	gap	Best	10.55%	12.55%	NAN	7.20%	7.47%	4.56%	8.73%	5.71%
		Mean	11.49%	13.62%	NAN	7.85%	8.87%	6.89%	9.17%	6.97%
HTS13	obj	Best	2.76E+02	2.76E+02	2.76E+02	2.42E+02	2.46E+02	2.42E+02	2.52E+02	2.44E+02
		Mean	2.76E+02	2.76E+02	2.76E+02	2.49E+02	2.51E+02	2.48E+02	2.59E+02	2.53E+02
	gap	Best	14.49%	14.49%	14.49%	2.48%	4.07%	2.48%	6.35%	3.28%
		Mean	14.49%	14.49%	14.49%	5.26%	5.97%	4.81%	8.79%	6.71%
HTS14	obj	Best	1.00E+03	1.01E+03	NAN	9.21E+02	9.20E+02	9.17E+02	9.34E+02	9.21E+02
		Mean	1.00E+03	1.01E+03	NAN	9.29E+02	9.33E+02	9.20E+02	9.37E+02	9.23E+02

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
	gap	Best	9.00%	9.81%	NAN	1.19%	1.09%	0.76%	2.57%	1.19%
		Mean	9.00%	10.29%	NAN	2.00%	2.50%	1.13%	2.92%	1.37%
HTS15	obj	Best	2.57E+02	2.57E+02	2.57E+02	2.34E+02	2.34E+02	2.27E+02	2.34E+02	2.34E+02
		Mean	2.57E+02	2.57E+02	2.57E+02	2.35E+02	2.34E+02	2.34E+02	2.35E+02	2.35E+02
	gap	Best	15.56%	15.56%	15.56%	7.26%	7.26%	4.41%	7.26%	7.26%
		Mean	15.56%	15.56%	15.56%	7.74%	7.40%	7.18%	7.82%	7.59%
HTS16	obj	Best	5.00E+02	5.29E+02	NAN	4.75E+02	4.80E+02	4.75E+02	4.82E+02	4.75E+02
		Mean	5.01E+02	5.37E+02	NAN	4.79E+02	4.83E+02	4.77E+02	4.88E+02	4.77E+02
	gap	Best	6.00%	11.15%	NAN	1.05%	2.08%	1.05%	2.49%	1.05%
		Mean	6.15%	12.38%	NAN	1.79%	2.61%	1.50%	3.64%	1.55%
HTS17	obj	Best	4.88E+02	5.08E+02	NAN	4.57E+02	4.57E+02	4.56E+02	4.59E+02	4.56E+02
		Mean	5.10E+02	5.13E+02	NAN	4.59E+02	4.59E+02	4.58E+02	4.62E+02	4.58E+02
	gap	Best	6.56%	10.24%	NAN	0.22%	0.22%	0.00%	0.65%	0.00%
		Mean	10.48%	11.16%	NAN	0.74%	0.65%	0.39%	1.34%	0.44%
HTS18	obj	Best	3.35E+02	3.30E+02	4.14E+02	3.12E+02	3.11E+02	3.11E+02	3.13E+02	3.11E+02
		Mean	3.38E+02	3.44E+02	4.57E+02	3.14E+02	3.13E+02	3.12E+02	3.15E+02	3.12E+02
	gap	Best	8.66%	7.27%	26.09%	1.92%	1.61%	1.61%	2.24%	1.61%
		Mean	9.52%	10.98%	32.50%	2.61%	2.18%	1.92%	2.96%	1.80%
HTS19	obj	Best	2.55E+02	2.55E+02	2.70E+02	2.46E+02	2.37E+02	2.47E+02	2.47E+02	2.46E+02
		Mean	2.58E+02	2.61E+02	3.14E+02	2.48E+02	2.45E+02	2.51E+02	2.48E+02	2.47E+02
	gap	Best	9.02%	9.02%	14.07%	5.69%	2.11%	6.07%	6.07%	5.69%
		Mean	10.14%	11.01%	24.92%	6.30%	5.36%	7.61%	6.60%	5.88%
HTS20	obj	Best	3.25E+02	3.38E+02	NAN	3.27E+02	3.25E+02	3.21E+02	3.37E+02	3.21E+02
		Mean	3.32E+02	3.48E+02	NAN	3.31E+02	3.38E+02	3.26E+02	3.41E+02	3.23E+02
	gap	Best	3.69%	7.40%	NAN	4.28%	3.69%	2.49%	7.12%	2.49%
		Mean	5.77%	10.01%	NAN	5.49%	7.32%	3.86%	8.15%	3.21%
HTS21	obj	Best	1.11E+03	1.13E+03	NAN	1.06E+03	1.05E+03	1.06E+03	1.07E+03	1.04E+03
		Mean	1.13E+03	1.14E+03	NAN	1.06E+03	1.06E+03	1.06E+03	1.08E+03	1.05E+03
	gap	Best	5.95%	7.70%	NAN	1.42%	0.57%	1.51%	2.80%	0.00%
		Mean	7.93%	8.85%	NAN	1.97%	1.32%	1.82%	3.12%	0.83%
HTS22	obj	Best	7.42E+02	7.50E+02	7.87E+02	7.06E+02	7.05E+02	6.95E+02	7.03E+02	6.94E+02
		Mean	7.47E+02	7.57E+02	7.91E+02	7.07E+02	7.08E+02	7.01E+02	7.07E+02	6.97E+02
	gap	Best	7.82%	8.80%	13.09%	3.12%	2.98%	1.58%	2.70%	1.44%
		Mean	8.41%	9.64%	13.56%	3.25%	3.36%	2.39%	3.25%	1.92%
HTS23	obj	Best	2.07E+03	2.09E+03	NAN	1.88E+03	1.90E+03	1.85E+03	1.91E+03	1.91E+03
		Mean	NAN	2.11E+03	NAN	1.89E+03	1.90E+03	1.87E+03	1.91E+03	1.92E+03
	gap	Best	12.31%	13.15%	NAN	3.51%	4.17%	1.78%	4.67%	5.07%
		Mean	NAN	13.84%	NAN	4.16%	4.54%	2.82%	4.88%	5.53%
HTS24	obj	Best	2.16E+03	2.21E+03	NAN	2.05E+03	2.05E+03	2.04E+03	2.06E+03	2.09E+03
		Mean	2.17E+03	2.25E+03	NAN	2.06E+03	2.06E+03	2.05E+03	2.07E+03	2.16E+03
	gap	Best	7.54%	9.67%	NAN	2.34%	2.58%	1.91%	2.96%	4.31%
		Mean	7.84%	11.19%	NAN	2.92%	3.06%	2.35%	3.49%	7.30%
HTS25	obj	Best	9.70E+02	1.07E+03	NAN	9.60E+02	9.49E+02	9.43E+02	9.67E+02	9.43E+02
		Mean	1.00E+03	1.11E+03	NAN	9.63E+02	9.54E+02	9.48E+02	9.73E+02	9.51E+02
	gap	Best	4.85%	13.74%	NAN	3.85%	2.74%	2.12%	4.55%	2.12%
		Mean	7.72%	17.00%	NAN	4.13%	3.23%	2.61%	5.10%	2.98%
HTS26	obj	Best	5.90E+02	6.31E+02	7.21E+02	5.83E+02	5.86E+02	5.83E+02	6.03E+02	5.89E+02

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
HTS27	gap	Mean	6.27E+02	6.47E+02	7.51E+02	5.91E+02	5.94E+02	5.91E+02	6.05E+02	5.93E+02
		Best	3.22%	9.51%	20.80%	2.06%	2.56%	2.06%	5.31%	3.06%
		Mean	8.85%	11.70%	23.67%	3.44%	3.80%	3.31%	5.56%	3.65%
	obj	Best	5.56E+02	5.77E+02	6.13E+02	5.53E+02	5.50E+02	5.52E+02	5.52E+02	5.50E+02
		Mean	5.61E+02	5.88E+02	6.13E+02	5.55E+02	5.53E+02	5.54E+02	5.55E+02	5.51E+02
		Best	1.80%	5.37%	10.93%	1.27%	0.73%	1.09%	1.09%	0.73%
HTS28	gap	Mean	2.64%	7.20%	10.99%	1.69%	1.30%	1.47%	1.69%	0.91%
	obj	Best	NAN	1.39E+03	NAN	1.10E+03	1.11E+03	1.10E+03	1.11E+03	1.10E+03
		Mean	NAN	1.43E+03	NAN	1.10E+03	1.11E+03	1.10E+03	1.11E+03	1.10E+03
		Best	NAN	22.75%	NAN	2.37%	2.90%	2.37%	3.33%	2.37%
	gap	Mean	NAN	24.94%	NAN	2.86%	3.26%	2.63%	3.51%	2.60%
		Best	NAN	1.38E+03	NAN	1.09E+03	1.09E+03	1.09E+03	1.09E+03	1.09E+03
HTS29	obj	Mean	NAN	1.51E+03	NAN	1.10E+03	1.10E+03	1.09E+03	1.10E+03	1.09E+03
		Best	NAN	21.45%	NAN	0.46%	0.73%	0.28%	0.91%	0.28%
		Mean	NAN	28.14%	NAN	1.15%	1.00%	0.75%	1.36%	0.59%
	gap	Best	1.29E+03	1.41E+03	NAN	1.13E+03	1.12E+03	1.11E+03	1.13E+03	1.11E+03
		Mean	1.30E+03	1.46E+03	NAN	1.13E+03	1.13E+03	1.12E+03	1.13E+03	1.12E+03
		Best	14.54%	21.69%	NAN	0.98%	0.18%	0.09%	1.41%	0.00%
HTS30	gap	Mean	14.75%	24.17%	NAN	1.69%	1.03%	0.34%	1.71%	0.30%
	obj	Best	1.32E+03	1.39E+03	NAN	1.13E+03	1.14E+03	1.12E+03	1.16E+03	1.13E+03
		Mean	1.32E+03	1.43E+03	NAN	1.15E+03	1.16E+03	1.14E+03	1.16E+03	1.14E+03
		Best	15.43%	19.64%	NAN	1.59%	2.71%	0.71%	3.80%	1.59%
	gap	Mean	15.57%	21.95%	NAN	3.02%	4.00%	2.34%	4.25%	2.77%
		Best	1.23E+03	1.25E+03	NAN	9.98E+02	9.94E+02	9.95E+02	9.97E+02	9.87E+02
HTS31	obj	Mean	1.23E+03	1.30E+03	NAN	1.00E+03	9.98E+02	9.98E+02	1.00E+03	9.91E+02
		Best	20.08%	21.42%	NAN	1.50%	1.11%	1.21%	1.40%	0.41%
		Mean	20.36%	24.38%	NAN	1.95%	1.52%	1.52%	1.68%	0.79%
	gap	Best	1.15E+03	1.21E+03	NAN	1.02E+03	1.01E+03	1.00E+03	1.00E+03	1.00E+03
		Mean	1.15E+03	1.25E+03	NAN	1.03E+03	1.02E+03	1.01E+03	1.02E+03	1.01E+03
		Best	13.28%	18.07%	NAN	2.55%	1.88%	1.00%	1.00%	1.00%
HTS32	gap	Mean	13.65%	20.52%	NAN	3.33%	2.40%	1.41%	2.62%	1.49%
	obj	Best	1.17E+03	1.24E+03	NAN	1.01E+03	1.01E+03	9.98E+02	1.02E+03	9.98E+02
		Mean	1.21E+03	1.26E+03	NAN	1.02E+03	1.02E+03	1.00E+03	1.03E+03	1.01E+03
		Best	14.80%	19.68%	NAN	1.29%	1.39%	0.20%	2.73%	0.20%
	gap	Mean	17.23%	21.21%	NAN	2.00%	2.00%	0.48%	3.09%	1.05%
		Best	1.51E+03	1.22E+03	1.29E+03	1.43E+03	1.35E+03	1.26E+03	1.36E+03	1.63E+03

3.9 Job shop scheduling problem (JSSP)

Table S-21 exhibits the experimental results for JSSP problems.

Table S-21 Experimental results on JSSP.

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
JSSP01	obj	Best	1.42E+03	1.23E+03	1.33E+03	1.43E+03	1.38E+03	1.27E+03	1.48E+03	1.60E+03
		Mean	1.42E+03	1.23E+03	1.33E+03	1.48E+03	1.44E+03	1.32E+03	1.52E+03	1.80E+03
	gap	Best	32.30%	21.69%	27.35%	32.35%	30.30%	23.97%	34.82%	39.90%
		Mean	32.30%	21.69%	27.35%	34.76%	33.07%	26.77%	36.73%	45.93%
JSSP02	obj	Best	1.51E+03	1.22E+03	1.29E+03	1.43E+03	1.35E+03	1.26E+03	1.36E+03	1.63E+03
		Mean	1.51E+03	1.22E+03	1.30E+03	1.47E+03	1.41E+03	1.29E+03	1.51E+03	1.85E+03

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
JSSP03	gap	Best	38.97%	24.38%	28.60%	35.68%	31.83%	27.02%	32.18%	43.60%
		Mean	38.97%	24.38%	29.02%	37.29%	34.48%	28.63%	38.55%	49.87%
	obj	Best	1.49E+03	1.22E+03	1.29E+03	1.44E+03	1.44E+03	1.29E+03	1.43E+03	1.61E+03
		Mean	1.49E+03	1.22E+03	1.29E+03	1.48E+03	1.49E+03	1.35E+03	1.49E+03	1.67E+03
	gap	Best	36.70%	23.20%	27.30%	34.68%	34.68%	27.24%	34.22%	41.61%
		Mean	36.70%	23.20%	27.30%	36.58%	36.74%	30.20%	36.61%	43.54%
JSSP04	obj	Best	1.44E+03	1.23E+03	1.34E+03	1.40E+03	1.32E+03	1.27E+03	1.45E+03	1.59E+03
		Mean	1.44E+03	1.23E+03	1.34E+03	1.48E+03	1.38E+03	1.31E+03	1.52E+03	1.75E+03
	gap	Best	35.02%	23.80%	30.28%	33.40%	28.90%	26.26%	35.29%	41.01%
		Mean	35.05%	23.80%	30.28%	36.51%	32.03%	28.64%	38.36%	45.95%
JSSP05	obj	Best	1.46E+03	1.24E+03	1.30E+03	1.38E+03	1.41E+03	1.28E+03	1.54E+03	1.67E+03
		Mean	1.46E+03	1.24E+03	1.30E+03	1.46E+03	1.46E+03	1.33E+03	1.61E+03	1.78E+03
	gap	Best	38.00%	26.91%	30.18%	34.13%	35.49%	29.36%	41.14%	45.53%
		Mean	38.00%	26.91%	30.18%	37.84%	37.71%	31.69%	43.47%	49.08%
JSSP06	obj	Best	1.80E+03	1.37E+03	3.47E+03	1.52E+03	1.52E+03	1.44E+03	1.73E+03	2.06E+03
		Mean	1.80E+03	1.37E+03	3.47E+03	1.72E+03	1.82E+03	1.47E+03	1.87E+03	2.31E+03
	gap	Best	43.65%	25.97%	70.82%	33.29%	33.29%	29.48%	41.64%	50.97%
		Mean	43.65%	26.02%	70.82%	40.66%	44.18%	31.23%	45.71%	55.68%
JSSP07	obj	Best	1.58E+03	1.35E+03	2.42E+03	1.61E+03	1.45E+03	1.41E+03	1.64E+03	1.86E+03
		Mean	1.64E+03	1.35E+03	2.42E+03	1.70E+03	1.52E+03	1.43E+03	1.73E+03	2.33E+03
	gap	Best	37.30%	26.39%	59.16%	38.66%	31.63%	29.74%	39.74%	46.69%
		Mean	39.78%	26.39%	59.16%	41.78%	34.76%	30.76%	42.66%	56.70%
JSSP08	obj	Best	1.81E+03	1.46E+03	1.76E+03	1.73E+03	1.64E+03	1.53E+03	1.82E+03	2.17E+03
		Mean	1.81E+03	1.46E+03	1.76E+03	1.75E+03	1.70E+03	1.57E+03	1.93E+03	2.38E+03
	gap	Best	42.83%	29.34%	41.17%	40.19%	37.17%	32.53%	43.15%	52.35%
		Mean	42.83%	29.34%	41.17%	40.89%	39.15%	34.37%	46.40%	56.09%
JSSP09	obj	Best	1.71E+03	1.34E+03	1.80E+03	1.57E+03	1.50E+03	1.45E+03	1.66E+03	1.98E+03
		Mean	1.71E+03	1.34E+03	1.80E+03	1.67E+03	1.58E+03	1.48E+03	1.79E+03	2.39E+03
	gap	Best	44.42%	28.76%	47.17%	39.35%	36.77%	34.50%	42.81%	51.92%
		Mean	44.42%	29.18%	47.17%	42.89%	39.56%	35.63%	46.75%	59.69%
JSSP10	obj	Best	1.78E+03	1.35E+03	1.62E+03	1.61E+03	1.49E+03	1.39E+03	1.80E+03	2.03E+03
		Mean	1.78E+03	1.36E+03	1.62E+03	1.71E+03	1.63E+03	1.44E+03	1.87E+03	2.21E+03
	gap	Best	47.98%	31.16%	42.65%	42.36%	37.72%	33.43%	48.36%	54.38%
		Mean	47.98%	31.54%	42.65%	45.63%	42.83%	35.66%	50.29%	57.72%
JSSP11	obj	Best	2.10E+03	1.64E+03	2.76E+03	2.02E+03	1.87E+03	1.77E+03	2.10E+03	2.43E+03
		Mean	2.10E+03	1.65E+03	2.80E+03	2.11E+03	2.13E+03	1.82E+03	2.22E+03	3.32E+03
	gap	Best	41.94%	25.88%	55.95%	39.81%	34.92%	31.17%	41.94%	49.81%
		Mean	41.94%	26.13%	56.48%	42.33%	42.80%	33.21%	45.08%	61.55%
JSSP12	obj	Best	2.06E+03	1.60E+03	2.04E+03	2.02E+03	1.85E+03	1.76E+03	2.12E+03	2.56E+03
		Mean	2.06E+03	1.61E+03	2.04E+03	2.11E+03	1.93E+03	1.82E+03	2.25E+03	3.51E+03
	gap	Best	40.72%	23.56%	39.99%	39.52%	33.86%	30.43%	42.28%	52.28%
		Mean	40.72%	24.20%	39.99%	42.06%	36.37%	32.65%	45.60%	63.81%
JSSP13	obj	Best	2.07E+03	1.60E+03	2.01E+03	1.83E+03	1.88E+03	1.70E+03	2.21E+03	2.49E+03
		Mean	2.07E+03	1.61E+03	2.01E+03	2.06E+03	1.96E+03	1.76E+03	2.29E+03	3.27E+03
	gap	Best	43.04%	26.08%	41.40%	35.71%	37.12%	30.77%	46.55%	52.65%
		Mean	43.04%	26.57%	41.40%	42.31%	39.88%	33.10%	48.36%	62.97%

Pro.	Metric	Status	GUROBI	OR- TOOLS	SCIP	SA	VNS	LNS	TS	GA
JSSP14	obj	Best	2.18E+03	1.69E+03	2.11E+03	2.11E+03	1.97E+03	1.87E+03	2.30E+03	2.57E+03
		Mean	2.18E+03	1.69E+03	2.11E+03	2.21E+03	2.12E+03	1.90E+03	2.43E+03	3.03E+03
	gap	Best	40.81%	23.38%	38.84%	38.67%	34.57%	30.78%	43.85%	49.81%
		Mean	40.83%	23.66%	38.84%	41.64%	39.01%	31.96%	46.72%	57.00%
JSSP15	obj	Best	2.09E+03	1.63E+03	2.10E+03	1.96E+03	1.92E+03	1.76E+03	2.05E+03	2.62E+03
		Mean	2.09E+03	1.64E+03	2.15E+03	2.14E+03	2.02E+03	1.79E+03	2.24E+03	3.42E+03
	gap	Best	41.29%	24.86%	41.54%	37.27%	36.09%	30.40%	40.15%	53.13%
		Mean	41.29%	24.97%	42.86%	42.41%	39.21%	31.52%	45.05%	62.87%
JSSP16	obj	Best	2.47E+03	1.76E+03	1.76E+04	2.24E+03	2.02E+03	1.92E+03	2.46E+03	2.67E+03
		Mean	2.47E+03	1.77E+03	1.76E+04	2.31E+03	2.29E+03	1.96E+03	2.59E+03	3.19E+03
	gap	Best	59.92%	43.88%	94.37%	55.80%	51.04%	48.52%	59.77%	62.94%
		Mean	59.92%	44.07%	94.37%	57.17%	56.77%	49.53%	61.72%	68.71%
JSSP17	obj	Best	2.44E+03	1.84E+03	1.67E+04	2.07E+03	2.22E+03	1.96E+03	2.49E+03	2.82E+03
		Mean	2.44E+03	1.87E+03	1.67E+04	2.24E+03	2.43E+03	2.02E+03	2.61E+03	3.43E+03
	gap	Best	60.07%	46.98%	94.16%	52.94%	56.04%	50.18%	60.84%	65.45%
		Mean	60.07%	47.72%	94.16%	56.37%	59.77%	51.71%	62.68%	71.10%
JSSP18	obj	Best	2.53E+03	1.82E+03	1.80E+04	2.28E+03	2.07E+03	2.03E+03	2.53E+03	2.81E+03
		Mean	2.53E+03	1.83E+03	1.80E+04	2.40E+03	2.26E+03	2.04E+03	2.64E+03	3.07E+03
	gap	Best	60.96%	45.68%	94.51%	56.70%	52.22%	51.21%	60.96%	64.78%
		Mean	60.96%	45.87%	94.51%	58.83%	56.12%	51.59%	62.49%	67.69%
JSSP19	obj	Best	2.50E+03	1.80E+03	NAN	2.30E+03	2.20E+03	1.96E+03	2.48E+03	2.13E+03
		Mean	2.50E+03	1.80E+03	NAN	2.40E+03	2.28E+03	2.01E+03	2.58E+03	2.37E+03
	gap	Best	58.25%	41.78%	NAN	54.53%	52.39%	46.57%	57.86%	50.82%
		Mean	58.25%	42.01%	NAN	56.46%	54.10%	48.01%	59.47%	55.54%
JSSP20	obj	Best	2.53E+03	1.80E+03	1.48E+04	2.08E+03	2.08E+03	2.01E+03	2.45E+03	2.29E+03
		Mean	2.53E+03	1.80E+03	1.48E+04	2.31E+03	2.30E+03	2.03E+03	2.54E+03	2.43E+03
	gap	Best	64.19%	49.58%	93.87%	56.51%	56.51%	55.04%	63.09%	60.45%
		Mean	64.19%	49.58%	93.87%	60.69%	60.52%	55.35%	64.34%	62.55%
JSSP21	obj	Best	2.73E+03	2.03E+03	2.39E+04	2.72E+03	2.62E+03	2.48E+03	2.86E+03	3.22E+03
		Mean	2.73E+03	2.06E+03	2.39E+04	2.85E+03	2.78E+03	2.56E+03	3.01E+03	3.56E+03
	gap	Best	54.90%	39.31%	94.85%	54.69%	53.03%	50.40%	56.94%	61.74%
		Mean	54.90%	40.08%	94.85%	56.65%	55.59%	51.87%	59.05%	65.35%
JSSP22	obj	Best	2.71E+03	1.90E+03	2.37E+04	2.74E+03	2.35E+03	2.31E+03	2.90E+03	3.37E+03
		Mean	2.71E+03	1.92E+03	2.37E+04	2.86E+03	2.57E+03	2.36E+03	3.07E+03	3.52E+03
	gap	Best	54.63%	35.33%	94.82%	55.03%	47.66%	46.66%	57.54%	63.52%
		Mean	54.63%	35.85%	94.82%	56.91%	51.92%	47.87%	59.92%	65.07%
JSSP23	obj	Best	2.79E+03	2.01E+03	2.18E+04	2.68E+03	2.58E+03	2.53E+03	2.93E+03	3.15E+03
		Mean	2.79E+03	2.02E+03	2.18E+04	2.84E+03	2.66E+03	2.59E+03	3.07E+03	3.56E+03
	gap	Best	55.11%	37.75%	94.26%	53.28%	51.34%	50.38%	57.26%	60.18%
		Mean	55.11%	37.88%	94.26%	55.84%	52.80%	51.54%	59.16%	64.59%
JSSP24	obj	Best	2.73E+03	1.98E+03	2.41E+04	2.76E+03	2.53E+03	2.37E+03	2.99E+03	3.34E+03
		Mean	2.73E+03	2.00E+03	2.41E+04	2.88E+03	2.70E+03	2.44E+03	3.07E+03	3.92E+03
	gap	Best	52.95%	35.12%	94.68%	53.50%	49.29%	45.84%	57.14%	61.65%
		Mean	53.00%	35.79%	94.68%	55.48%	52.40%	47.52%	58.25%	67.09%
JSSP25	obj	Best	2.83E+03	2.01E+03	2.10E+04	2.73E+03	2.61E+03	2.35E+03	2.83E+03	3.27E+03
		Mean	2.83E+03	2.03E+03	2.10E+04	2.86E+03	2.85E+03	2.41E+03	3.02E+03	5.43E+03

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
JSSP26	gap	Best	57.91%	40.65%	94.34%	56.43%	54.48%	49.25%	57.97%	63.65%
		Mean	57.91%	41.34%	94.34%	58.35%	58.15%	50.67%	60.46%	75.86%
	obj	Best	3.91E+03	2.76E+03	3.00E+04	3.46E+03	4.22E+03	3.40E+03	3.97E+03	4.51E+03
		Mean	3.91E+03	2.76E+03	3.00E+04	3.72E+03	4.35E+03	3.48E+03	4.17E+03	5.32E+03
	gap	Best	71.96%	60.29%	96.34%	68.32%	74.03%	67.74%	72.36%	75.71%
		Mean	71.96%	60.29%	96.34%	70.47%	74.67%	68.50%	73.70%	79.26%
JSSP27	obj	Best	3.60E+03	2.76E+03	2.84E+04	3.52E+03	3.85E+03	3.33E+03	4.14E+03	4.38E+03
		Mean	3.60E+03	2.76E+03	2.84E+04	3.74E+03	4.04E+03	3.44E+03	4.27E+03	5.28E+03
	gap	Best	70.81%	61.92%	96.31%	70.15%	72.77%	68.50%	74.64%	76.05%
		Mean	70.81%	61.92%	96.31%	71.88%	73.99%	69.45%	75.39%	79.94%
JSSP28	obj	Best	3.89E+03	2.68E+03	2.75E+04	3.31E+03	3.64E+03	3.21E+03	3.82E+03	4.52E+03
		Mean	3.89E+03	2.68E+03	2.75E+04	3.71E+03	3.80E+03	3.26E+03	4.06E+03	5.28E+03
	gap	Best	72.59%	60.25%	96.13%	67.85%	70.70%	66.83%	72.11%	76.42%
		Mean	72.59%	60.25%	96.13%	71.17%	71.98%	67.36%	73.72%	79.68%
JSSP29	obj	Best	3.88E+03	2.78E+03	3.08E+04	3.61E+03	3.41E+03	3.23E+03	4.04E+03	4.56E+03
		Mean	3.88E+03	2.78E+03	3.08E+04	3.83E+03	3.83E+03	3.32E+03	4.18E+03	5.64E+03
	gap	Best	72.94%	62.24%	96.59%	70.87%	69.21%	67.44%	74.02%	76.98%
		Mean	72.94%	62.24%	96.59%	72.54%	72.46%	68.36%	74.83%	81.02%
JSSP30	obj	Best	3.85E+03	2.72E+03	2.88E+04	3.41E+03	3.41E+03	3.11E+03	4.04E+03	4.39E+03
		Mean	3.85E+03	2.72E+03	2.88E+04	3.71E+03	3.76E+03	3.24E+03	4.14E+03	5.21E+03
	gap	Best	69.57%	56.96%	95.93%	65.62%	65.62%	62.29%	70.97%	73.31%
		Mean	69.57%	56.96%	95.93%	68.38%	68.68%	63.80%	71.71%	77.29%
JSSP31	obj	Best	4.04E+03	2.76E+03	NAN	4.91E+03	4.79E+03	4.47E+03	5.37E+03	5.94E+03
		Mean	4.04E+03	2.76E+03	NAN	5.26E+03	5.19E+03	4.60E+03	5.60E+03	9.50E+03
	gap	Best	68.12%	53.21%	NAN	73.75%	73.11%	71.18%	76.01%	78.29%
		Mean	68.12%	53.27%	NAN	75.41%	75.08%	71.99%	76.95%	85.69%
JSSP32	obj	Best	4.34E+03	2.87E+03	4.02E+04	5.14E+03	4.47E+03	4.46E+03	5.38E+03	5.99E+03
		Mean	4.34E+03	2.89E+03	4.02E+04	5.59E+03	4.55E+03	4.70E+03	5.54E+03	9.32E+03
	gap	Best	70.44%	55.23%	96.81%	75.01%	71.30%	71.19%	76.11%	78.57%
		Mean	70.44%	55.49%	96.81%	76.95%	71.76%	72.62%	76.82%	85.49%
JSSP33	obj	Best	4.01E+03	2.70E+03	NAN	5.41E+03	4.03E+03	4.38E+03	4.88E+03	5.86E+03
		Mean	4.01E+03	2.70E+03	NAN	5.64E+03	4.24E+03	4.56E+03	5.13E+03	9.88E+03
	gap	Best	66.74%	50.60%	NAN	75.31%	66.85%	69.53%	72.65%	77.20%
		Mean	66.74%	50.60%	NAN	76.32%	68.52%	70.71%	73.97%	85.58%
JSSP34	obj	Best	4.31E+03	2.85E+03	3.94E+04	5.57E+03	4.68E+03	4.58E+03	5.20E+03	6.30E+03
		Mean	4.31E+03	2.86E+03	3.94E+04	5.74E+03	4.86E+03	4.72E+03	5.58E+03	9.63E+03
	gap	Best	68.86%	52.84%	96.59%	75.89%	71.31%	70.70%	74.20%	78.71%
		Mean	68.86%	53.00%	96.59%	76.62%	72.39%	71.55%	75.92%	85.37%
JSSP35	obj	Best	4.14E+03	2.78E+03	NAN	5.55E+03	6.45E+03	4.36E+03	4.84E+03	7.77E+03
		Mean	4.14E+03	2.79E+03	NAN	5.63E+03	7.08E+03	4.53E+03	5.56E+03	1.05E+04
	gap	Best	67.57%	51.76%	NAN	75.79%	79.16%	69.22%	72.25%	82.72%
		Mean	67.57%	51.79%	NAN	76.13%	80.98%	70.31%	75.68%	86.88%

3.10 Graph coloring problem (GC)

The experimental results for GC problems are presented in Table S-22.

Table S-22 Experimental results on GC.

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
GC01	obj	Best	2.20E+01	1.60E+01	2.00E+01	1.70E+01	1.60E+01	1.70E+01	1.70E+01	1.80E+01
		Mean	2.20E+01	1.60E+01	2.04E+01	1.74E+01	1.72E+01	1.74E+01	1.80E+01	1.83E+01
	gap	Best	54.55%	37.50%	50.00%	41.18%	37.50%	41.18%	41.18%	44.44%
		Mean	54.55%	37.50%	50.95%	42.48%	41.65%	42.48%	44.33%	45.42%
GC02	obj	Best	2.10E+01	1.60E+01	2.30E+01	1.70E+01	1.70E+01	1.70E+01	1.70E+01	1.80E+01
		Mean	2.10E+01	1.60E+01	2.30E+01	1.75E+01	1.75E+01	1.78E+01	1.82E+01	1.85E+01
	gap	Best	47.62%	31.25%	52.17%	35.29%	35.29%	35.29%	35.29%	38.89%
		Mean	47.62%	31.25%	52.17%	37.09%	37.09%	38.29%	39.36%	40.50%
GC03	obj	Best	1.80E+01	1.50E+01	2.30E+01	1.80E+01	1.60E+01	1.70E+01	1.70E+01	1.70E+01
		Mean	1.80E+01	1.56E+01	2.30E+01	1.85E+01	1.72E+01	1.75E+01	1.80E+01	1.82E+01
	gap	Best	38.89%	26.67%	52.17%	38.89%	31.25%	35.29%	35.29%	35.29%
		Mean	38.89%	29.42%	52.17%	40.50%	35.82%	37.09%	38.76%	39.36%
GC04	obj	Best	1.90E+01	1.60E+01	2.30E+01	1.80E+01	1.60E+01	1.60E+01	1.60E+01	1.80E+01
		Mean	1.90E+01	1.60E+01	2.30E+01	1.85E+01	1.83E+01	1.68E+01	1.78E+01	1.83E+01
	gap	Best	52.63%	43.75%	60.87%	50.00%	43.75%	43.75%	43.75%	50.00%
		Mean	52.63%	43.75%	60.87%	51.32%	50.87%	46.25%	49.21%	50.88%
GC05	obj	Best	1.70E+01	1.50E+01	2.10E+01	1.70E+01	1.70E+01	1.60E+01	1.70E+01	1.80E+01
		Mean	1.72E+01	1.58E+01	2.14E+01	1.77E+01	1.73E+01	1.68E+01	1.74E+01	1.85E+01
	gap	Best	47.06%	40.00%	57.14%	47.06%	47.06%	43.75%	47.06%	50.00%
		Mean	47.65%	43.00%	57.92%	49.02%	48.04%	46.38%	48.24%	51.32%
GC06	obj	Best	1.80E+01	1.60E+01	2.20E+01	1.80E+01	1.70E+01	1.70E+01	1.90E+01	1.70E+01
		Mean	1.80E+01	1.60E+01	2.20E+01	1.83E+01	1.75E+01	1.78E+01	1.90E+01	1.83E+01
	gap	Best	38.89%	31.25%	50.00%	38.89%	35.29%	35.29%	42.11%	35.29%
		Mean	38.89%	31.25%	50.00%	39.96%	37.09%	38.16%	42.11%	39.90%
GC07	obj	Best	1.80E+01	1.60E+01	2.30E+01	1.70E+01	1.70E+01	1.70E+01	1.80E+01	1.70E+01
		Mean	1.80E+01	1.60E+01	2.30E+01	1.82E+01	1.78E+01	1.76E+01	1.85E+01	1.83E+01
	gap	Best	38.89%	31.25%	52.17%	35.29%	35.29%	35.29%	38.89%	35.29%
		Mean	38.89%	31.25%	52.17%	39.36%	38.29%	37.45%	40.50%	39.90%
GC08	obj	Best	1.80E+01	1.60E+01	2.20E+01	1.70E+01	1.70E+01	1.70E+01	1.70E+01	1.80E+01
		Mean	1.82E+01	1.60E+01	2.20E+01	1.80E+01	1.70E+01	1.70E+01	1.74E+01	1.85E+01
	gap	Best	38.89%	31.25%	50.00%	35.29%	35.29%	35.29%	35.29%	38.89%
		Mean	39.53%	31.25%	50.00%	38.76%	35.29%	35.29%	36.73%	40.50%
GC09	obj	Best	1.70E+01	1.60E+01	2.20E+01	1.70E+01	1.60E+01	1.60E+01	1.70E+01	1.70E+01
		Mean	1.70E+01	1.60E+01	2.20E+01	1.74E+01	1.73E+01	1.68E+01	1.78E+01	1.85E+01
	gap	Best	35.29%	31.25%	50.00%	35.29%	31.25%	31.25%	35.29%	35.29%
		Mean	35.29%	31.25%	50.00%	36.73%	36.42%	34.47%	38.16%	40.43%
GC10	obj	Best	1.80E+01	1.60E+01	2.60E+01	1.70E+01	1.70E+01	1.60E+01	1.70E+01	1.80E+01
		Mean	1.80E+01	1.60E+01	2.60E+01	1.78E+01	1.77E+01	1.75E+01	1.82E+01	1.83E+01
	gap	Best	38.89%	31.25%	57.69%	35.29%	35.29%	31.25%	35.29%	38.89%
		Mean	38.89%	31.25%	57.69%	38.17%	37.69%	37.02%	39.36%	39.96%
GC11	obj	Best	1.80E+01	1.50E+01	2.40E+01	1.80E+01	1.70E+01	1.60E+01	1.70E+01	1.70E+01

Pro.	Metric	Status	GUROBI	OR- TOOLS	SCIP	SA	VNS	LNS	TS	GA
	gap	Mean	1.80E+01	1.50E+01	2.48E+01	1.83E+01	1.85E+01	1.68E+01	1.82E+01	1.80E+01
		Best	38.89%	26.67%	54.17%	38.89%	35.29%	31.25%	35.29%	35.29%
		Mean	38.89%	26.67%	55.58%	39.96%	40.54%	34.49%	39.36%	38.76%
GC12	obj	Best	1.90E+01	1.60E+01	2.80E+01	1.80E+01	1.70E+01	1.70E+01	1.70E+01	1.70E+01
		Mean	1.90E+01	1.60E+01	2.80E+01	1.83E+01	1.75E+01	1.78E+01	1.85E+01	1.82E+01
	gap	Best	52.63%	43.75%	67.86%	50.00%	47.06%	47.06%	47.06%	47.06%
		Mean	52.63%	43.75%	67.86%	50.88%	48.53%	49.41%	51.26%	50.39%
GC13	obj	Best	2.20E+01	1.50E+01	2.10E+01	1.80E+01	1.60E+01	1.60E+01	1.70E+01	1.70E+01
		Mean	2.20E+01	1.54E+01	2.10E+01	1.80E+01	1.73E+01	1.70E+01	1.78E+01	1.78E+01
	gap	Best	59.09%	40.00%	57.14%	50.00%	43.75%	43.75%	47.06%	47.06%
		Mean	59.09%	41.50%	57.14%	50.00%	47.98%	46.94%	49.51%	49.41%
GC14	obj	Best	1.80E+01	1.60E+01	2.30E+01	1.70E+01	1.70E+01	1.70E+01	1.80E+01	1.80E+01
		Mean	1.88E+01	1.60E+01	2.30E+01	1.78E+01	1.75E+01	1.80E+01	1.85E+01	1.83E+01
	gap	Best	38.89%	31.25%	52.17%	35.29%	35.29%	35.29%	38.89%	38.89%
		Mean	41.33%	31.25%	52.17%	38.17%	37.09%	38.76%	40.50%	39.96%
GC15	obj	Best	2.10E+01	1.60E+01	2.20E+01	1.70E+01	1.70E+01	1.60E+01	1.80E+01	1.80E+01
		Mean	2.10E+01	1.60E+01	2.22E+01	1.82E+01	1.73E+01	1.70E+01	1.85E+01	1.88E+01
	gap	Best	47.62%	31.25%	50.00%	35.29%	35.29%	31.25%	38.89%	38.89%
		Mean	47.62%	31.25%	50.43%	39.36%	36.49%	35.20%	40.50%	41.57%
GC16	obj	Best	2.00E+01	1.50E+01	2.10E+01	1.70E+01	1.70E+01	1.70E+01	1.70E+01	1.80E+01
		Mean	2.00E+01	1.58E+01	2.14E+01	1.77E+01	1.80E+01	1.73E+01	1.82E+01	1.84E+01
	gap	Best	45.00%	26.67%	47.62%	35.29%	35.29%	35.29%	35.29%	38.89%
		Mean	45.00%	30.33%	48.57%	37.69%	38.84%	36.49%	39.36%	40.18%
GC17	obj	Best	1.90E+01	1.60E+01	2.20E+01	1.80E+01	1.70E+01	1.70E+01	1.80E+01	1.70E+01
		Mean	1.90E+01	1.60E+01	2.20E+01	1.85E+01	1.78E+01	1.72E+01	1.85E+01	1.84E+01
	gap	Best	36.84%	25.00%	45.45%	33.33%	29.41%	29.41%	33.33%	29.41%
		Mean	36.84%	25.00%	45.45%	35.09%	32.55%	30.20%	35.09%	34.65%
GC18	obj	Best	1.80E+01	1.60E+01	2.40E+01	1.70E+01	1.60E+01	1.70E+01	1.70E+01	1.80E+01
		Mean	1.80E+01	1.60E+01	2.40E+01	1.80E+01	1.70E+01	1.75E+01	1.82E+01	1.85E+01
	gap	Best	38.89%	31.25%	54.17%	35.29%	31.25%	35.29%	35.29%	38.89%
		Mean	38.89%	31.25%	54.17%	38.76%	35.14%	37.09%	39.36%	40.50%
GC19	obj	Best	2.20E+01	1.60E+01	2.40E+01	1.80E+01	1.70E+01	1.70E+01	1.80E+01	1.80E+01
		Mean	2.20E+01	1.60E+01	2.40E+01	1.80E+01	1.74E+01	1.80E+01	1.87E+01	1.87E+01
	gap	Best	59.09%	43.75%	62.50%	50.00%	47.06%	47.06%	50.00%	50.00%
		Mean	59.09%	43.75%	62.50%	50.00%	48.24%	49.90%	51.75%	51.75%
GC20	obj	Best	1.80E+01	1.50E+01	2.60E+01	1.70E+01	1.60E+01	1.60E+01	1.70E+01	1.70E+01
		Mean	1.80E+01	1.50E+01	2.68E+01	1.75E+01	1.72E+01	1.63E+01	1.75E+01	1.78E+01
	gap	Best	44.44%	33.33%	61.54%	41.18%	37.50%	37.50%	41.18%	41.18%
		Mean	44.44%	33.33%	62.64%	42.81%	41.65%	38.73%	42.81%	43.72%
GC21	obj	Best	NAN	3.80E+01	7.90E+01	4.30E+01	4.20E+01	4.30E+01	4.30E+01	4.50E+01
		Mean	NAN	3.90E+01	7.90E+01	4.36E+01	4.28E+01	4.42E+01	4.36E+01	4.63E+01
	gap	Best	NAN	68.42%	84.81%	72.09%	71.43%	72.09%	72.09%	73.33%

Pro.	Metric	Status	GUROBI	OR-TOOLS	SCIP	SA	VNS	LNS	TS	GA
		Mean	NAN	69.22%	84.81%	72.47%	71.97%	72.84%	72.47%	74.08%
GC22	obj	Best	NAN	4.00E+01	7.30E+01	4.50E+01	4.20E+01	4.40E+01	4.40E+01	4.60E+01
		Mean	NAN	4.00E+01	7.40E+01	4.53E+01	4.32E+01	4.54E+01	4.48E+01	4.63E+01
	gap	Best	NAN	72.50%	84.93%	75.56%	73.81%	75.00%	75.00%	76.09%
		Mean	NAN	72.50%	85.13%	75.73%	74.51%	75.76%	75.45%	76.26%
GC23	obj	Best	NAN	3.80E+01	7.90E+01	4.30E+01	4.30E+01	4.30E+01	4.30E+01	4.40E+01
		Mean	NAN	3.92E+01	7.90E+01	4.40E+01	4.35E+01	4.53E+01	4.42E+01	4.58E+01
	gap	Best	NAN	76.32%	88.61%	79.07%	79.07%	79.07%	79.07%	79.55%
		Mean	NAN	77.03%	88.61%	79.53%	79.31%	80.13%	79.61%	80.35%
GC24	obj	Best	NAN	3.90E+01	7.20E+01	4.30E+01	4.20E+01	4.30E+01	4.40E+01	4.50E+01
		Mean	NAN	3.96E+01	7.22E+01	4.36E+01	4.32E+01	4.48E+01	4.50E+01	4.58E+01
	gap	Best	NAN	74.36%	86.11%	76.74%	76.19%	76.74%	77.27%	77.78%
		Mean	NAN	74.74%	86.15%	77.06%	76.83%	77.68%	77.77%	78.16%
GC25	obj	Best	NAN	3.80E+01	7.90E+01	4.20E+01	4.20E+01	4.30E+01	4.40E+01	4.60E+01
		Mean	NAN	3.84E+01	7.90E+01	4.30E+01	4.22E+01	4.48E+01	4.46E+01	4.62E+01
	gap	Best	NAN	73.68%	87.34%	76.19%	76.19%	76.74%	77.27%	78.26%
		Mean	NAN	73.95%	87.34%	76.74%	76.30%	77.66%	77.58%	78.35%
GC26	obj	Best	NAN	4.00E+01	7.90E+01	4.30E+01	4.30E+01	4.40E+01	4.30E+01	4.50E+01
		Mean	NAN	4.00E+01	7.90E+01	4.40E+01	4.33E+01	4.52E+01	4.50E+01	4.58E+01
	gap	Best	NAN	75.00%	87.34%	76.74%	76.74%	77.27%	76.74%	77.78%
		Mean	NAN	75.00%	87.34%	77.26%	76.92%	77.87%	77.76%	78.16%
GC27	obj	Best	NAN	3.80E+01	7.00E+01	4.30E+01	4.20E+01	4.40E+01	4.30E+01	4.40E+01
		Mean	NAN	3.88E+01	7.10E+01	4.36E+01	4.28E+01	4.52E+01	4.42E+01	4.46E+01
	gap	Best	NAN	71.05%	84.29%	74.42%	73.81%	75.00%	74.42%	75.00%
		Mean	NAN	71.65%	84.51%	74.77%	74.31%	75.66%	75.10%	75.33%
GC28	obj	Best	NAN	3.90E+01	7.10E+01	4.30E+01	4.30E+01	4.30E+01	4.30E+01	4.60E+01
		Mean	NAN	3.90E+01	7.22E+01	4.35E+01	4.35E+01	4.45E+01	4.48E+01	4.84E+01
	gap	Best	NAN	74.36%	85.92%	76.74%	76.74%	76.74%	76.74%	78.26%
		Mean	NAN	74.36%	86.15%	77.01%	77.01%	77.51%	77.68%	79.26%
GC29	obj	Best	NAN	3.80E+01	8.00E+01	4.50E+01	4.30E+01	4.50E+01	4.30E+01	4.70E+01
		Mean	NAN	3.88E+01	8.00E+01	4.50E+01	4.34E+01	4.58E+01	4.42E+01	4.80E+01
	gap	Best	NAN	73.68%	87.50%	77.78%	76.74%	77.78%	76.74%	78.72%
		Mean	NAN	74.22%	87.50%	77.78%	76.96%	78.16%	77.36%	79.16%
GC30	obj	Best	NAN	4.00E+01	7.20E+01	4.30E+01	4.30E+01	4.40E+01	4.40E+01	4.70E+01
		Mean	NAN	4.00E+01	7.30E+01	4.43E+01	4.33E+01	4.44E+01	4.47E+01	4.87E+01
	gap	Best	NAN	75.00%	86.11%	76.74%	76.74%	77.27%	77.27%	78.72%
		Mean	NAN	75.00%	86.30%	77.43%	76.92%	77.47%	77.61%	79.44%

4 Detailed Experimental Results for qVNS, aVNS, and rVNS

4.1 Multi-depot vehicle routing problem with time windows (MDVRPTW)

The experimental results for qVNS, aVNS, and rVNS for solving MDVRPTW instances are shown in Table S-23.

Table S-23 Experimental results for qVNS, aVNS, and rVNS on MDVRPTW.

Pro.	Metric	qVNS	aVNS	rVNS
MDVRPTW01	Mean obj	5.521E+03	5.714E+03	5.824E+03
	Mean gap	6.836%	9.839%	11.529%
MDVRPTW02	Mean obj	1.021E+04	1.045E+04	1.066E+04
	Mean gap	23.571%	25.199%	26.673%
MDVRPTW03	Mean obj	1.482E+04	1.470E+04	1.524E+04
	Mean gap	75.982%	75.774%	76.648%
MDVRPTW04	Mean obj	1.840E+04	1.855E+04	1.996E+04
	Mean gap	79.381%	79.539%	80.978%
MDVRPTW05	Mean obj	2.384E+04	2.393E+04	2.624E+04
	Mean gap	88.031%	88.077%	89.125%
MDVRPTW06	Mean obj	2.697E+04	2.711E+04	3.786E+04
	Mean gap	NAN	NAN	NAN
MDVRPTW07	Mean obj	8.640E+03	8.681E+03	8.847E+03
	Mean gap	28.884%	29.217%	30.551%
MDVRPTW08	Mean obj	1.396E+04	1.425E+04	1.530E+04
	Mean gap	66.348%	67.028%	69.303%
MDVRPTW09	Mean obj	2.002E+04	1.994E+04	2.118E+04
	Mean gap	80.721%	80.640%	81.770%
MDVRPTW10	Mean obj	2.902E+04	2.917E+04	3.424E+04
	Mean gap	88.504%	88.560%	90.250%
MDVRPTW11	Mean obj	5.169E+03	5.187E+03	5.222E+03
	Mean gap	6.758%	7.085%	7.695%
MDVRPTW12	Mean obj	9.214E+03	9.429E+03	9.500E+03
	Mean gap	12.341%	14.277%	15.061%
MDVRPTW13	Mean obj	1.385E+04	1.396E+04	1.402E+04
	Mean gap	77.024%	77.197%	77.298%
MDVRPTW14	Mean obj	1.713E+04	1.740E+04	1.771E+04
	Mean gap	85.900%	86.112%	86.362%
MDVRPTW15	Mean obj	2.304E+04	2.327E+04	2.508E+04
	Mean gap	NAN	NAN	NAN
MDVRPTW16	Mean obj	2.681E+04	2.703E+04	2.754E+04
	Mean gap	NAN	NAN	NAN
MDVRPTW17	Mean obj	7.580E+03	7.686E+03	7.630E+03
	Mean gap	NAN	NAN	NAN
MDVRPTW18	Mean obj	1.377E+04	1.386E+04	1.403E+04
	Mean gap	NAN	NAN	NAN
MDVRPTW19	Mean obj	1.917E+04	1.933E+04	1.965E+04
	Mean gap	NAN	NAN	NAN
MDVRPTW20	Mean obj	2.857E+04	2.896E+04	3.217E+04
	Mean gap	NAN	NAN	NAN

4.2 Vehicle routing problem with pickup and delivery (VRPPD)

The experimental results for qVNS, aVNS, and rVNS for solving VRPPD instances are shown in Table S-24.

Table S-24 Experimental results for qVNS, aVNS, and rVNS on VRPPD.

Pro.	Metric	qVNS	aVNS	rVNS
VRPPD01	Mean obj	1.737E+03	1.762E+03	1.776E+03
	Mean gap	42.221%	43.052%	43.516%
VRPPD02	Mean obj	1.870E+03	1.903E+03	1.919E+03
	Mean gap	45.904%	46.814%	47.264%
VRPPD03	Mean obj	2.271E+03	2.317E+03	2.335E+03
	Mean gap	84.879%	85.178%	85.293%
VRPPD04	Mean obj	1.694E+03	1.720E+03	1.713E+03
	Mean gap	80.310%	80.600%	80.541%
VRPPD05	Mean obj	2.212E+03	2.239E+03	2.254E+03
	Mean gap	65.545%	65.948%	66.181%
VRPPD06	Mean obj	2.412E+03	2.404E+03	2.420E+03
	Mean gap	67.435%	67.324%	67.538%
VRPPD07	Mean obj	2.739E+03	2.755E+03	2.764E+03
	Mean gap	79.584%	79.700%	79.770%
VRPPD08	Mean obj	2.574E+03	2.603E+03	2.621E+03
	Mean gap	67.791%	68.161%	68.388%
VRPPD09	Mean obj	2.085E+03	2.108E+03	2.126E+03
	Mean gap	61.341%	61.764%	62.089%
VRPPD10	Mean obj	2.187E+03	2.217E+03	2.226E+03
	Mean gap	61.911%	62.410%	62.556%
VRPPD11	Mean obj	1.694E+03	1.694E+03	1.703E+03
	Mean gap	60.952%	60.942%	61.155%
VRPPD12	Mean obj	2.096E+03	2.126E+03	2.142E+03
	Mean gap	83.354%	83.588%	83.717%
VRPPD13	Mean obj	1.811E+03	1.833E+03	1.841E+03
	Mean gap	71.733%	72.067%	72.186%
VRPPD14	Mean obj	1.733E+03	1.748E+03	1.759E+03
	Mean gap	78.304%	78.485%	78.628%
VRPPD15	Mean obj	1.817E+03	1.834E+03	1.844E+03
	Mean gap	73.700%	73.944%	74.084%
VRPPD16	Mean obj	1.213E+03	1.228E+03	1.237E+03
	Mean gap	63.554%	63.988%	64.235%
VRPPD17	Mean obj	1.470E+03	1.488E+03	1.495E+03
	Mean gap	69.149%	69.512%	69.663%
VRPPD18	Mean obj	1.986E+03	2.015E+03	2.035E+03
	Mean gap	84.952%	85.167%	85.316%
VRPPD19	Mean obj	1.443E+03	1.463E+03	1.475E+03
	Mean gap	74.849%	75.182%	75.395%
VRPPD20	Mean obj	1.936E+03	1.961E+03	1.975E+03
	Mean gap	84.186%	84.391%	84.497%
VRPPD21	Mean obj	1.582E+03	1.613E+03	1.629E+03
	Mean gap	76.585%	77.018%	77.240%
VRPPD22	Mean obj	1.459E+03	1.483E+03	1.492E+03
	Mean gap	61.696%	62.292%	62.534%
VRPPD23	Mean obj	2.025E+03	2.018E+03	2.039E+03
	Mean gap	84.301%	84.244%	84.408%

Pro.	Metric	qVNS	aVNS	rVNS
VRPPD24	Mean obj	1.239E+03	1.248E+03	1.253E+03
	Mean gap	73.880%	74.065%	74.158%
VRPPD25	Mean obj	1.438E+03	1.454E+03	1.462E+03
	Mean gap	74.393%	74.666%	74.800%
VRPPD26	Mean obj	1.917E+03	1.933E+03	1.943E+03
	Mean gap	76.361%	76.560%	76.678%
VRPPD27	Mean obj	1.971E+03	1.997E+03	2.011E+03
	Mean gap	73.583%	73.921%	74.105%
VRPPD28	Mean obj	2.472E+03	2.490E+03	2.501E+03
	Mean gap	81.567%	81.704%	81.787%
VRPPD29	Mean obj	1.931E+03	1.957E+03	1.970E+03
	Mean gap	73.735%	74.081%	74.250%
VRPPD30	Mean obj	2.428E+03	2.446E+03	2.457E+03
	Mean gap	79.113%	79.265%	79.363%

4.3 Generalized assignment problem (GAP)

The experimental results for qVNS, aVNS, and rVNS for solving GAP instances are shown in Table S-25.

Table S-25 Experimental results for qVNS, aVNS, and rVNS on GAP.

Pro.	Metric	qVNS	aVNS	rVNS
GAP01	Mean obj	1.699E+03	1.699E+03	1.699E+03
	Mean gap	0.039%	0.047%	0.047%
GAP02	Mean obj	3.235E+03	3.235E+03	3.235E+03
	Mean gap	0.000%	0.000%	0.000%
GAP03	Mean obj	1.361E+03	1.361E+03	1.361E+03
	Mean gap	0.086%	0.059%	0.059%
GAP04	Mean obj	2.625E+03	2.627E+03	2.627E+03
	Mean gap	0.091%	0.152%	0.152%
GAP05	Mean obj	1.158E+03	1.158E+03	1.158E+03
	Mean gap	0.000%	0.000%	0.000%
GAP06	Mean obj	2.339E+03	2.339E+03	2.339E+03
	Mean gap	0.000%	0.000%	0.000%
GAP07	Mean obj	1.963E+03	2.001E+03	2.020E+03
	Mean gap	6.049%	7.786%	8.680%
GAP08	Mean obj	3.672E+03	3.713E+03	3.734E+03
	Mean gap	3.242%	4.318%	4.854%
GAP09	Mean obj	1.454E+03	1.467E+03	1.478E+03
	Mean gap	3.174%	4.053%	4.785%
GAP10	Mean obj	2.996E+03	3.015E+03	3.026E+03
	Mean gap	5.630%	6.215%	6.557%
GAP11	Mean obj	1.213E+03	1.211E+03	1.216E+03
	Mean gap	3.844%	3.690%	4.087%
GAP12	Mean obj	2.390E+03	2.406E+03	2.414E+03
	Mean gap	2.110%	2.759%	3.081%
GAP13	Mean obj	1.998E+03	2.024E+03	2.034E+03
	Mean gap	3.332%	4.533%	5.023%

Pro.	Metric	qVNS	aVNS	rVNS
GAP14	Mean obj	3.575E+03	3.621E+03	3.643E+03
	Mean gap	3.281%	4.522%	5.128%
GAP15	Mean obj	1.508E+03	1.533E+03	1.546E+03
	Mean gap	7.016%	8.500%	9.228%
GAP16	Mean obj	2.935E+03	2.966E+03	2.982E+03
	Mean gap	4.367%	5.352%	5.879%
GAP17	Mean obj	5.794E+03	5.854E+03	5.885E+03
	Mean gap	3.389%	4.367%	4.870%
GAP18	Mean obj	1.193E+04	1.227E+04	1.243E+04
	Mean gap	4.859%	7.325%	8.531%
GAP19	Mean obj	1.307E+03	1.316E+03	1.319E+03
	Mean gap	4.866%	5.563%	5.766%
GAP20	Mean obj	2.528E+03	2.552E+03	2.562E+03
	Mean gap	5.400%	6.270%	6.634%
GAP21	Mean obj	5.180E+03	5.255E+03	5.283E+03
	Mean gap	7.667%	8.951%	9.434%
GAP22	Mean obj	1.076E+04	1.096E+04	1.104E+04
	Mean gap	7.201%	8.848%	9.453%
GAP23	Mean obj	4.354E+03	4.372E+03	4.380E+03
	Mean gap	2.523%	2.921%	3.092%
GAP24	Mean obj	9.529E+03	9.565E+03	9.577E+03
	Mean gap	2.126%	2.497%	2.620%
GAP25	Mean obj	2.080E+04	2.149E+04	2.171E+04
	Mean gap	9.562%	12.205%	13.086%
GAP26	Mean obj	1.803E+04	1.821E+04	1.826E+04
	Mean gap	4.898%	5.804%	6.091%
GAP27	Mean obj	1.671E+04	1.678E+04	1.684E+04
	Mean gap	2.537%	2.964%	3.290%
GAP28	Mean obj	6.844E+03	6.856E+03	6.862E+03
	Mean gap	7.179%	7.333%	7.417%
GAP29	Mean obj	1.384E+04	1.385E+04	1.386E+04
	Mean gap	7.907%	8.026%	8.070%
GAP30	Mean obj	6.951E+03	6.991E+03	7.010E+03
	Mean gap	8.679%	9.203%	9.454%
GAP31	Mean obj	1.363E+04	1.375E+04	1.380E+04
	Mean gap	8.839%	9.593%	9.950%
GAP32	Mean obj	2.735E+04	2.729E+04	2.738E+04
	Mean gap	8.732%	8.541%	8.848%
GAP33	Mean obj	6.156E+04	6.205E+04	6.222E+04
	Mean gap	9.995%	10.712%	10.947%
GAP34	Mean obj	6.731E+03	6.763E+03	6.778E+03
	Mean gap	8.226%	8.661%	8.865%
GAP35	Mean obj	1.332E+04	1.337E+04	1.339E+04
	Mean gap	8.218%	8.521%	8.644%
GAP36	Mean obj	2.719E+04	2.742E+04	2.756E+04
	Mean gap	9.653%	10.413%	10.874%

Pro.	Metric	qVNS	aVNS	rVNS
GAP37	Mean obj	6.198E+04	6.223E+04	6.245E+04
	Mean gap	11.525%	11.889%	12.202%
GAP38	Mean obj	2.685E+04	2.696E+04	2.703E+04
	Mean gap	9.308%	9.689%	9.909%
GAP39	Mean obj	6.061E+04	6.088E+04	6.106E+04
	Mean gap	9.993%	10.399%	10.662%
GAP40	Mean obj	1.078E+05	1.096E+05	1.113E+05
	Mean gap	9.072%	10.660%	12.133%
GAP41	Mean obj	1.073E+05	1.088E+05	1.101E+05
	Mean gap	9.434%	10.656%	11.793%
GAP42	Mean obj	1.075E+05	1.087E+05	1.097E+05
	Mean gap	9.711%	10.690%	11.580%
GAP43	Mean obj	1.585E+04	1.652E+04	1.683E+04
	Mean gap	19.820%	22.862%	24.320%
GAP44	Mean obj	3.463E+04	3.616E+04	3.698E+04
	Mean gap	27.846%	30.730%	32.377%
GAP45	Mean obj	1.449E+04	1.477E+04	1.493E+04
	Mean gap	20.010%	21.529%	22.441%
GAP46	Mean obj	3.031E+04	3.107E+04	3.147E+04
	Mean gap	22.968%	24.827%	25.808%
GAP47	Mean obj	5.431E+04	5.724E+04	5.824E+04
	Mean gap	15.623%	19.564%	20.935%
GAP48	Mean obj	1.288E+05	1.367E+05	1.397E+05
	Mean gap	20.383%	24.369%	25.980%
GAP49	Mean obj	9.989E+03	1.014E+04	1.021E+04
	Mean gap	15.523%	16.730%	17.369%
GAP50	Mean obj	2.653E+04	2.716E+04	2.749E+04
	Mean gap	15.554%	17.507%	18.525%
GAP51	Mean obj	5.362E+04	5.494E+04	5.533E+04
	Mean gap	16.235%	18.261%	18.852%
GAP52	Mean obj	1.238E+05	1.296E+05	1.317E+05
	Mean gap	18.799%	22.050%	23.266%
GAP53	Mean obj	5.312E+04	5.508E+04	5.579E+04
	Mean gap	15.992%	18.848%	19.897%
GAP54	Mean obj	1.226E+05	1.268E+05	1.283E+05
	Mean gap	18.239%	20.760%	21.736%
GAP55	Mean obj	2.795E+05	2.876E+05	2.891E+05
	Mean gap	35.233%	37.161%	37.494%
GAP56	Mean obj	2.635E+05	2.707E+05	2.755E+05
	Mean gap	32.178%	33.979%	35.194%
GAP57	Mean obj	2.665E+05	2.709E+05	2.724E+05
	Mean gap	33.632%	34.711%	35.067%

4.4 Capacitated facility location problem (CFLP)

The experimental results for qVNS, aVNS, and rVNS for solving CFLP instances are shown in Table S-26.

Table S-26 Experimental results for qVNS, aVNS, and rVNS on CFLP.

Pro.	Metric	qVNS	aVNS	rVNS
CFLP01	Mean obj	3.520E+03	3.582E+03	3.610E+03
	Mean gap	19.182%	20.578%	21.200%
CFLP02	Mean obj	3.670E+03	3.745E+03	3.777E+03
	Mean gap	18.867%	20.453%	21.149%
CFLP03	Mean obj	3.664E+03	3.732E+03	3.767E+03
	Mean gap	16.998%	18.485%	19.260%
CFLP04	Mean obj	3.660E+03	3.702E+03	3.724E+03
	Mean gap	18.433%	19.343%	19.822%
CFLP05	Mean obj	3.623E+03	3.675E+03	3.695E+03
	Mean gap	16.064%	17.213%	17.672%
CFLP06	Mean obj	3.639E+03	3.697E+03	3.719E+03
	Mean gap	18.781%	20.035%	20.505%
CFLP07	Mean obj	3.661E+03	3.717E+03	3.749E+03
	Mean gap	21.112%	22.319%	22.991%
CFLP08	Mean obj	3.660E+03	3.719E+03	3.760E+03
	Mean gap	19.600%	20.909%	21.796%
CFLP09	Mean obj	2.764E+03	2.749E+03	2.770E+03
	Mean gap	19.184%	18.721%	19.363%
CFLP10	Mean obj	2.636E+03	2.685E+03	2.699E+03
	Mean gap	12.602%	14.182%	14.640%
CFLP11	Mean obj	2.632E+03	2.687E+03	2.717E+03
	Mean gap	14.553%	16.277%	17.240%
CFLP12	Mean obj	2.664E+03	2.685E+03	2.694E+03
	Mean gap	15.886%	16.533%	16.813%
CFLP13	Mean obj	2.654E+03	2.707E+03	2.738E+03
	Mean gap	15.013%	16.663%	17.640%
CFLP14	Mean obj	2.516E+03	2.563E+03	2.595E+03
	Mean gap	13.030%	14.687%	15.777%
CFLP15	Mean obj	2.640E+03	2.673E+03	2.691E+03
	Mean gap	15.274%	16.319%	16.900%
CFLP16	Mean obj	2.662E+03	2.700E+03	2.724E+03
	Mean gap	14.774%	15.939%	16.701%
CFLP17	Mean obj	2.415E+03	2.470E+03	2.501E+03
	Mean gap	14.727%	16.603%	17.662%
CFLP18	Mean obj	2.293E+03	2.333E+03	2.350E+03
	Mean gap	14.534%	15.950%	16.562%
CFLP19	Mean obj	2.411E+03	2.459E+03	2.494E+03
	Mean gap	12.603%	14.366%	15.633%
CFLP20	Mean obj	2.327E+03	2.381E+03	2.412E+03
	Mean gap	12.933%	14.864%	15.983%
CFLP21	Mean obj	2.305E+03	2.323E+03	2.334E+03
	Mean gap	14.082%	14.775%	15.178%
CFLP22	Mean obj	2.214E+03	2.242E+03	2.263E+03
	Mean gap	12.064%	13.168%	14.023%
CFLP23	Mean obj	2.394E+03	2.450E+03	2.483E+03
	Mean gap	13.709%	15.630%	16.778%

Pro.	Metric	qVNS	aVNS	rVNS
CFLP24	Mean obj	2.338E+03	2.407E+03	2.457E+03
	Mean gap	13.136%	15.617%	17.489%
CFLP25	Mean obj	2.214E+03	2.236E+03	2.249E+03
	Mean gap	14.874%	15.726%	16.222%
CFLP26	Mean obj	2.485E+03	2.520E+03	2.536E+03
	Mean gap	16.675%	17.797%	18.307%
CFLP27	Mean obj	2.198E+03	2.246E+03	2.276E+03
	Mean gap	11.826%	13.666%	14.863%
CFLP28	Mean obj	2.290E+03	2.338E+03	2.363E+03
	Mean gap	14.961%	16.672%	17.567%
CFLP29	Mean obj	2.301E+03	2.348E+03	2.365E+03
	Mean gap	14.976%	16.595%	17.219%
CFLP30	Mean obj	2.129E+03	2.156E+03	2.168E+03
	Mean gap	11.073%	12.187%	12.673%
CFLP31	Mean obj	2.300E+03	2.341E+03	2.361E+03
	Mean gap	11.125%	12.618%	13.378%
CFLP32	Mean obj	2.390E+03	2.459E+03	2.496E+03
	Mean gap	18.602%	20.798%	22.022%
CFLP33	Mean obj	2.170E+03	2.237E+03	2.268E+03
	Mean gap	10.543%	13.072%	14.309%
CFLP34	Mean obj	2.299E+03	2.345E+03	2.368E+03
	Mean gap	12.870%	14.511%	15.347%
CFLP35	Mean obj	2.304E+03	2.350E+03	2.370E+03
	Mean gap	10.270%	12.037%	12.778%
CFLP36	Mean obj	2.362E+03	2.418E+03	2.437E+03
	Mean gap	17.887%	19.680%	20.319%
CFLP37	Mean obj	2.255E+03	2.324E+03	2.353E+03
	Mean gap	13.318%	15.716%	16.761%
CFLP38	Mean obj	2.307E+03	2.347E+03	2.362E+03
	Mean gap	12.744%	14.166%	14.734%
CFLP39	Mean obj	2.299E+03	2.376E+03	2.436E+03
	Mean gap	14.357%	17.176%	19.409%
CFLP40	Mean obj	2.299E+03	2.339E+03	2.356E+03
	Mean gap	13.259%	14.735%	15.351%

4.5 Bin packing problem with conflicts (BPPC)

The experimental results for qVNS, aVNS, and rVNS for solving BPPC instances are shown in Table S-27.

Table S-27 Experimental results for qVNS, aVNS, and rVNS on BPPC.

Pro.	Metric	qVNS	aVNS	rVNS
BPPC01	Mean obj	1.060E+02	1.066E+02	1.066E+02
	Mean gap	31.132%	31.518%	31.518%
BPPC02	Mean obj	1.050E+02	1.060E+02	1.065E+02
	Mean gap	2.857%	3.774%	4.223%
BPPC03	Mean obj	1.043E+02	1.048E+02	1.054E+02
	Mean gap	7.027%	7.441%	7.968%

Pro.	Metric	qVNS	aVNS	rVNS
BPPC04	Mean obj	1.052E+02	1.060E+02	1.066E+02
	Mean gap	4.942%	5.657%	6.189%
BPPC05	Mean obj	1.206E+02	1.224E+02	1.248E+02
	Mean gap	46.097%	46.895%	47.882%
BPPC06	Mean obj	1.353E+02	1.352E+02	1.358E+02
	Mean gap	94.085%	94.083%	94.106%
BPPC07	Mean obj	1.684E+02	1.698E+02	1.712E+02
	Mean gap	94.062%	94.110%	94.159%
BPPC08	Mean obj	1.812E+02	1.810E+02	1.816E+02
	Mean gap	98.344%	98.343%	98.348%
BPPC09	Mean obj	2.050E+02	2.050E+02	2.052E+02
	Mean gap	97.073%	97.073%	97.076%
BPPC10	Mean obj	2.288E+02	2.302E+02	2.304E+02
	Mean gap	92.570%	92.615%	92.621%
BPPC11	Mean obj	2.142E+02	2.152E+02	2.170E+02
	Mean gap	66.386%	66.542%	66.820%
BPPC12	Mean obj	2.137E+02	2.140E+02	2.145E+02
	Mean gap	52.262%	52.336%	52.447%
BPPC13	Mean obj	2.153E+02	2.162E+02	2.168E+02
	Mean gap	99.071%	99.075%	99.077%
BPPC14	Mean obj	2.192E+02	2.198E+02	2.206E+02
	Mean gap	95.894%	95.905%	95.920%
BPPC15	Mean obj	2.282E+02	2.290E+02	2.293E+02
	Mean gap	78.966%	79.039%	79.062%
BPPC16	Mean obj	2.534E+02	2.540E+02	2.543E+02
	Mean gap	94.475%	94.488%	94.493%
BPPC17	Mean obj	3.023E+02	3.024E+02	3.034E+02
	Mean gap	97.354%	97.354%	97.363%
BPPC18	Mean obj	3.468E+02	3.494E+02	3.500E+02
	Mean gap	95.386%	95.421%	95.429%
BPPC19	Mean obj	4.054E+02	4.064E+02	4.070E+02
	Mean gap	99.260%	99.262%	99.263%
BPPC20	Mean obj	4.593E+02	4.600E+02	4.604E+02
	Mean gap	91.945%	91.957%	91.964%
BPPC21	Mean obj	2.100E+01	2.180E+01	2.200E+01
	Mean gap	4.762%	8.225%	9.091%
BPPC22	Mean obj	2.133E+01	2.180E+01	2.160E+01
	Mean gap	6.205%	8.225%	7.359%
BPPC23	Mean obj	2.150E+01	2.200E+01	2.200E+01
	Mean gap	6.926%	9.091%	9.091%
BPPC24	Mean obj	2.100E+01	2.180E+01	2.200E+01
	Mean gap	4.762%	8.225%	9.091%
BPPC25	Mean obj	2.233E+01	2.240E+01	2.260E+01
	Mean gap	1.449%	1.739%	2.609%
BPPC26	Mean obj	2.700E+01	2.740E+01	2.720E+01
	Mean gap	3.704%	5.079%	4.392%
BPPC27	Mean obj	4.300E+01	4.300E+01	4.300E+01

Pro.	Metric	qVNS	aVNS	rVNS
	Mean gap	2.326%	2.326%	2.326%
BPPC28	Mean obj	4.100E+01	4.100E+01	4.100E+01
	Mean gap	0.000%	0.000%	0.000%
BPPC29	Mean obj	4.600E+01	4.600E+01	4.620E+01
	Mean gap	0.000%	0.000%	0.426%
BPPC30	Mean obj	5.600E+01	5.600E+01	5.600E+01
	Mean gap	7.143%	7.143%	7.143%
BPPC31	Mean obj	4.267E+01	4.300E+01	4.375E+01
	Mean gap	6.238%	6.977%	8.562%
BPPC32	Mean obj	4.300E+01	4.300E+01	4.300E+01
	Mean gap	6.977%	6.977%	6.977%
BPPC33	Mean obj	4.300E+01	4.300E+01	4.340E+01
	Mean gap	6.977%	6.977%	7.822%
BPPC34	Mean obj	4.300E+01	4.340E+01	4.360E+01
	Mean gap	6.977%	7.822%	8.245%
BPPC35	Mean obj	5.133E+01	5.140E+01	5.160E+01
	Mean gap	22.071%	22.172%	22.462%
BPPC36	Mean obj	5.917E+01	5.940E+01	5.940E+01
	Mean gap	32.379%	32.648%	32.655%
BPPC37	Mean obj	7.700E+01	7.700E+01	7.800E+01
	Mean gap	48.052%	48.052%	48.718%
BPPC38	Mean obj	8.300E+01	8.300E+01	8.320E+01
	Mean gap	53.012%	53.012%	53.124%
BPPC39	Mean obj	1.020E+02	1.020E+02	1.022E+02
	Mean gap	59.804%	59.804%	59.882%
BPPC40	Mean obj	1.110E+02	1.112E+02	1.114E+02
	Mean gap	59.459%	59.532%	59.604%
BPPC41	Mean obj	8.840E+01	8.900E+01	9.000E+01
	Mean gap	6.101%	6.737%	7.778%
BPPC42	Mean obj	8.900E+01	8.920E+01	9.075E+01
	Mean gap	7.865%	8.070%	9.634%
BPPC43	Mean obj	8.933E+01	8.940E+01	9.060E+01
	Mean gap	7.087%	7.156%	8.386%
BPPC44	Mean obj	9.033E+01	9.040E+01	9.140E+01
	Mean gap	9.223%	9.289%	10.282%
BPPC45	Mean obj	1.020E+02	1.022E+02	1.030E+02
	Mean gap	88.235%	88.258%	88.349%
BPPC46	Mean obj	1.340E+02	1.342E+02	1.342E+02
	Mean gap	71.642%	71.684%	71.684%
BPPC47	Mean obj	1.595E+02	1.596E+02	1.608E+02
	Mean gap	89.969%	89.975%	90.047%
BPPC48	Mean obj	1.754E+02	1.758E+02	1.760E+02
	Mean gap	90.308%	90.330%	90.341%
BPPC49	Mean obj	1.985E+02	1.986E+02	1.994E+02
	Mean gap	87.909%	87.915%	87.964%
BPPC50	Mean obj	2.280E+02	2.280E+02	2.280E+02
	Mean gap	90.351%	90.351%	90.351%

Pro.	Metric	qVNS	aVNS	rVNS
BPPC51	Mean obj	1.800E+02	1.800E+02	1.816E+02
	Mean gap	7.776%	7.776%	8.589%
BPPC52	Mean obj	1.792E+02	1.798E+02	1.826E+02
	Mean gap	25.222%	25.471%	26.615%
BPPC53	Mean obj	1.794E+02	1.798E+02	1.833E+02
	Mean gap	48.160%	48.275%	49.249%
BPPC54	Mean obj	1.825E+02	1.826E+02	1.846E+02
	Mean gap	49.041%	49.069%	49.620%
BPPC55	Mean obj	2.288E+02	2.292E+02	2.300E+02
	Mean gap	91.696%	91.710%	91.739%
BPPC56	Mean obj	2.403E+02	2.404E+02	2.402E+02
	Mean gap	99.168%	99.168%	99.167%
BPPC57	Mean obj	3.050E+02	3.056E+02	3.056E+02
	Mean gap	99.344%	99.346%	99.346%
BPPC58	Mean obj	3.696E+02	3.702E+02	3.700E+02
	Mean gap	99.188%	99.190%	99.189%
BPPC59	Mean obj	4.134E+02	4.142E+02	4.158E+02
	Mean gap	99.032%	99.034%	99.038%
BPPC60	Mean obj	4.518E+02	4.524E+02	4.535E+02
	Mean gap	98.008%	98.011%	98.015%

4.6 Generalized bin packing problem (GBPPI)

The experimental results for qVNS, aVNS, and rVNS for solving GBPPI instances are shown in Table S-28.

Table S-28 Experimental results for qVNS, aVNS, and rVNS on GBPPI.

Pro.	Metric	qVNS	aVNS	rVNS
GBPPI01	Mean obj	3.614E+02	3.742E+02	4.268E+02
	Mean gap	21.546%	24.183%	33.640%
GBPPI02	Mean obj	8.980E+02	9.254E+02	9.543E+02
	Mean gap	24.277%	26.566%	28.639%
GBPPI03	Mean obj	5.600E+02	5.668E+02	6.273E+02
	Mean gap	14.775%	15.807%	23.847%
GBPPI04	Mean obj	9.392E+02	9.576E+02	1.033E+03
	Mean gap	17.308%	18.894%	24.832%
GBPPI05	Mean obj	1.481E+03	1.474E+03	1.517E+03
	Mean gap	23.911%	23.519%	25.794%
GBPPI06	Mean obj	2.084E+03	2.125E+03	2.135E+03
	Mean gap	20.688%	22.175%	22.574%
GBPPI07	Mean obj	1.874E+03	1.910E+03	2.098E+03
	Mean gap	16.748%	18.287%	25.639%
GBPPI08	Mean obj	2.583E+03	2.509E+03	2.715E+03
	Mean gap	21.282%	18.942%	25.080%
GBPPI09	Mean obj	3.687E+03	3.678E+03	4.000E+03
	Mean gap	22.865%	22.672%	29.031%
GBPPI10	Mean obj	3.155E+03	3.200E+03	3.718E+03
	Mean gap	17.159%	18.305%	29.695%

Pro.	Metric	qVNS	aVNS	rVNS
GBPPI11	Mean obj	5.331E+03	5.377E+03	5.849E+03
	Mean gap	15.637%	16.352%	23.096%
GBPPI12	Mean obj	7.761E+03	7.864E+03	8.427E+03
	Mean gap	23.325%	24.348%	29.414%
GBPPI13	Mean obj	7.748E+03	7.834E+03	9.477E+03
	Mean gap	12.175%	13.111%	28.201%
GBPPI14	Mean obj	1.258E+04	1.267E+04	1.390E+04
	Mean gap	9.504%	10.120%	18.124%
GBPPI15	Mean obj	2.122E+04	2.135E+04	2.173E+04
	Mean gap	30.110%	30.511%	31.742%
GBPPI16	Mean obj	4.312E+02	4.360E+02	4.475E+02
	Mean gap	21.127%	21.994%	23.996%
GBPPI17	Mean obj	6.212E+02	6.334E+02	6.370E+02
	Mean gap	22.775%	24.262%	24.782%
GBPPI18	Mean obj	9.060E+02	9.206E+02	9.903E+02
	Mean gap	13.410%	14.787%	20.789%
GBPPI19	Mean obj	1.543E+03	1.520E+03	1.617E+03
	Mean gap	17.318%	16.067%	21.079%
GBPPI20	Mean obj	2.277E+03	2.306E+03	2.485E+03
	Mean gap	15.140%	16.166%	22.251%
GBPPI21	Mean obj	2.508E+03	2.532E+03	2.717E+03
	Mean gap	13.549%	14.351%	20.191%
GBPPI22	Mean obj	5.490E+03	5.528E+03	6.006E+03
	Mean gap	13.868%	14.460%	21.273%
GBPPI23	Mean obj	3.955E+03	3.979E+03	4.569E+03
	Mean gap	14.933%	15.454%	26.346%
GBPPI24	Mean obj	1.045E+04	1.053E+04	1.119E+04
	Mean gap	16.569%	17.191%	22.111%
GBPPI25	Mean obj	1.512E+04	1.522E+04	1.575E+04
	Mean gap	14.709%	15.269%	18.109%
GBPPI26	Mean obj	4.162E+02	4.354E+02	4.628E+02
	Mean gap	17.269%	21.329%	25.962%
GBPPI27	Mean obj	9.390E+02	9.474E+02	1.035E+03
	Mean gap	20.593%	21.322%	27.753%
GBPPI28	Mean obj	6.458E+02	6.608E+02	6.938E+02
	Mean gap	16.467%	18.355%	22.259%
GBPPI29	Mean obj	9.404E+02	9.568E+02	1.002E+03
	Mean gap	23.269%	24.587%	27.984%
GBPPI30	Mean obj	1.083E+03	1.100E+03	1.195E+03
	Mean gap	12.746%	14.080%	20.962%
GBPPI31	Mean obj	1.972E+03	2.025E+03	2.048E+03
	Mean gap	15.567%	17.857%	18.900%
GBPPI32	Mean obj	1.445E+03	1.487E+03	1.692E+03
	Mean gap	18.880%	21.162%	30.731%
GBPPI33	Mean obj	2.914E+03	2.993E+03	3.227E+03
	Mean gap	13.754%	16.058%	22.233%
GBPPI34	Mean obj	3.620E+03	3.696E+03	3.861E+03

Pro.	Metric	qVNS	aVNS	rVNS
GBPPI35	Mean gap	22.638%	24.203%	27.482%
	Mean obj	4.076E+03	4.151E+03	4.467E+03
	Mean gap	15.467%	16.995%	22.892%
GBPPI36	Mean obj	5.122E+03	5.067E+03	5.447E+03
	Mean gap	21.182%	20.339%	25.903%
GBPPI37	Mean obj	7.946E+03	8.035E+03	8.237E+03
	Mean gap	23.889%	24.723%	26.556%
GBPPI38	Mean obj	9.650E+03	9.467E+03	1.062E+04
	Mean gap	27.367%	25.966%	33.976%
GBPPI39	Mean obj	1.319E+04	1.328E+04	1.430E+04
	Mean gap	24.123%	24.645%	30.034%
GBPPI40	Mean obj	2.031E+04	2.048E+04	2.125E+04
	Mean gap	24.700%	25.296%	28.030%
GBPPI41	Mean obj	4.116E+02	4.162E+02	4.338E+02
	Mean gap	7.177%	8.205%	11.900%
GBPPI42	Mean obj	5.770E+02	5.894E+02	6.538E+02
	Mean gap	10.137%	12.092%	20.721%
GBPPI43	Mean obj	1.122E+03	1.137E+03	1.240E+03
	Mean gap	14.239%	15.381%	22.396%
GBPPI44	Mean obj	1.347E+03	1.369E+03	1.389E+03
	Mean gap	16.923%	18.283%	19.494%
GBPPI45	Mean obj	1.764E+03	1.789E+03	1.957E+03
	Mean gap	17.288%	18.474%	25.470%
GBPPI46	Mean obj	2.942E+03	2.981E+03	3.077E+03
	Mean gap	13.833%	14.961%	17.622%
GBPPI47	Mean obj	5.241E+03	5.300E+03	5.599E+03
	Mean gap	14.360%	15.289%	19.820%
GBPPI48	Mean obj	3.708E+03	3.744E+03	4.300E+03
	Mean gap	14.589%	15.413%	26.371%
GBPPI49	Mean obj	1.421E+04	1.428E+04	1.494E+04
	Mean gap	11.522%	11.962%	15.890%
GBPPI50	Mean obj	1.358E+04	1.364E+04	1.417E+04
	Mean gap	11.132%	11.537%	14.834%

4.7 Quadratic multiple knapsack problem (QMKP)

The experimental results for qVNS, aVNS, and rVNS for solving QMKP instances are shown in Table S-29.

Table S-29 Experimental results for qVNS, aVNS, and rVNS on QMKP.

Pro.	Metric	qVNS	aVNS	rVNS
QMKP01	Mean obj	9.908E+03	9.943E+03	9.604E+03
	Mean gap	0.713%	0.366%	3.918%
QMKP02	Mean obj	1.053E+04	1.053E+04	1.047E+04
	Mean gap	0.000%	0.000%	0.504%
QMKP03	Mean obj	8.516E+03	8.644E+03	8.105E+03
	Mean gap	2.653%	1.145%	7.869%
QMKP04	Mean obj	6.040E+03	5.745E+03	5.645E+03

Pro.	Metric	qVNS	aVNS	rVNS
	Mean gap	78.615%	88.022%	91.870%
QMKP05	Mean obj	5.471E+03	5.156E+03	5.343E+03
	Mean gap	51.513%	60.901%	55.203%
QMKP06	Mean obj	1.987E+04	1.987E+04	1.979E+04
	Mean gap	0.000%	0.000%	0.406%
QMKP07	Mean obj	1.692E+04	1.598E+04	1.555E+04
	Mean gap	18.378%	25.418%	28.925%
QMKP08	Mean obj	2.684E+04	2.684E+04	2.676E+04
	Mean gap	0.000%	0.000%	0.315%
QMKP09	Mean obj	6.597E+03	5.690E+03	5.913E+03
	Mean gap	112.842%	147.052%	138.052%
QMKP10	Mean obj	5.191E+03	5.047E+03	4.911E+03
	Mean gap	20.371%	23.807%	27.256%
QMKP11	Mean obj	1.215E+04	1.214E+04	1.189E+04
	Mean gap	0.374%	0.460%	2.516%
QMKP12	Mean obj	1.334E+04	1.334E+04	1.333E+04
	Mean gap	0.000%	0.000%	0.078%
QMKP13	Mean obj	9.448E+03	8.765E+03	8.165E+03
	Mean gap	48.604%	60.637%	72.428%
QMKP14	Mean obj	1.944E+04	1.937E+04	1.883E+04
	Mean gap	0.547%	0.893%	3.836%
QMKP15	Mean obj	1.245E+04	1.132E+04	1.140E+04
	Mean gap	35.466%	49.368%	48.491%
QMKP16	Mean obj	1.415E+04	1.204E+04	1.211E+04
	Mean gap	62.778%	92.645%	90.374%
QMKP17	Mean obj	3.351E+04	3.351E+04	3.348E+04
	Mean gap	0.000%	0.000%	0.103%
QMKP18	Mean obj	3.133E+04	3.113E+04	3.094E+04
	Mean gap	0.758%	1.415%	2.040%
QMKP19	Mean obj	1.554E+04	1.554E+04	1.553E+04
	Mean gap	0.000%	0.000%	0.062%
QMKP20	Mean obj	1.116E+04	1.093E+04	9.876E+03
	Mean gap	19.809%	22.358%	35.521%
QMKP21	Mean obj	1.032E+04	1.002E+04	9.904E+03
	Mean gap	14.280%	17.818%	19.256%
QMKP22	Mean obj	1.440E+04	1.305E+04	1.333E+04
	Mean gap	58.547%	75.379%	71.583%
QMKP23	Mean obj	6.564E+03	6.111E+03	6.114E+03
	Mean gap	132.355%	149.676%	149.676%
QMKP24	Mean obj	1.745E+04	1.757E+04	1.705E+04
	Mean gap	43.821%	42.795%	47.266%
QMKP25	Mean obj	4.769E+04	4.769E+04	4.767E+04
	Mean gap	0.000%	0.000%	0.032%
QMKP26	Mean obj	2.918E+04	2.889E+04	2.765E+04
	Mean gap	16.884%	18.102%	23.418%
QMKP27	Mean obj	2.953E+04	2.894E+04	2.827E+04
	Mean gap	21.879%	24.389%	27.301%

Pro.	Metric	qVNS	aVNS	rVNS
QMKP28	Mean obj	1.173E+04	1.105E+04	1.043E+04
	Mean gap	23.641%	31.499%	39.308%
QMKP29	Mean obj	1.970E+04	1.971E+04	1.959E+04
	Mean gap	0.030%	0.000%	0.597%
QMKP30	Mean obj	1.439E+04	1.462E+04	1.368E+04
	Mean gap	7.237%	5.588%	12.869%
QMKP31	Mean obj	2.293E+04	2.289E+04	2.156E+04
	Mean gap	26.640%	26.906%	34.723%
QMKP32	Mean obj	2.684E+04	2.676E+04	2.532E+04
	Mean gap	10.050%	10.417%	16.715%
QMKP33	Mean obj	2.553E+04	2.547E+04	2.477E+04
	Mean gap	19.459%	19.768%	23.220%
QMKP34	Mean obj	5.125E+04	5.125E+04	5.121E+04
	Mean gap	0.000%	0.000%	0.090%
QMKP35	Mean obj	1.427E+04	1.094E+04	1.253E+04
	Mean gap	183.325%	270.759%	226.114%
QMKP36	Mean obj	5.071E+04	5.069E+04	5.066E+04
	Mean gap	0.000%	0.048%	0.101%
QMKP37	Mean obj	2.096E+04	2.096E+04	2.059E+04
	Mean gap	0.000%	0.000%	1.794%
QMKP38	Mean obj	1.943E+04	1.961E+04	1.849E+04
	Mean gap	1.136%	0.217%	6.324%
QMKP39	Mean obj	7.995E+03	7.029E+03	7.053E+03
	Mean gap	80.049%	105.771%	104.682%
QMKP40	Mean obj	9.993E+03	8.410E+03	9.392E+03
	Mean gap	193.577%	250.128%	213.423%
QMKP41	Mean obj	3.918E+04	3.918E+04	3.882E+04
	Mean gap	0.000%	0.000%	0.932%
QMKP42	Mean obj	2.478E+04	2.429E+04	2.353E+04
	Mean gap	42.646%	45.551%	50.279%
QMKP43	Mean obj	6.762E+04	6.762E+04	6.760E+04
	Mean gap	0.000%	0.000%	0.024%
QMKP44	Mean obj	6.281E+04	6.281E+04	6.275E+04
	Mean gap	0.000%	0.000%	0.086%
QMKP45	Mean obj	4.399E+04	4.382E+04	4.210E+04
	Mean gap	27.822%	28.337%	33.578%

4.8 High school timetabling problem (HTS)

The experimental results for qVNS, aVNS, and rVNS for solving HTS instances are shown in Table S-30.

Table S-30 Experimental results for qVNS, aVNS, and rVNS on HTS.

Pro.	Metric	qVNS	aVNS	rVNS
HTS01	Mean obj	7.268E+02	7.322E+02	7.433E+02
	Mean gap	10.136%	10.802%	12.142%
HTS02	Mean obj	7.362E+02	7.342E+02	7.390E+02
	Mean gap	8.040%	7.789%	8.389%

Pro.	Metric	qVNS	aVNS	rVNS
HTS03	Mean obj	7.356E+02	7.376E+02	7.365E+02
	Mean gap	2.935%	3.198%	3.054%
HTS04	Mean obj	7.470E+02	7.500E+02	7.530E+02
	Mean gap	3.077%	3.464%	3.850%
HTS05	Mean obj	6.298E+02	6.312E+02	6.340E+02
	Mean gap	2.667%	2.882%	3.312%
HTS06	Mean obj	8.208E+02	8.216E+02	8.303E+02
	Mean gap	8.507%	8.592%	9.545%
HTS07	Mean obj	1.229E+03	1.232E+03	1.235E+03
	Mean gap	0.862%	2.727%	2.956%
HTS08	Mean obj	6.780E+02	6.730E+02	6.838E+02
	Mean gap	8.693%	8.015%	9.468%
HTS09	Mean obj	8.176E+02	8.190E+02	8.265E+02
	Mean gap	3.987%	4.151%	5.021%
HTS10	Mean obj	3.128E+02	3.134E+02	3.175E+02
	Mean gap	4.731%	4.913%	6.136%
HTS11	Mean obj	1.005E+03	1.009E+03	1.021E+03
	Mean gap	4.953%	5.366%	6.483%
HTS12	Mean obj	1.033E+03	1.026E+03	1.040E+03
	Mean gap	8.868%	8.300%	9.497%
HTS13	Mean obj	2.510E+02	2.528E+02	2.620E+02
	Mean gap	5.966%	6.643%	9.924%
HTS14	Mean obj	9.334E+02	9.262E+02	9.398E+02
	Mean gap	2.504%	1.746%	3.166%
HTS15	Mean obj	2.343E+02	2.344E+02	2.363E+02
	Mean gap	7.396%	7.423%	8.148%
HTS16	Mean obj	4.826E+02	4.848E+02	4.948E+02
	Mean gap	2.606%	3.045%	4.989%
HTS17	Mean obj	4.590E+02	4.610E+02	4.658E+02
	Mean gap	0.653%	1.080%	2.087%
HTS18	Mean obj	3.128E+02	3.132E+02	3.158E+02
	Mean gap	2.183%	2.298%	3.101%
HTS19	Mean obj	2.452E+02	2.494E+02	2.495E+02
	Mean gap	5.355%	6.949%	7.013%
HTS20	Mean obj	3.378E+02	3.302E+02	3.430E+02
	Mean gap	7.325%	5.192%	8.744%
HTS21	Mean obj	1.057E+03	1.060E+03	1.081E+03
	Mean gap	1.322%	1.640%	3.514%
HTS22	Mean obj	7.078E+02	7.098E+02	7.113E+02
	Mean gap	3.362%	3.633%	3.828%
HTS23	Mean obj	1.902E+03	1.906E+03	1.914E+03
	Mean gap	4.541%	4.711%	5.095%
HTS24	Mean obj	2.063E+03	2.067E+03	2.082E+03
	Mean gap	3.062%	3.232%	3.926%
HTS25	Mean obj	9.538E+02	9.572E+02	9.785E+02
	Mean gap	3.227%	3.569%	5.666%

Pro.	Metric	qVNS	aVNS	rVNS
HTS26	Mean obj	5.936E+02	5.964E+02	6.076E+02
	Mean gap	3.800%	4.255%	6.017%
HTS27	Mean obj	5.532E+02	5.554E+02	5.583E+02
	Mean gap	1.300%	1.689%	2.193%
HTS28	Mean obj	1.109E+03	1.111E+03	1.114E+03
	Mean gap	3.263%	3.420%	3.659%
HTS29	Mean obj	1.095E+03	1.100E+03	1.104E+03
	Mean gap	1.004%	1.483%	1.832%
HTS30	Mean obj	1.127E+03	1.131E+03	1.138E+03
	Mean gap	1.025%	2.329%	2.877%
HTS31	Mean obj	1.160E+03	1.163E+03	1.167E+03
	Mean gap	4.001%	4.259%	4.586%
HTS32	Mean obj	9.982E+02	1.002E+03	1.003E+03
	Mean gap	1.521%	1.854%	1.945%
HTS33	Mean obj	1.017E+03	1.023E+03	1.035E+03
	Mean gap	2.396%	2.924%	4.025%
HTS34	Mean obj	1.016E+03	1.020E+03	1.031E+03
	Mean gap	2.003%	2.367%	3.348%

4.9 Job shop scheduling problem (JSSP)

The experimental results for qVNS, aVNS, and rVNS for solving JSSP instances are shown in Table S-31.

Table S-31 Experimental results for qVNS, aVNS, and rVNS on JSSP.

Pro.	Metric	qVNS	aVNS	rVNS
JSSP01	Mean obj	1.442E+03	1.478E+03	1.589E+03
	Mean gap	33.074%	34.695%	39.215%
JSSP02	Mean obj	1.407E+03	1.433E+03	1.632E+03
	Mean gap	34.484%	35.672%	43.458%
JSSP03	Mean obj	1.487E+03	1.521E+03	1.542E+03
	Mean gap	36.738%	38.125%	38.923%
JSSP04	Mean obj	1.377E+03	1.425E+03	1.599E+03
	Mean gap	32.031%	34.226%	41.360%
JSSP05	Mean obj	1.457E+03	1.484E+03	1.690E+03
	Mean gap	37.713%	38.843%	46.233%
JSSP06	Mean obj	1.817E+03	1.671E+03	1.958E+03
	Mean gap	44.180%	39.282%	48.242%
JSSP07	Mean obj	1.520E+03	1.553E+03	1.801E+03
	Mean gap	34.756%	36.162%	44.948%
JSSP08	Mean obj	1.698E+03	1.733E+03	2.025E+03
	Mean gap	39.149%	40.346%	48.905%
JSSP09	Mean obj	1.576E+03	1.658E+03	1.902E+03
	Mean gap	39.558%	42.277%	49.921%
JSSP10	Mean obj	1.628E+03	1.737E+03	1.942E+03
	Mean gap	42.830%	46.162%	52.186%
JSSP11	Mean obj	2.130E+03	2.100E+03	2.327E+03
	Mean gap	42.805%	41.988%	47.652%

Pro.	Metric	qVNS	aVNS	rVNS
JSSP12	Mean obj	1.925E+03	2.028E+03	2.397E+03
	Mean gap	36.374%	39.265%	48.851%
JSSP13	Mean obj	1.963E+03	2.067E+03	2.369E+03
	Mean gap	39.877%	42.603%	50.171%
JSSP14	Mean obj	2.120E+03	2.185E+03	2.527E+03
	Mean gap	39.011%	40.867%	48.888%
JSSP15	Mean obj	2.024E+03	2.126E+03	2.416E+03
	Mean gap	39.212%	41.895%	49.092%
JSSP16	Mean obj	2.293E+03	2.266E+03	2.645E+03
	Mean gap	56.765%	56.258%	62.563%
JSSP17	Mean obj	2.426E+03	2.380E+03	2.699E+03
	Mean gap	59.771%	59.001%	63.841%
JSSP18	Mean obj	2.256E+03	2.323E+03	2.717E+03
	Mean gap	56.118%	57.450%	63.619%
JSSP19	Mean obj	2.280E+03	2.381E+03	2.672E+03
	Mean gap	54.100%	55.887%	60.853%
JSSP20	Mean obj	2.299E+03	2.373E+03	2.631E+03
	Mean gap	60.521%	61.837%	65.563%
JSSP21	Mean obj	2.980E+03	2.863E+03	3.129E+03
	Mean gap	58.567%	56.871%	60.605%
JSSP22	Mean obj	2.570E+03	2.677E+03	3.211E+03
	Mean gap	51.922%	53.866%	61.672%
JSSP23	Mean obj	2.657E+03	2.698E+03	3.172E+03
	Mean gap	52.802%	53.532%	60.459%
JSSP24	Mean obj	2.696E+03	2.775E+03	3.177E+03
	Mean gap	52.402%	53.766%	59.602%
JSSP25	Mean obj	2.852E+03	2.936E+03	3.162E+03
	Mean gap	58.152%	59.417%	62.318%
JSSP26	Mean obj	4.347E+03	4.299E+03	4.347E+03
	Mean gap	74.673%	74.498%	74.777%
JSSP27	Mean obj	4.039E+03	4.113E+03	4.359E+03
	Mean gap	73.988%	74.467%	75.920%
JSSP28	Mean obj	3.804E+03	3.878E+03	4.294E+03
	Mean gap	71.985%	72.529%	75.172%
JSSP29	Mean obj	3.834E+03	4.064E+03	4.291E+03
	Mean gap	72.457%	74.012%	75.517%
JSSP30	Mean obj	3.762E+03	3.898E+03	4.247E+03
	Mean gap	68.676%	69.823%	72.385%
JSSP31	Mean obj	5.188E+03	5.374E+03	5.776E+03
	Mean gap	75.078%	75.954%	77.668%
JSSP32	Mean obj	4.548E+03	4.657E+03	5.645E+03
	Mean gap	71.759%	72.383%	77.250%
JSSP33	Mean obj	4.244E+03	4.314E+03	5.269E+03
	Mean gap	68.520%	69.055%	74.657%
JSSP34	Mean obj	4.864E+03	4.969E+03	5.730E+03
	Mean gap	72.393%	72.973%	76.584%
JSSP35	Mean obj	7.084E+03	7.349E+03	7.477E+03

Pro.	Metric	qVNS	aVNS	rVNS
	Mean gap	80.984%	81.695%	82.027%

4.10 Graph coloring problem (GC)

The experimental results for qVNS, aVNS, and rVNS for solving GC instances are shown in Table S-32.

Table S-32 Experimental results for qVNS, aVNS, and rVNS on GC.

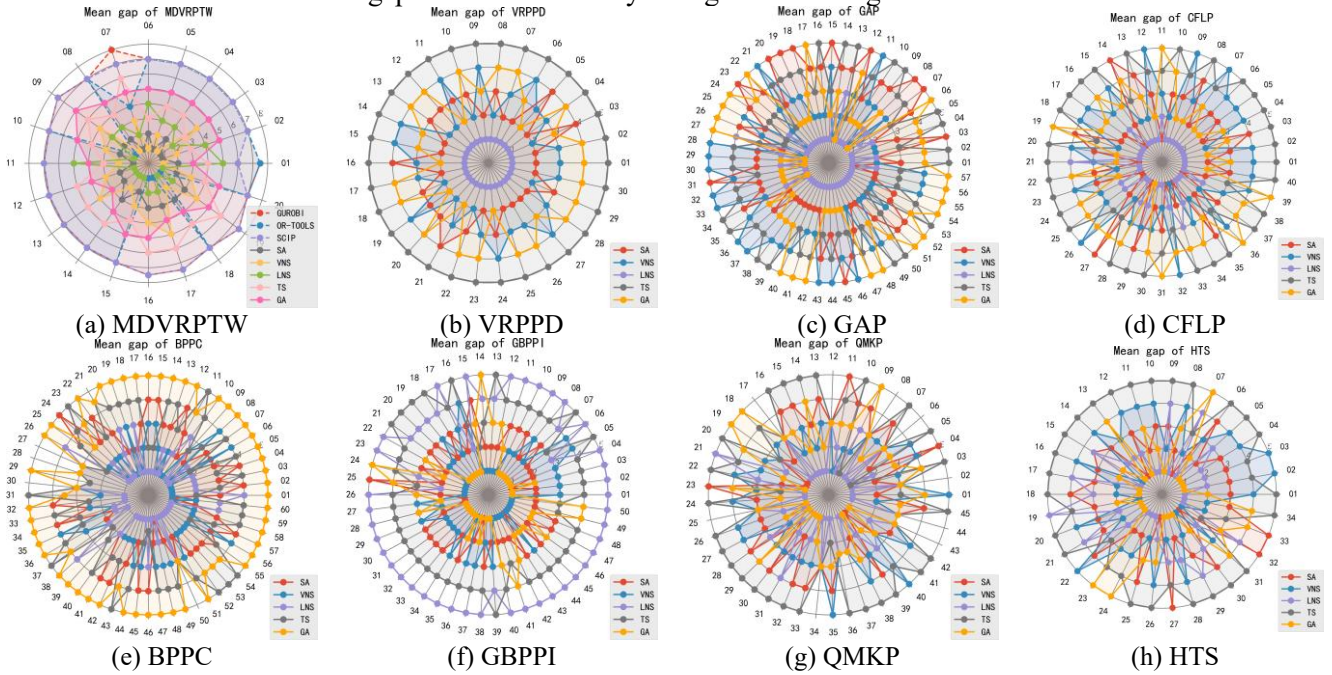
Pro.	Metric	qVNS	aVNS	rVNS
GC01	Mean obj	1.717E+01	1.760E+01	1.840E+01
	Mean gap	41.653%	43.137%	45.614%
GC02	Mean obj	1.750E+01	1.800E+01	1.800E+01
	Mean gap	37.092%	38.889%	38.889%
GC03	Mean obj	1.717E+01	1.800E+01	1.900E+01
	Mean gap	35.818%	38.889%	42.105%
GC04	Mean obj	1.833E+01	1.760E+01	1.900E+01
	Mean gap	50.871%	48.824%	52.105%
GC05	Mean obj	1.740E+01	1.740E+01	1.820E+01
	Mean gap	48.235%	48.235%	50.000%
GC06	Mean obj	1.750E+01	1.800E+01	1.900E+01
	Mean gap	37.092%	38.813%	41.462%
GC07	Mean obj	1.800E+01	1.800E+01	1.840E+01
	Mean gap	38.889%	38.889%	40.175%
GC08	Mean obj	1.700E+01	1.740E+01	1.840E+01
	Mean gap	35.294%	36.732%	40.175%
GC09	Mean obj	1.733E+01	1.760E+01	1.850E+01
	Mean gap	36.417%	37.451%	39.456%
GC10	Mean obj	1.767E+01	1.780E+01	1.840E+01
	Mean gap	37.691%	38.170%	40.175%
GC11	Mean obj	1.850E+01	1.800E+01	1.900E+01
	Mean gap	40.541%	38.889%	41.462%
GC12	Mean obj	1.750E+01	1.780E+01	1.900E+01
	Mean gap	48.529%	49.412%	52.105%
GC13	Mean obj	1.733E+01	1.780E+01	1.860E+01
	Mean gap	47.978%	49.412%	51.579%
GC14	Mean obj	1.750E+01	1.800E+01	1.860E+01
	Mean gap	37.092%	38.889%	40.819%
GC15	Mean obj	1.733E+01	1.780E+01	1.900E+01
	Mean gap	36.492%	38.094%	41.462%
GC16	Mean obj	1.800E+01	1.740E+01	1.820E+01
	Mean gap	38.841%	36.732%	38.889%
GC17	Mean obj	1.780E+01	1.840E+01	1.900E+01
	Mean gap	32.549%	34.737%	36.842%
GC18	Mean obj	1.700E+01	1.760E+01	1.875E+01
	Mean gap	35.144%	37.451%	40.100%
GC19	Mean obj	1.740E+01	1.820E+01	1.900E+01
	Mean gap	48.235%	50.526%	52.105%
GC20	Mean obj	1.717E+01	1.760E+01	1.760E+01

Pro.	Metric	qVNS	aVNS	rVNS
	Mean gap	41.653%	43.137%	43.137%
GC21	Mean obj	4.283E+01	4.360E+01	4.500E+01
	Mean gap	71.972%	72.468%	72.872%
GC22	Mean obj	4.317E+01	4.380E+01	4.600E+01
	Mean gap	74.511%	74.884%	75.981%
GC23	Mean obj	4.350E+01	4.400E+01	4.550E+01
	Mean gap	79.308%	79.545%	79.988%
GC24	Mean obj	4.317E+01	4.400E+01	4.500E+01
	Mean gap	76.828%	77.273%	77.677%
GC25	Mean obj	4.220E+01	4.300E+01	4.425E+01
	Mean gap	76.301%	76.734%	77.141%
GC26	Mean obj	4.333E+01	4.380E+01	4.475E+01
	Mean gap	76.920%	77.167%	77.470%
GC27	Mean obj	4.283E+01	4.340E+01	4.460E+01
	Mean gap	74.308%	74.646%	75.333%
GC28	Mean obj	4.350E+01	4.400E+01	4.400E+01
	Mean gap	77.008%	77.273%	77.167%
GC29	Mean obj	4.340E+01	4.440E+01	4.560E+01
	Mean gap	76.956%	77.475%	78.068%
GC30	Mean obj	4.333E+01	4.380E+01	4.460E+01
	Mean gap	76.920%	77.162%	77.576%

5 Figures in the Paper

5.1 Figures for 5 algorithms in REMS

Fig. S-1 illustrates the radar chart of the mean gap values obtained by 5 metaheuristic algorithms across 10 problems. Among these charts, a point closer to the center of the circle indicates better mean gap values achieved by an algorithm for a given instance.



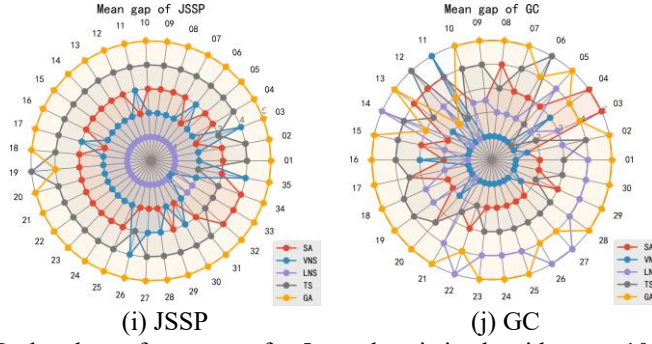


Fig. S-1 Radar chart of mean gap for 5 metaheuristic algorithms on 10 problems.

Fig. S-2 presents the critical difference (CD) plot of mean gap for 5 metaheuristic algorithms on 10 problems, with a significance level set at 0.05. The plot visually reveals whether the performance differences between pairs of algorithms are statistically significant. Specifically, if two algorithms are connected by a horizontal line, their performance differences are not statistically significant.

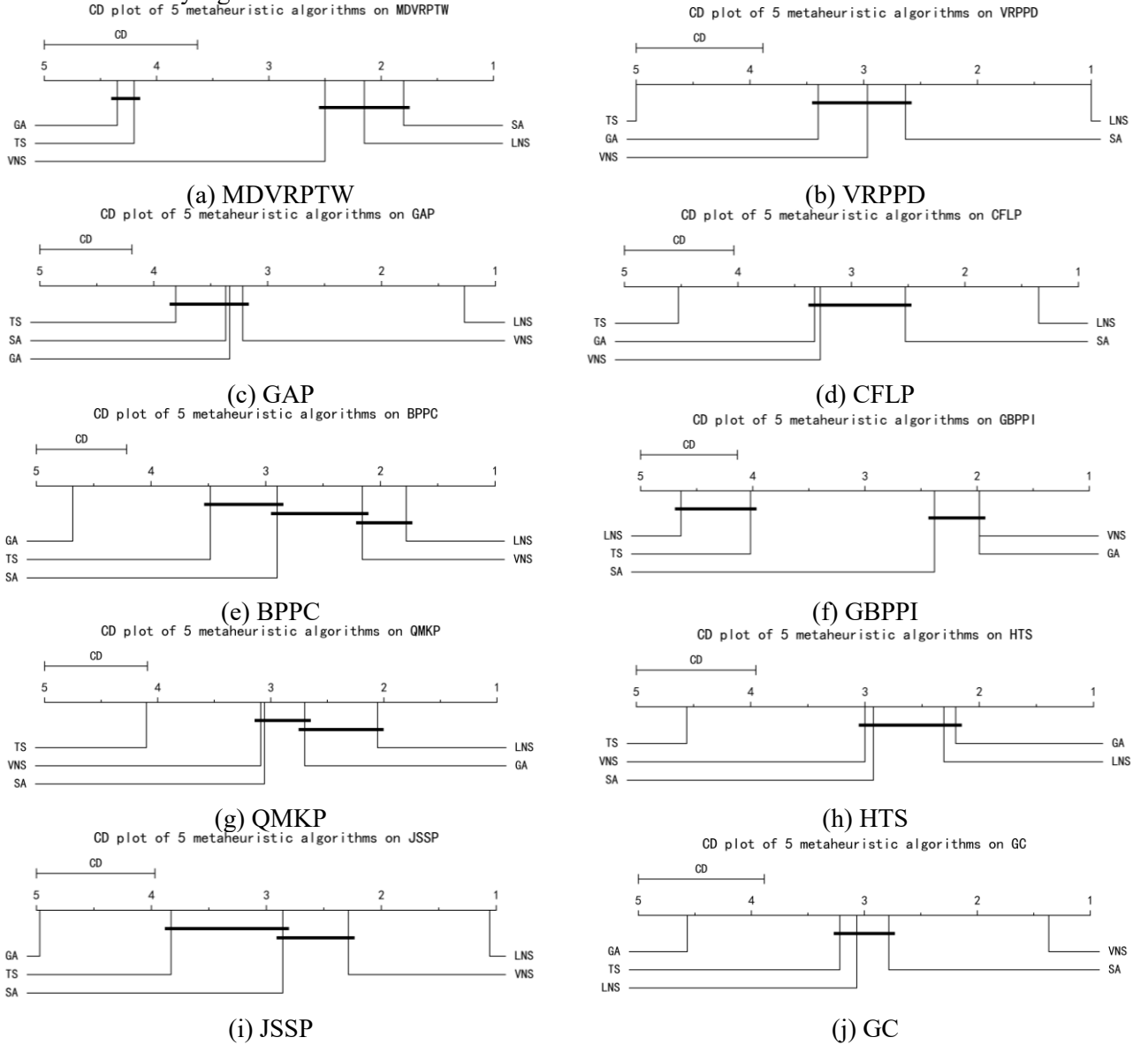


Fig. S-2 CD plot of the mean gap for 5 metaheuristic algorithms on 10 problems.

Fig. S-3 to Fig. S-12 display the convergence curves for 5 metaheuristic algorithms on 4 instances for the 10 problem types.

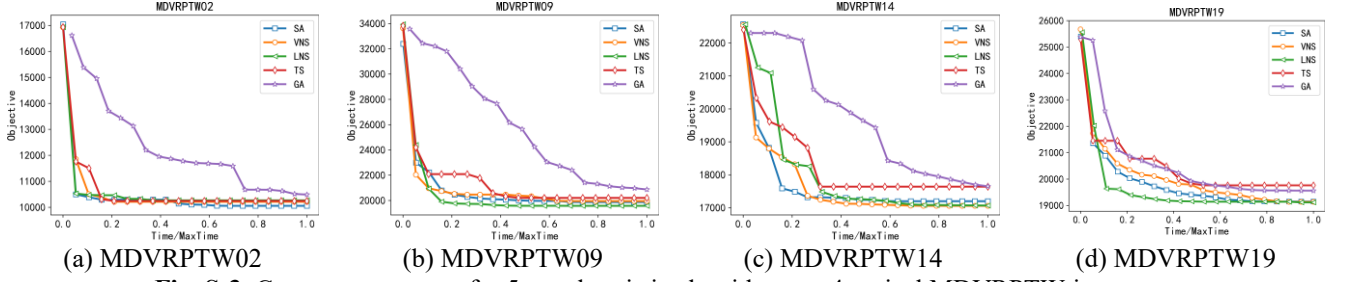


Fig. S-3 Convergence curve for 5 metaheuristic algorithms on 4 typical MDVRPTW instances.

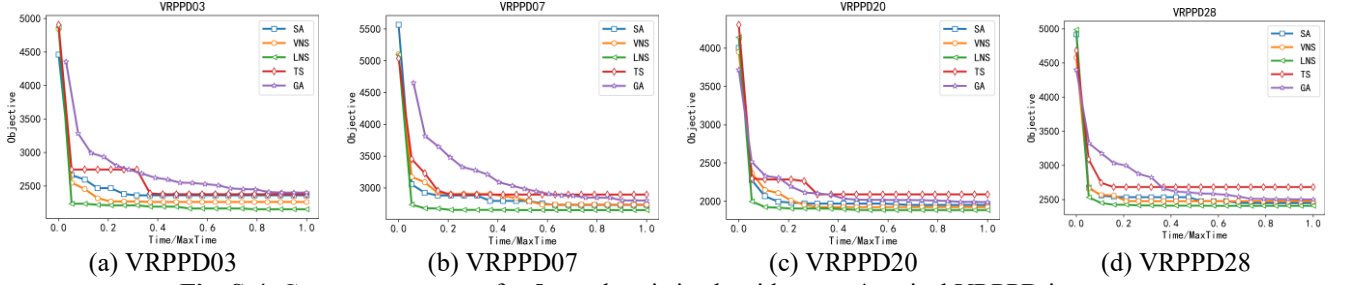


Fig. S-4 Convergence curve for 5 metaheuristic algorithms on 4 typical VRPPD instances.

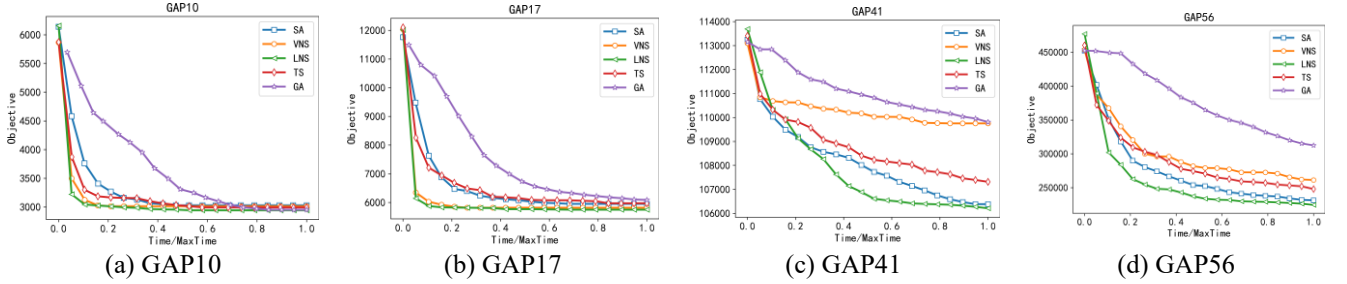


Fig. S-5 Convergence curve for 5 metaheuristic algorithms on 4 typical GAP instances.

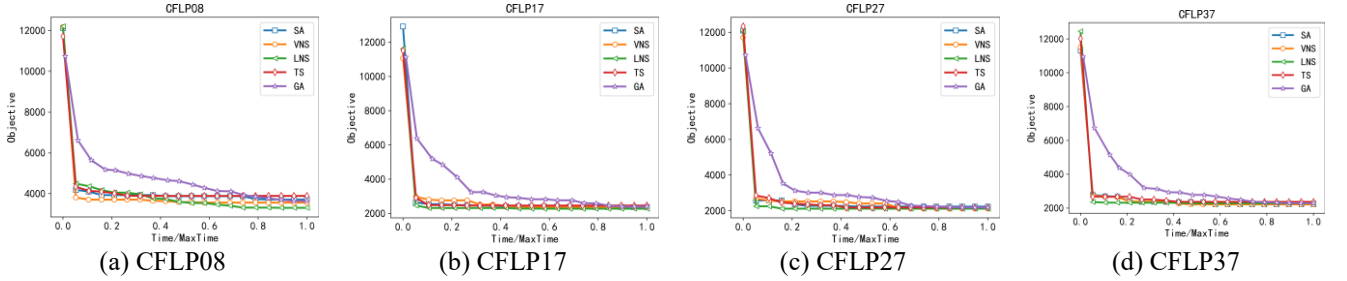


Fig. S-6 Convergence curve for 5 metaheuristic algorithms on 4 typical CFLP instances

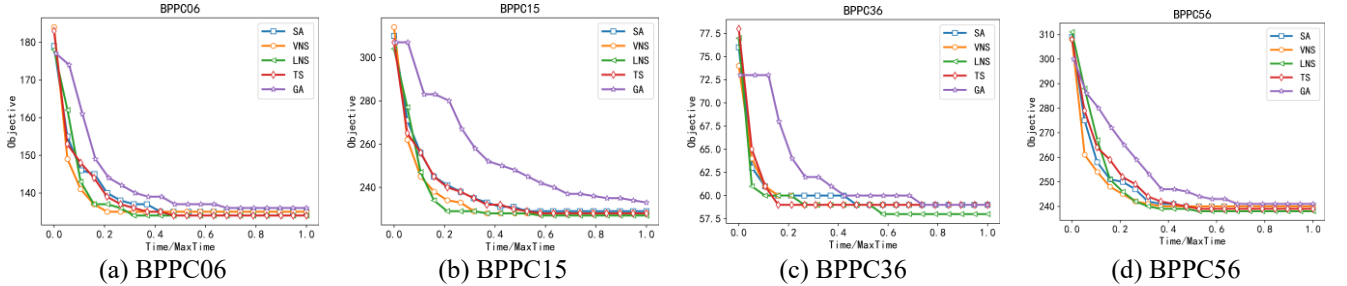


Fig. S-7 Convergence curve for 5 metaheuristic algorithms on 4 typical BPPC instances.

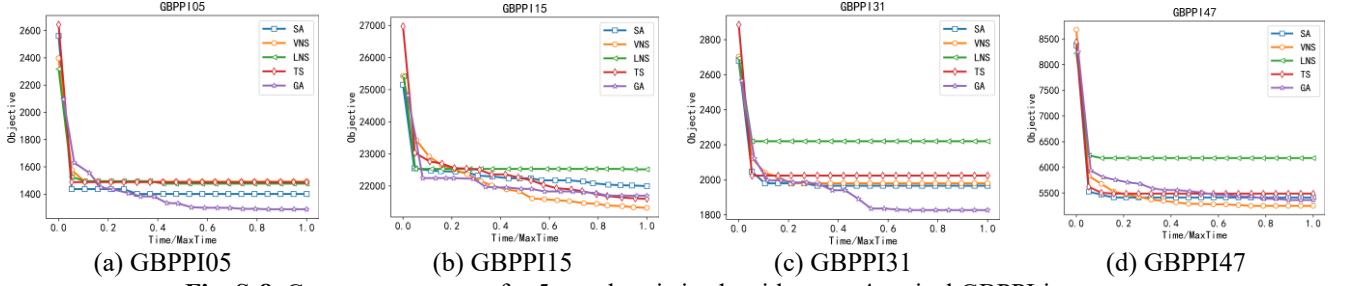


Fig. S-8 Convergence curve for 5 metaheuristic algorithms on 4 typical GBPPI instances.

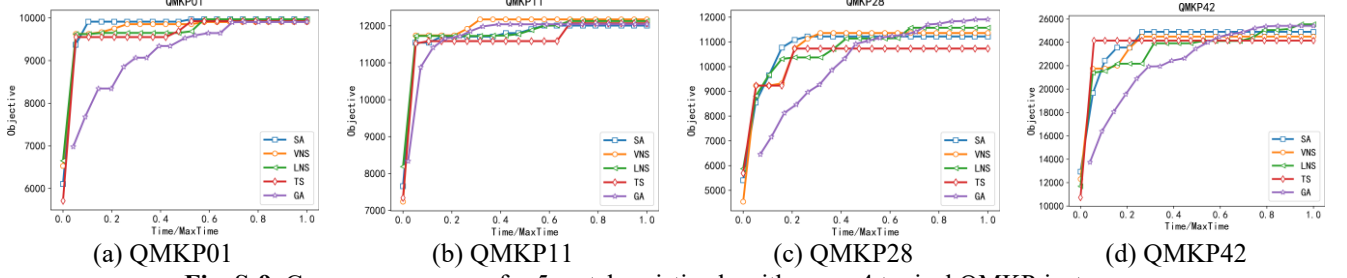


Fig. S-9 Convergence curve for 5 metaheuristic algorithms on 4 typical QMKP instances.

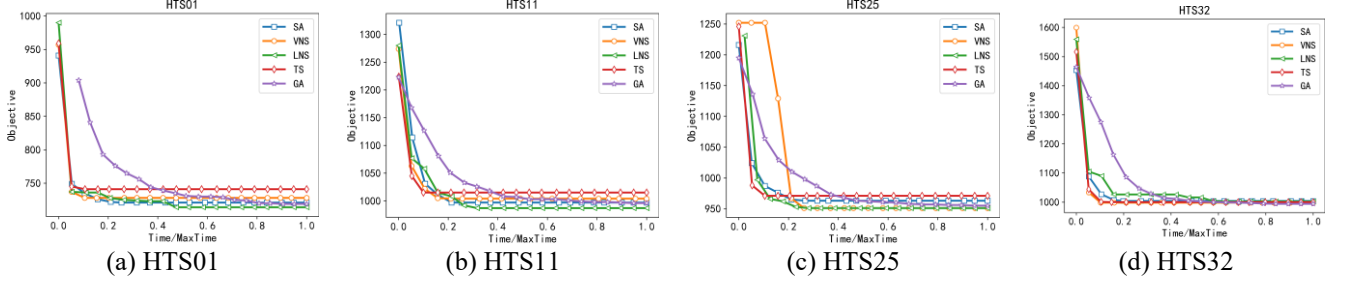


Fig. S-10 Convergence curve for 5 metaheuristic algorithms on 4 typical HTS instances.

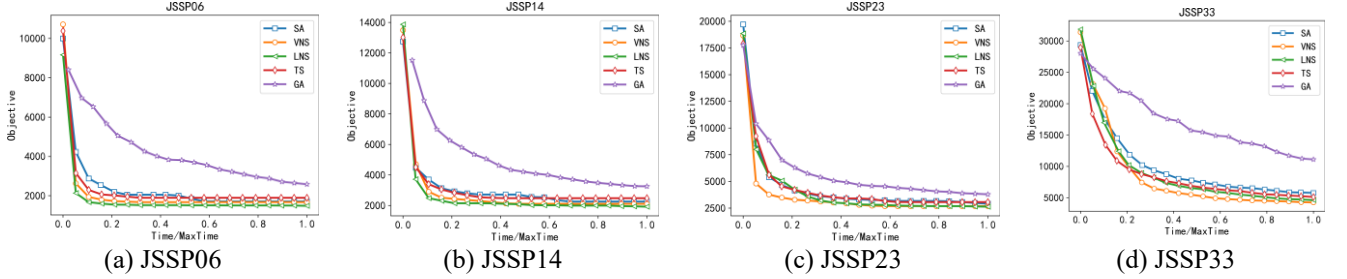


Fig. S-11 Convergence curve for 5 metaheuristic algorithms on 4 typical JSSP instances.

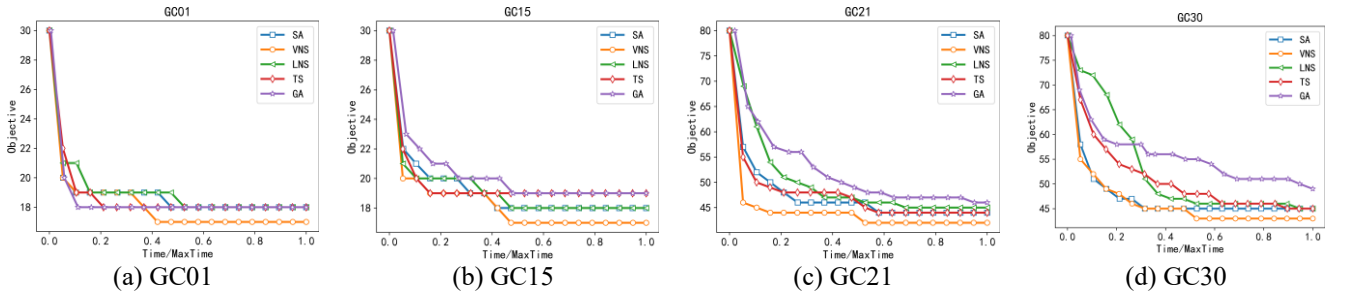


Fig. S-12 Convergence curve for 5 metaheuristic algorithms on 4 typical GC instances.

5.2 Figures for 5 methods in REMS and other solvers

The radar chart of the mean gap values obtained by 8 algorithms on 10 problems is presented in Fig. S-13.

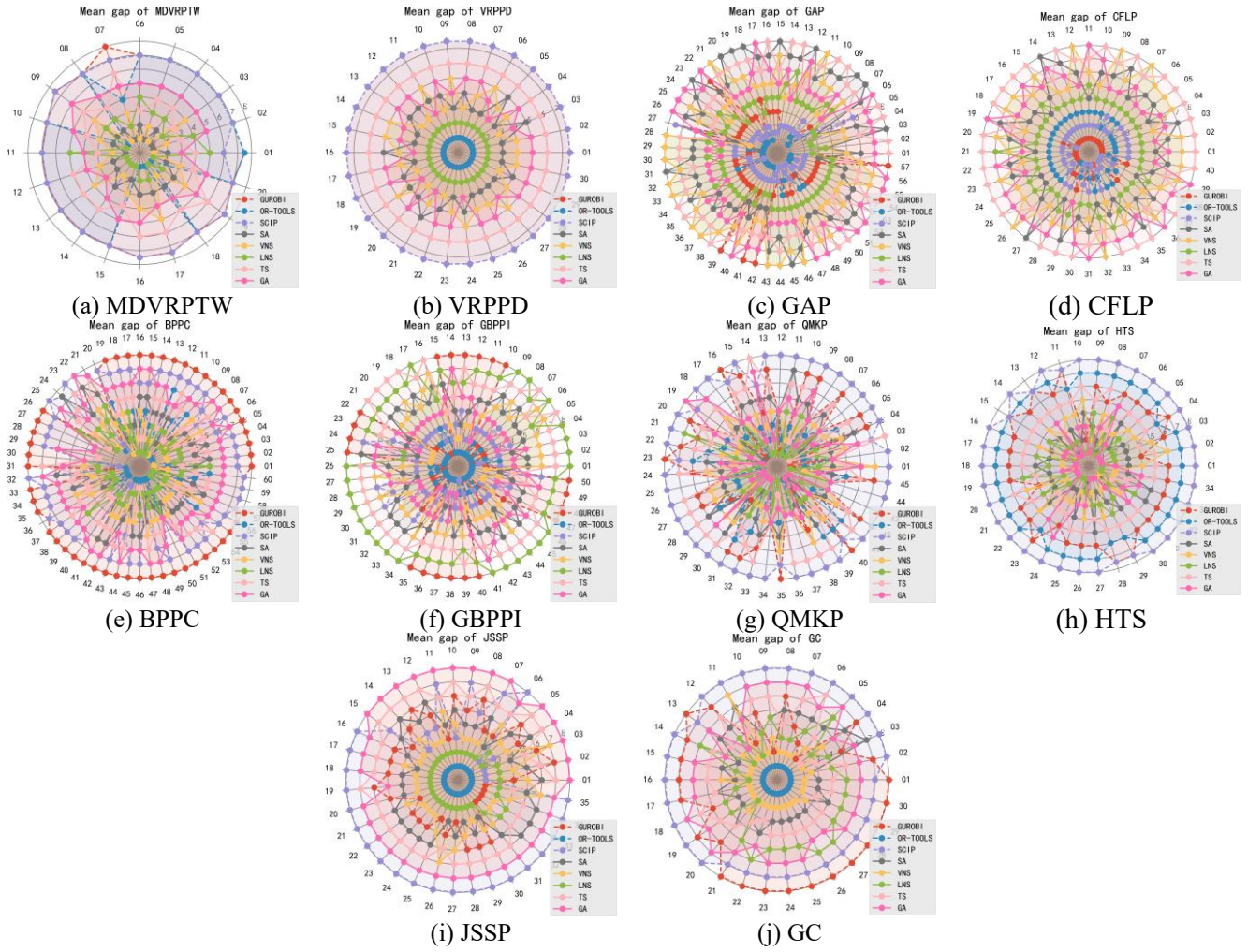
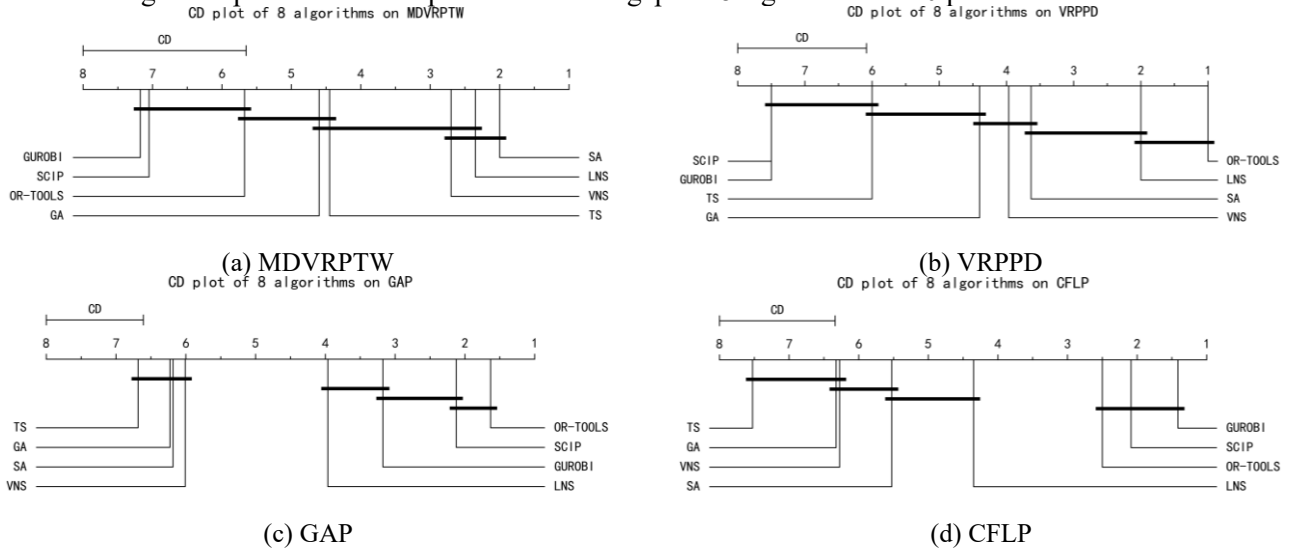
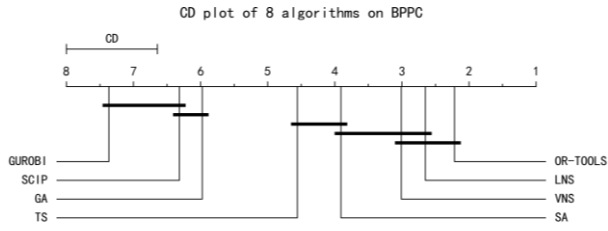


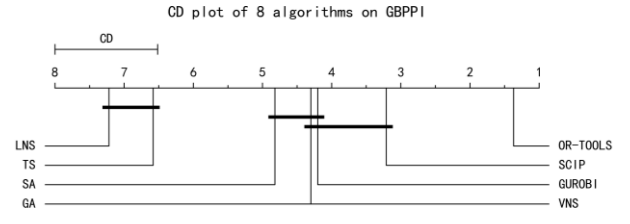
Fig. S-13 Radar chart of mean gap for 8 algorithms on 10 problems.

Fig. S-14 presents the CD plot of the mean gap for 8 algorithms on 10 problems.

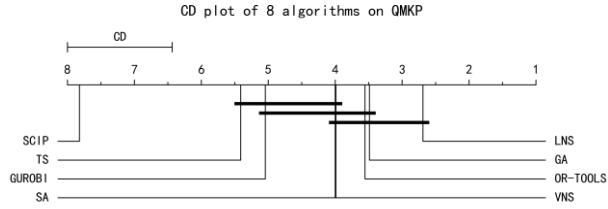




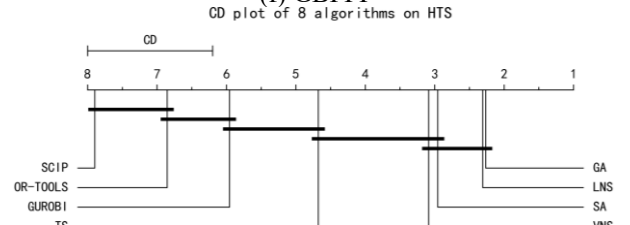
(e) BPPC



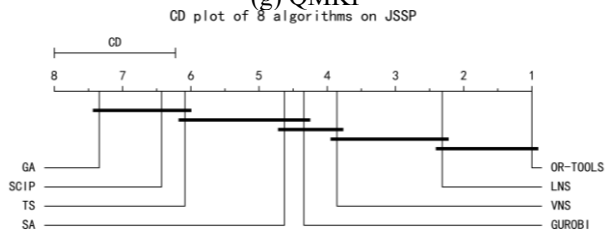
(f) GBPI



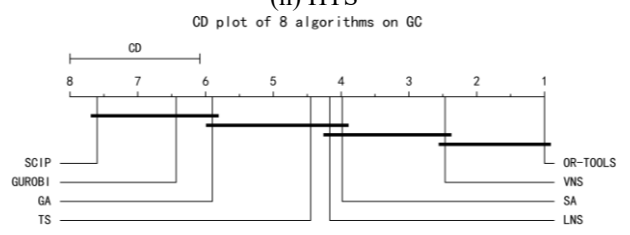
(g) QMKP



(h) HTS



(i) JSSP



(j) GC

Fig. S-14 CD plot of mean gap for 8 algorithms on 10 problems.

Fig. S-15 to Fig. S-24 show the convergence curves for 8 algorithms on 4 typical instances for each problem type.

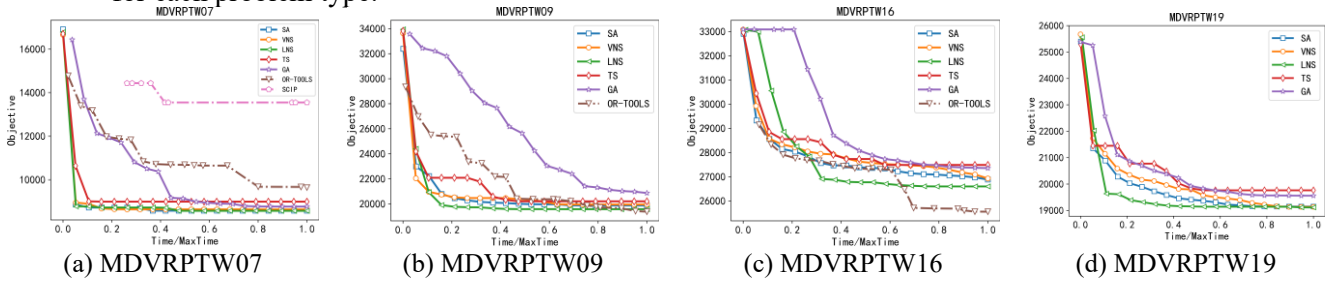


Fig. S-15 Convergence curve for 8 algorithms on 4 typical MDVRPTW instances.

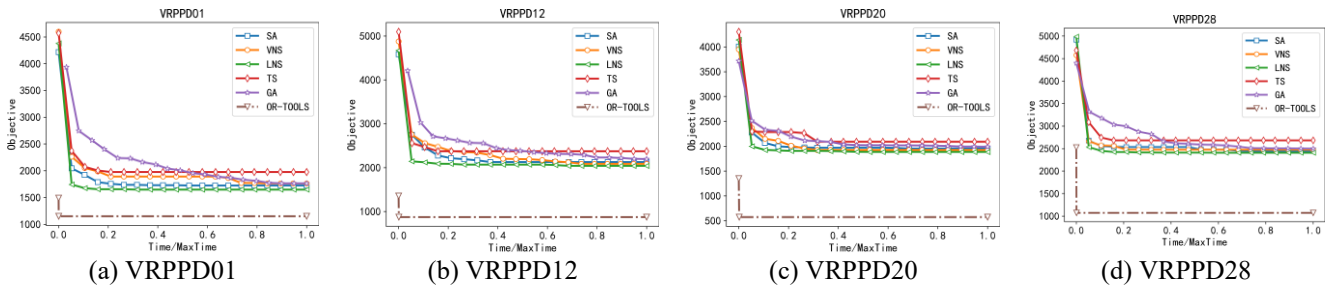
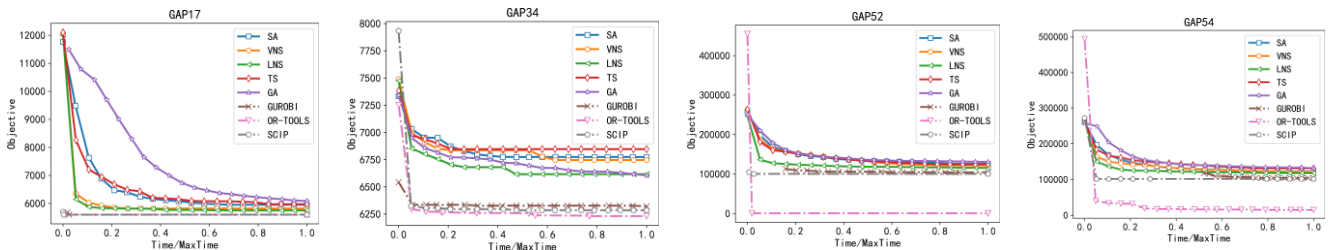


Fig. S-16 Convergence curve for 8 algorithms on 4 typical VRPPD instances.

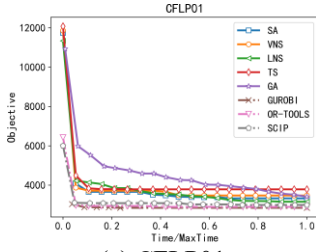


(a) GAP17

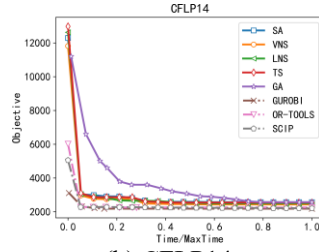
(b) GAP34

(c) GAP52

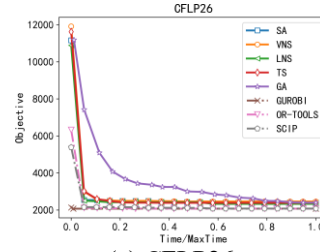
(d) GAP54

Fig. S-17 Convergence curve for 8 algorithms on 4 typical GAP instances.

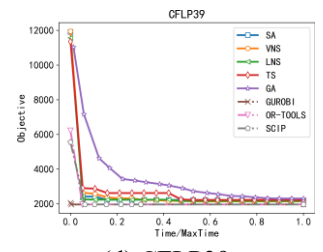
(a) CFLP01



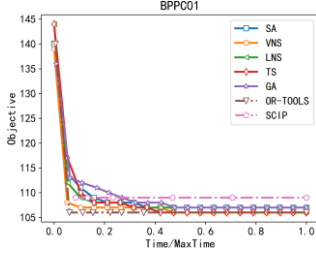
(b) CFLP14



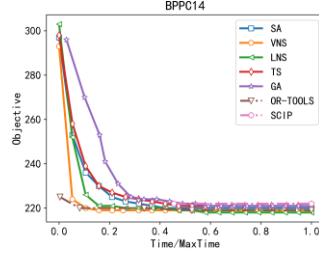
(c) CFLP26



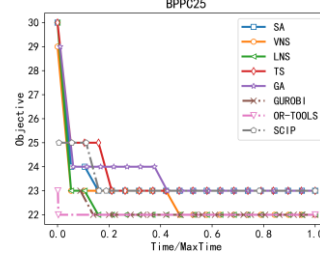
(d) CFLP39

Fig. S-18 Convergence curve for 8 algorithms on 4 typical CFLP instances.

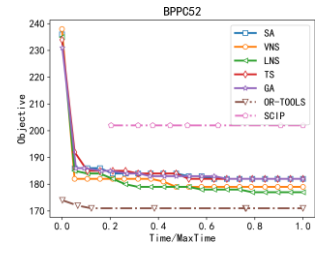
(a) BPPC01



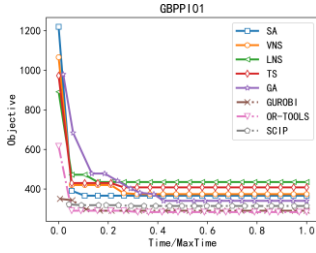
(b) BPPC14



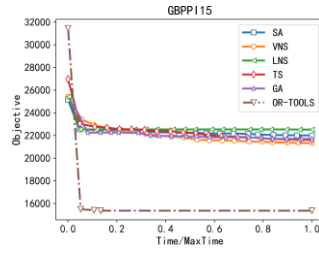
(c) BPPC25



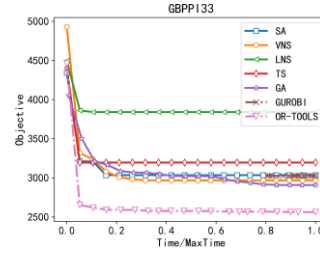
(d) BPPC52

Fig. S-19 Convergence curve for 8 metaheuristic algorithms on 4 typical BPPC problems.

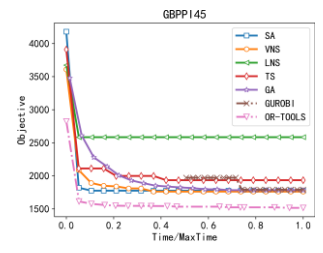
(a) GBPPI01



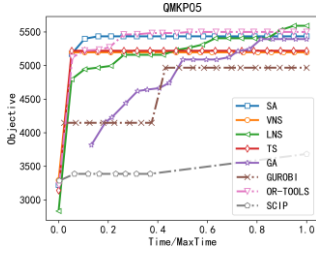
(b) GBPPI15



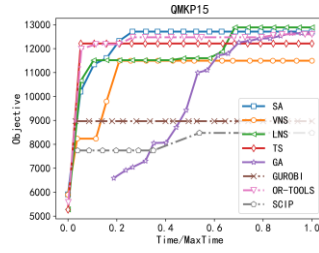
(c) GBPPI33



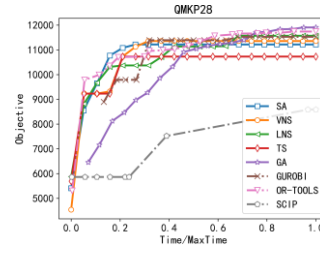
(d) GBPPI45

Fig. S-20 Convergence curve for 8 algorithms on 4 typical GBPPI instances.

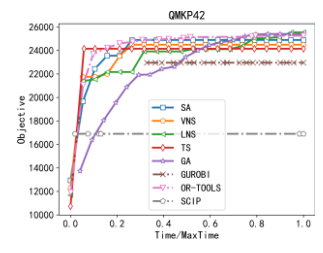
(a) QMKP05



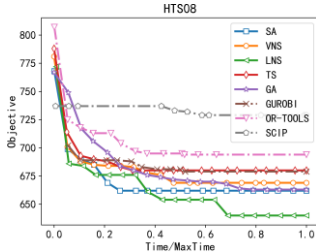
(b) QMKP15



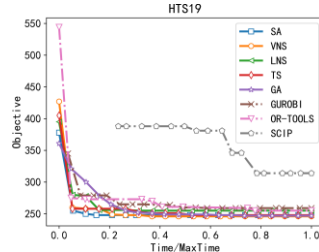
(c) QMKP28



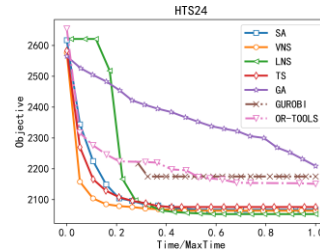
(d) QMKP42

Fig. S-21 Convergence curve for 8 algorithms on 4 typical QMKP instances.

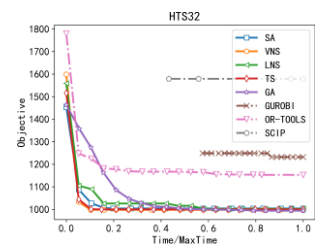
(a) HTS08



(b) HTS19



(c) HTS24



(d) HTS32

Fig. S-22 Convergence curve for 8 algorithms on 4 typical HTS instances.

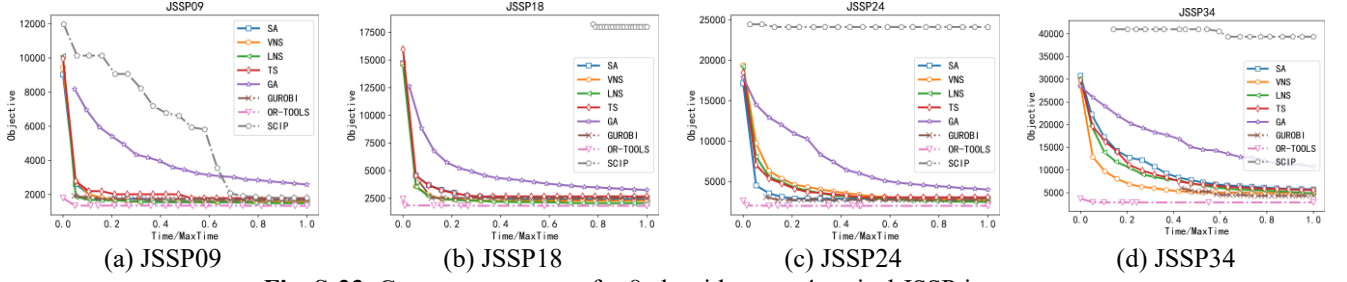


Fig. S-23 Convergence curve for 8 algorithms on 4 typical JSSP instances.

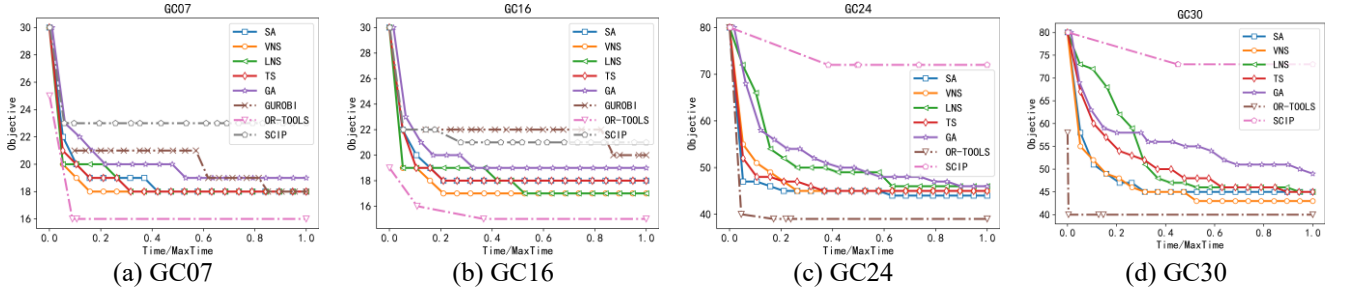


Fig. S-24 Convergence curve for 8 algorithms on 4 typical GC instances.

5.3 Figures for qVNS, aVNS, and rVNS

Fig. S-25 to Fig. S-34 show the convergence curve of objective function values for qVNS, aVNS, and rVNS on 4 typical instances for each problem type.

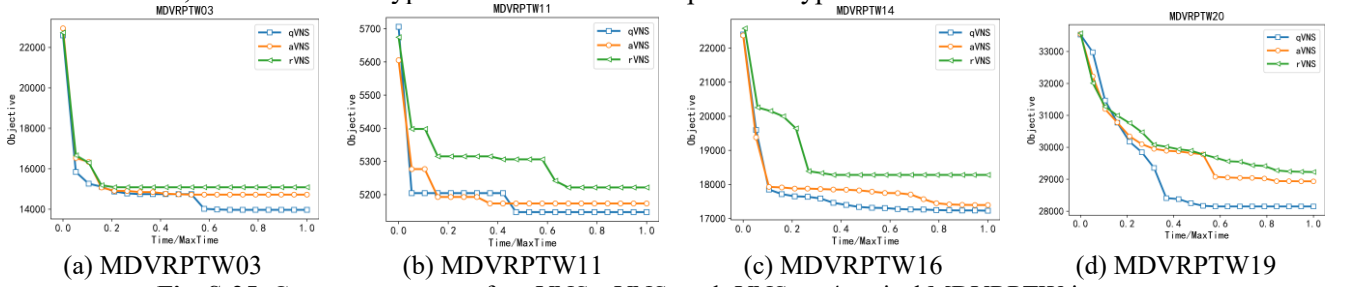


Fig. S-25 Convergence curve for qVNS, aVNS, and rVNS on 4 typical MDVRPTW instances.

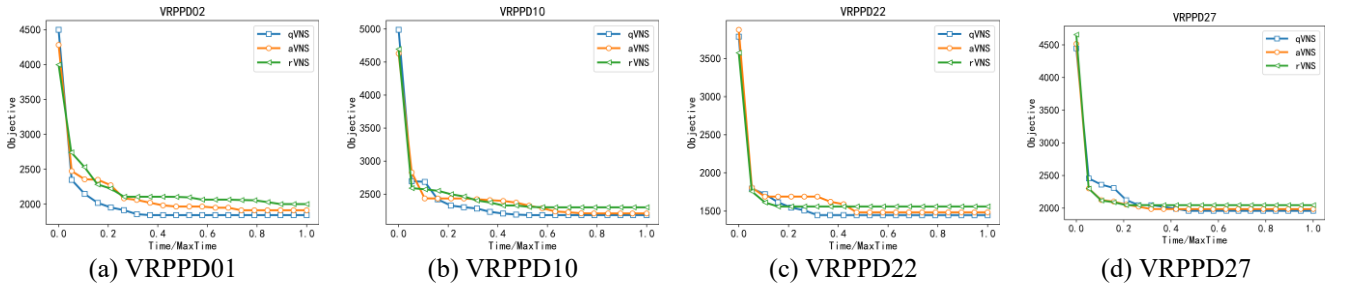


Fig. S-26 Convergence curve for qVNS, aVNS, and rVNS on 4 typical VRPPD instances.

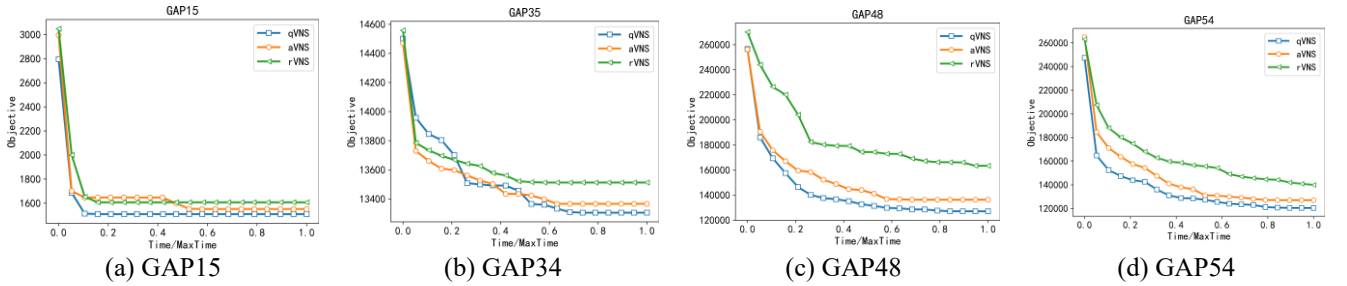


Fig. S-27 Convergence curve for qVNS, aVNS, and rVNS on 4 typical GAP instances.

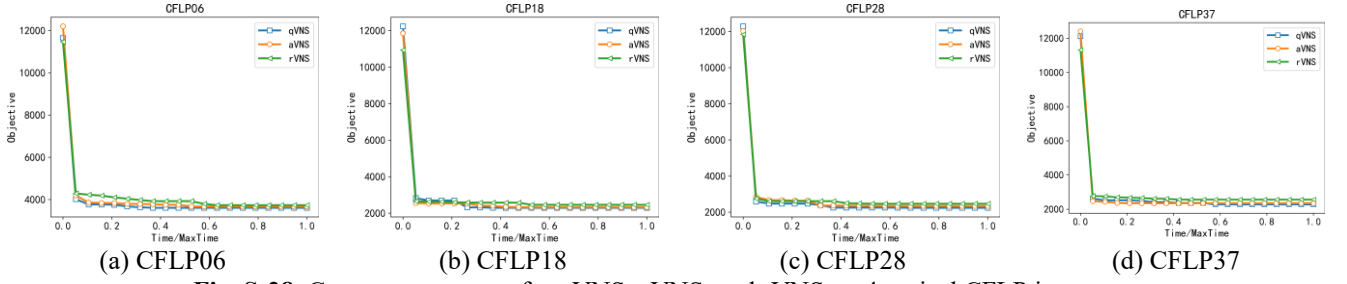


Fig. S-28 Convergence curve for qVNS, aVNS, and rVNS on 4 typical CFLP instances.

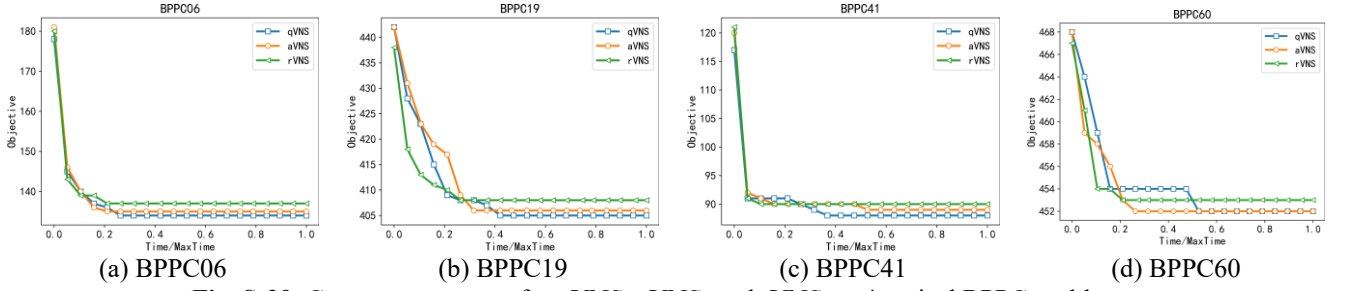


Fig. S-29 Convergence curve for qVNS, aVNS, and rVNS on 4 typical BPPC problems.

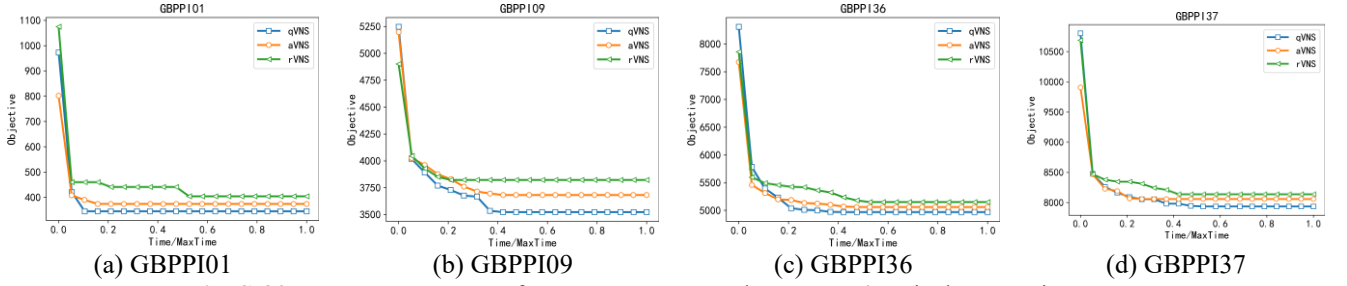


Fig. S-30 Convergence curve for qVNS, aVNS, and rVNS on 4 typical GBPPI instances.

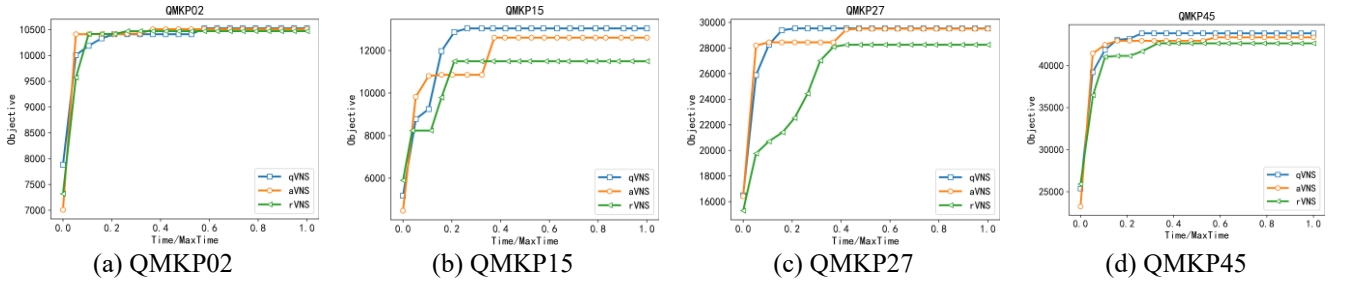


Fig. S-31 Convergence curve for qVNS, aVNS, and rVNS on 4 typical QMKP instances.

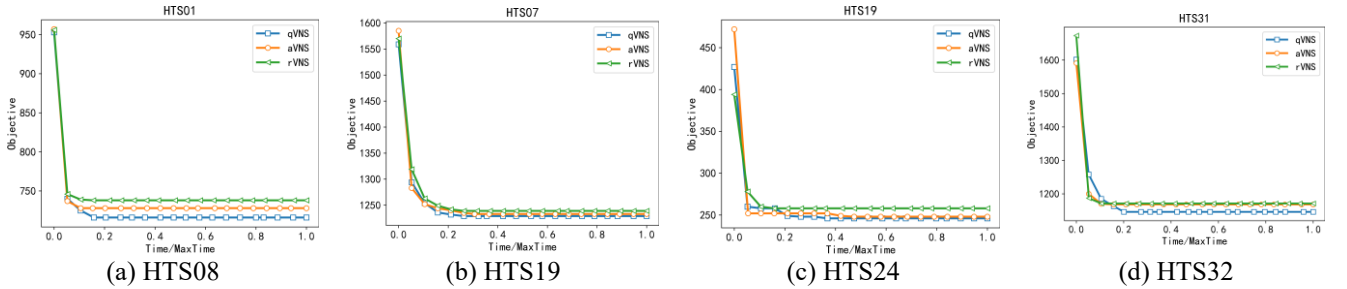


Fig. S-32 Convergence curve for qVNS, aVNS, and rVNS on 4 typical HTS instances.

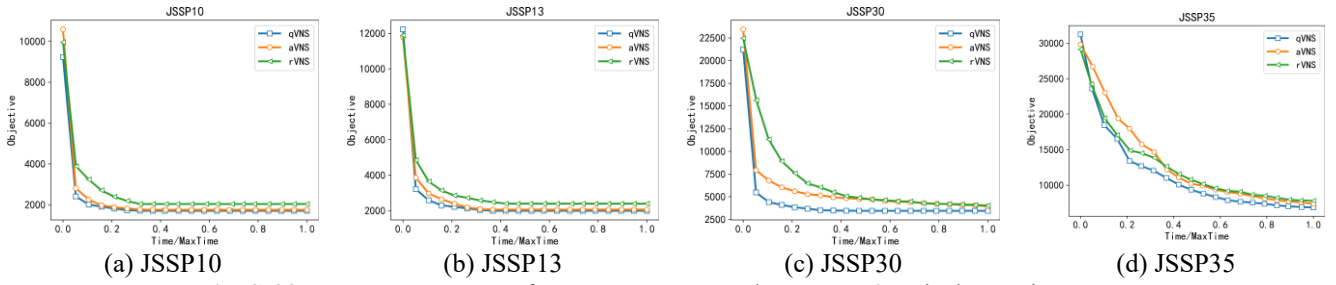


Fig. S-33 Convergence curve for qVNS, aVNS, and rVNS on 4 typical JSSP instances.

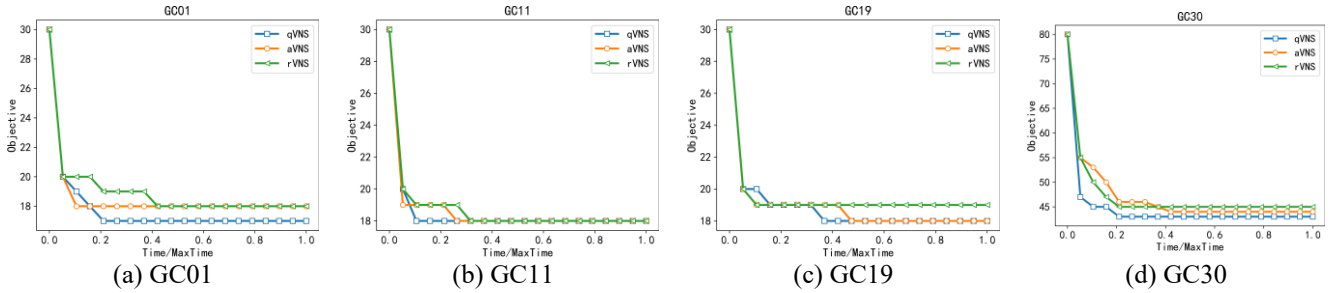


Fig. S-34 Convergence curve for qVNS, aVNS, and rVNS on 4 typical GC instances.

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