EC.1. Proofs of statements

Observation 1. For any forward path $P = (i_0, ..., i_p)$ of G (with at least one arc) there exists a $\mathbf{t} \in \mathcal{T}_K$ maximizing $\tau_p^{\mathbf{t}}(P)$ and one subpath $P' = (i_k, ..., i_h)$ of P (possibly with $h = k$) that satisfy:

1. $t_{ij} = t_{ij}^0 + \delta_{ij}$ on all arcs (i, j) of P', and
2. $\tau_k^{\mathbf{t}}(P) = e_{i_k}$, and
3. $t_{i_h i_{h+1}} = t_{i_h i_{h+1}}^0 + \min\left\{\delta_{i_h i_{h+1}}, r(P, k, h)\right\}$, and $t_{i_s i_{s+1}} = t_{i_s i_{s+1}}^0$, $s = h+1, \ldots, p-1$.

Proof. Consider a $\mathbf{t} \in \mathcal{T}_K$ maximizing $\tau_p^{\mathbf{t}}(P)$ (which exists since $\mathcal{T}_K$ is bounded). Let i_k be the last node visited by P before i_p such that $\tau_{i_k}(\mathbf{t}) = e_{i_k}$ (possibly $i_k = 0$), that is, i_k is a node such that any node i_s visited by P after i_k until i_p has $\tau_s(\mathbf{t}) > e_{i_s}$.

For each arc (i, j), let $\hat{t}_{ij} = t_{ij}^0 + \delta_{ij}$. Consider the sequence of arcs $(i_k, i_{k+1}), ..., (i_{p-1}, i_p)$ traversed by P. Since $\tau_p^{\mathbf{t}}(P)$ is maximized by $\mathbf{t}$ and $\tau_{i_k}(\mathbf{t}) = e_{i_k}$, then either $t_{i_s i_{s+1}} = \hat{t}_{i_s i_{s+1}}, \forall s = k, ..., p-1$, or $\delta(P, k, p) = \Delta$ and $t_{i_h i_{h+1}} > t_{i_h i_{h+1}}^0$ for at least one arc (i_h, i_{h+1}), $k \le h < p$. In the former case, conditions 1. – 3. are obviously satisfied. In the latter case, let (i_h, i_{h+1}), $k \le h < p$, be the last arc of P satisfying $t_{i_h i_{h+1}} > t_{i_h i_{h+1}}^0$ and let P' be the subpath from i_k to i_h. Now, if 1. is satisfied then also 3. is satisfied. So, suppose that 1. is not satisfied. Then, since $\tau_s(\mathbf{t}) > e_{i_s}$ for all $s = k+1, ..., p-1$, there exists another travel time vector $\mathbf{t}' \in \mathcal{T}_K$ which can be obtained from $\mathbf{t}$ by subtracting one unit from $t_{i_h i_{h+1}}$ and adding one unit to another component $t_{i_{h'} i_{h'+1}}$, with $k \le h' < h$, without decreasing $\tau_s(\mathbf{t})$ for any $s = k+1, ..., p$. By repeatedly applying this procedure we can obtain a travel time vector $\mathbf{t}'$ yielding $\tau_{i_p}(\mathbf{t}') \ge \tau_{i_p}(\mathbf{t})$ that satisfies conditions 1. and 3.

Observation 3. Let $\tau_h(P)$ be the nominal departure time at each node i_h of a path $P = (i_0, ..., i_p)$. For any two nodes i_k and i_h, $k < h$, let $w(P, k, h)$ be the sum of the nominal waiting times $w_s(P)$ at the nodes i_s, $s = k+1, \ldots, h$. Then we have:

$$\tau_h^k(P) = \tau_h(P) + \delta(P, k, h) - w(P, k, h), \quad \forall h = 1, \ldots, p, \ \forall k \in \mathcal{I}_h(P).$$

Proof. For any $k \in \mathcal{I}_h(P)$ the departure time $\tau_h^k(P)$ is non-redundant implying that for any $s = k+1, \ldots, h-1$ we have $\tau_s^k(P) > \tau_s(P) \ge e_{i_s}$. Using this fact, definition (4) yields

$$\tau_s^k(P) = \tau_{s-1}^k(P) + t_{i_{s-1} i_s}^0 + \min\left\{r(P, k, s-1), \delta_{i_{s-1} i_s}\right\}, \quad \forall s = k+1, \ldots, h. \tag{6}$$

From this, using the definition of $r(P, \cdot, \cdot)$ we get $\tau_h^k(P) = \tau_k(P) + \sum_{s=k}^{h-1} t_{i_s i_{s+1}}^0 + \delta(P, k, h)$ which can be rewritten as in (6) since by definition of the waiting times $w_s(P)$ we have $\tau_h(P) = \tau_k(P) + \sum_{s=k}^{h-1} t_{i_s i_{s+1}}^0 + w(P, k, h)$.

DOMINANCE 1. Under uncertainty set $\mathcal{T}_K$ a forward path $P = (i_0, \ldots, i_p)$ dominates a forward path $P' = (i'_0, \ldots, i'_{p'})$ if (i) $i'_{p'} = i_p$, (ii) $c^{\mathbf{u}}(P) \leq c^{\mathbf{u}}(P')$, (iii) $\tau(P) \leq \tau(P')$, (iv) $N(P) = N(P')$, and (v) for each $k \in \mathcal{I}(P)$ there exists one $k' \in \mathcal{I}(P')$ such that

1. $\tau(P) + \delta(P, k, p) - w(P, k, p) \leq \tau(P') + \delta(P', k', p') - w(P', k', p')$, and
2. $\tau(P) - w(P, k, p) \leq \tau(P') - w(P', k', p')$

Proof. It is easy to see that if P and P' satisfy conditions (i)–(v) then after extending both P and P' with a same arc those conditions will be satisfied again. Thus, it is enough to show that for any arc (j, v) conditions (i)–(v) guarantee that if the extension $P' \oplus (j, v)$ of P' is feasible then the extension $P \oplus (j, v)$ is also feasible, and has smaller or equal cost.

Note also that (i)–(iv) are the standard DP dominance conditions that are well known to be valid for the TSPTW. Therefore, we only need to consider condition (v). In particular, letting $i'_{p'} = i_p = j$, we will show that condition (v) guarantees that for any possible robust feasible extension $P' \oplus (j, v)$ of P' the extension $P \oplus (j, v)$ is also robust feasible.

Using the definition of the effective delay $d(P, k, h)$ the robust feasibility condition for $P' \oplus (j, v)$ can be written as:

$$\tau_v^k(P') = \tau_v(P') + d(P', k, v) \leq l_v \quad \forall k = 1, ..., |P'| \tag{EC.1}$$

To simplify the notation let $\alpha_{jv}^k(P') = d(P', k, j) + \min\{\Delta - \delta(P', k, j), \delta_{jv}\} - w_v(P')$. Note that $d(P', k, v) = \max\{0, \alpha_{jv}^k(P')\}$. Thus, the feasibility condition (EC.1) can be written as

$$\tau_v^k(P') = \tau_j(P') + t_{jv}^0 + w_v(P') + \max\{0, \alpha_{jv}^k(P')\} \leq l_v, \quad \forall k = 1, ..., |P'|. \tag{EC.2}$$

Let K' be the value of k that maximizes the left hand side of (EC.2). Similarly, let K be the maximizer of the left hand side of (EC.2) when P' is replaced with P. We need to show that $\tau_v^K(P) \leq \tau_v^{K'}(P')$, but notice that we only need to consider the case when $\alpha_{jv}^K(P) > 0$ because otherwise $\tau_v^K(P)$ is the nominal service time at v on P which is clearly less than or equal than $\tau_v^{K'}(P')$ due to (iii).

From (v), taking $k = K$, we know that there is $k' \in \mathcal{I}(P')$ such that $\tau_j(P) + d(P, K, j) \leq \tau_j(P') + d(P', k', j)$ and $\tau_j(P) - w(P, K, j) \leq \tau_j(P') - w(P', k', j)$. We now prove that

$$\tau_j(P) + \alpha_{jv}^K(P) + w_v(P) \leq \tau_j(P') + \alpha_{jv}^{k'}(P') + w_v(P'). \tag{EC.3}$$

To see that (EC.3) holds, let $q_{Kj} = \min\{\Delta - \delta(P, K, j), \delta_{jv}\}$ and let $q_{k'j} = \min\{\Delta - \delta(P', k', j), \delta_{jv}\}$. Consider the following two possible cases.

- If $q_{Kj} = \Delta - \delta(P,K,j)$, then we can write $\tau_j(P) + \alpha^K_{jv}(P) + w_v(P) = \tau_j(P) + d(P,K,j) + \Delta - \delta(P,K,j) = \tau_j(P) - w(P,K,j) + \Delta$. Now, if $q_{k'j} = \Delta - \delta(P',k',j)$ then using the same observation we see that (EC.3) reduces to $\tau_j(P) - w(P,K,j) + \Delta \le \tau_j(P') - w(P',k',j) + \Delta$ which holds true due to point 2. of condition (v). Otherwise, we have $q_{k'j} = \delta_{jv}$ and (EC.3) can be written as $\tau_j(P) + d(P,K,j) + \Delta - \delta(P,K,j) \le \tau_j(P') + d(P',k',j) + \delta_{jv}$. Since $q_{Kj} = \Delta - \delta(P,K,j)$ we have $\Delta - \delta(P,K,j) \le \delta_{jv}$ and thus (EC.3) holds true due to point 2. of condition (v).
- If $q_{Kj} = \delta_{jv}$, then we can write $\tau_j(P) + \alpha^K_{jv}(P) + w_v(P) = \tau_j(P) + d(P,K,j) + \delta_{jv}$. Now, if $q_{k'j} = \Delta - \delta(P',k',j)$ then (EC.3) reduces to $\tau_j(P) + d(P,K,j) + \delta_{jv} \le \tau_j(P') + d(P',k',j) + \Delta - \delta(P',k',j)$, and since $q_{k'j} = \Delta - \delta(P',k',j)$ we have $\Delta - \delta(P',k',j) \le \delta_{jv} \le \Delta - \delta(P,K,j)$ which implies $\delta(P',k',j) \ge \delta(P,K,j)$. Therefore (EC.3) holds true. On the other hand, if $q_{k'j} = \delta_{jv}$ then (EC.3) reduces to $\tau_j(P) + d(P,K,j) + \delta_{jv} \le \tau_j(P') + d(P',k',j) + \delta_{jv}$ which is true because of point 1. of condition (v).

Finally, we can use (EC.3) together with (iii) which yields:

$$\begin{aligned}\tau^K_v(P) &= \tau_j(P) + t^0_{jv} + \alpha^K_{jv}(P) + w_v(P)\\ &\le \tau_j(P') + t^0_{jv} + \alpha^{k'}_{jv}(P') + w_v(P')\\ &\le \tau_j(P') + t^0_{jv} + \max\{\alpha^{k'}_{jv}(P'), 0\} + w_v(P')\\ &= \tau^{k'}_v(P') \le \tau^{K'}_v(P').\end{aligned} \tag{EC.4}$$

Observation 4. Let $P = (i_0, i_1, ..., i_p)$, $i_0 = 0$, be a robust feasible forward path ending at node i_p. A relaxation of any feasible tour (w.r.t. $\mathcal{T}_K$) that contains P is obtained by appending after P a backward *rng*-path $\hat{P} = (\hat{i}_0, \hat{i}_1, ..., \hat{i}_p)$ of minimum cost that starts from $\hat{i}_0 = i_p = j$ and satisfies:

(i) $N(P) \cap N(\hat{P}) = \{j\}$, where $N(\hat{P})$ is the *ng*-set of $\hat{P}$,

(ii) $\tau^{k'}(\hat{P}) \ge \tau^k(P) - \max\{(\delta(P,k,p) + \delta(\hat{P},0,k') - \Delta), 0\}, \quad \forall k \in \mathcal{I}(P),\ \forall k' \in \mathcal{I}(\hat{P})$.

Proof. For any robust feasible tour that contains P, let $\hat{P}$ be the path corresponding to the portion of the tour from node i_p to $n+1$. Note that $\hat{P}$ is a (elementary) backward *rng*-path. We show that $\hat{P}$ must satisfy (ii) (being obvious that it must satisfy (i)).

By contradiction, suppose that (ii) is not true for some $k \in \mathcal{I}(P)$ and $k' \in \mathcal{I}(\hat{P})$, that is,

$$\tau^{k'}(\hat{P}) < \tau^k(P) - \max\{(\delta(P,k,p) + \delta(\hat{P},0,k') - \Delta), 0\}. \tag{EC.5}$$

We have two cases.

Case 1. $\delta(P,k,p)+\delta(\hat{P},0,k')\leq\Delta$: Then, we can construct a $\mathbf{t}\in\mathcal{T}_K$ such that $\tau^k(P)=\tau^{\mathbf{t}}(P)$ and $\tau^{k'}(\hat{P})=\tau^{\mathbf{t}}(\hat{P})$, and from (EC.5) we have that $\tau^{\mathbf{t}}(P)>\tau^{\mathbf{t}}(\hat{P})$ meaning that the tour is not robust feasible. A contradiction.

Case 2. $\delta(P,k,p)+\delta(\hat{P},0,k')>\Delta$: Then, let $D=\delta(P,k,p)+\delta(\hat{P},0,k')-\Delta$ so that from (EC.5) we have $\tau^k(P)>\tau^{k'}(\hat{P})+D$. Let $A_1=\{(i_k,i_{k+1}),...,(i_{p-1},i_p)\}$ be the set of arcs traversed by P from i_k to i_p, and $A_2=\{(\hat{i}_0,\hat{i}_1),...,(\hat{i}_{k'-1},\hat{i}_{k'})\}$ be the set of arcs of $\hat{P}$ from $\hat{i}_0$ to $\hat{i}_{k'}$.

Consider a travel time vector $\mathbf{t}$ with $t_{ij}\in T_{ij},\ \forall(i,j)\in A,\ t_{ij}=t^0_{ij},\ \forall(i,j)\in A\setminus(A_1\cup A_2)$, and such that $\tau^k(P)=\tau^{\mathbf{t}}(P)$ and $\tau^{k'}(\hat{P})=\tau^{\mathbf{t}}(\hat{P})$. We see that $\mathbf{t}\notin\mathcal{T}_K$ because $\delta(P,k,p)+\delta(\hat{P},0,k')=\Delta+D$ implies $\sum_{(i,j)\in A}(t_{ij}-t^0_{ij})\geq\sum_{(i,j)\in A_1}(t_{ij}-t^0_{ij})+\sum_{(i,j)\in A_2}(t_{ij}-t^0_{ij})=\Delta+D>\Delta$. However, we can decrease by D units the components of $\mathbf{t}$ that correspond to the arcs $A_1\cup A_2$ to obtain a vector $\bar{\mathbf{t}}\in\mathcal{T}_K$. Each unit decrease of a component t_{ij} with $(i,j)\in A_1$ decreases $\tau^{\mathbf{t}}(P)$ by at most one, and each unit decrease of a component t_{ij} with $(i,j)\in A_2$ increases $\tau^{\mathbf{t}}(\hat{P})$ by at most one. Starting from $\mathbf{t}$, which yields $\tau^{\mathbf{t}}(P)-\tau^{\mathbf{t}}(\hat{P})>D$, and removing D units from its components corresponding to arcs $A_1\cup A_2$, we can obtain a $\bar{\mathbf{t}}\in\mathcal{T}_K$ with $D=0$ and such that $\tau^{\bar{\mathbf{t}}}(P)>\tau^{\bar{\mathbf{t}}}(\hat{P})$. This means that the tour is not robust feasible. A contradiction.

So, any robust feasible tour containing P has the form $P\oplus\hat{P}$ where $\hat{P}$ is a backward *rng*-path from j to $n+1$ (with j being the end node of P) that must satisfy (i) and (ii).

EC.2. Algorithm's modifications required to solve RTSPTW($\mathcal{T}_C$)

This section describes modifications to the DP algorithm of Section 6 that are needed for solving RTSPTW($\mathcal{T}_C$). We first provide a characterization of robust feasibility that is valid for $\mathcal{T}_C$ and then explain how to tailor steps 4.a, 4.b, 4.c and 4.d of the DP Algorithm 1 when using uncertainty set $\mathcal{T}_C$.

EC.2.1. Robust feasibility with respect to $\mathcal{T}_C$

A robust (multi-vehicle) routing problem with uncertainty set $\mathcal{T}_C$ was studied by Agra et al. (2013) and subsequently by Munari et al. (2019). In particular, Agra et al. provided an $O(n\Gamma)$ algorithm for testing the robust feasibility of a path $P=(i_0,...,i_p)$ that can be described as follows. Let $\tau^\gamma_h(P)$ be the earliest departure time from node i_h of P with respect to any travel time vector $\mathbf{t}\in\mathcal{T}_C$ where γ arcs (i,j) traversed by the subpath $(i_h,...,i_p)$ can have $t_{ij} = t^0_{ij} + \delta_{ij}$. More briefly, we say that $\tau^\gamma_h(P)$ is the departure time of P from i_h when γ arcs of P can have delay. The entire set of departure times $\tau^\gamma_h(P)$ can be computed by the recursion:

$$\tau^\gamma_h(P) = \max\{\tau^\gamma_{h-1}(P), \tau^{\gamma-1}_{h-1}(P) + t^0_{i_{h-1}i_h} + \delta_{i_{h-1}i_h}\} \quad \forall h = 1,\dots,p,\ \forall \gamma = 1,\dots \Gamma_h \qquad \text{(EC.6)}$$

where $\Gamma_h = \min\{\Gamma, h\}$ and we initialize $\tau^0_h(P) = \tau_h(P)$ for all $h = 0,\dots,p$. Path P is robust feasible if $\tau^{\Gamma_h}_h(P) \le l_{i_h}$, $\forall h = 1,\dots,p$. In this case, we define for each node i_h of P the set $\mathcal{S}_h(P)$ of non-redundant departure times from i_h as the set of all $\tau^\gamma_h(P)$, $\gamma = 1,\dots,\Gamma_h$, such that there is no $\gamma' < \gamma$ yielding $\tau^{\gamma'}_h(P) \ge \tau^\gamma_h(P)$ (note that $\mathcal{S}_h(P)$ includes $\tau_h(P)$).

To simplify the notation, in the following we drop the subscript p from $\tau^\gamma_p(P)$, $\mathcal{S}_p(P)$ and $\mathcal{I}_p(P)$ when $P = (i_0,...,i_p)$ is a forward path ending with last node i_p.

EC.2.2. Feasibility test and dominance with respect to $\mathcal{T}_C$

Under uncertainty set $\mathcal{T}_C$ an extension of a path $P = (i_0,\dots,i_{p-1})$ with an arc (i_{p-1}, i_p) at Step 4.*a* of Algorithm 1 is tested for feasibility by using recursion (EC.6) with $i_h = i_p$.

With regard to the dominance tests at Steps 4.*c* and 4.*d*, the dominance rule described in Section 6.1 cannot be used. However, Munari et al. (2019) proposed a valid dominance that they used within a DP algorithm to generate routes for the Robust Vehicle Routing Problem with Time Windows under uncertainty set $\mathcal{T}_C$. This dominance rule is also valid for the robust TSPTW with uncertainty set $\mathcal{T}_C$. Our algorithms use the following slight generalization of that rule.

Dominance 2 *A forward path* $P = (i_0,\dots,i_p)$ *dominates a forward path* $P' = (i'_0,\dots,i'_{p'})$ *if (i)* $i'_{p'} = i_p$, *(ii)* $c^{\mathbf{u}}(P) \le c^{\mathbf{u}}(P')$, *(iii)* $\tau(P) \le \tau(P')$, *(iv)* $N(P) \subseteq N(P')$, *(v)* $\tau^\gamma(P) \le \tau^\gamma(P')$ $\forall \gamma = 1,\dots,\min\{\Gamma_p, \Gamma_{p'}\}$ *and (vi)* $\tau^\gamma(P) \le \tau^{\gamma'}(P')$ *where* $\gamma = \Gamma_p$ *and* $\gamma' = \Gamma_{p'}$.

Note however that when Algorithm 1 is used to generate an optimal tour condition (*iv*) of Dominance 2 must be modified to $N(P) = N(P')$ and condition (*v*) reduces to $\tau^\gamma(P) \le \tau^\gamma(P')$, $\forall \gamma = 1,\dots,\Gamma_p$. In this case, Dominance 2 coincides with that of Munari et al. (2019). We do not provide a formal proof for the correctness of Dominance 2 as it is a straightforward extension of Proposition 4.1 of Munari et al. (2019).

EC.2.3. Computation of $lb(P)$ for a forward rng-path P under uncertainty set $\mathcal{T}_C$

The only difference with respect to the method described in Section 6.2.1 is that the index k^* used to compute the earliest departure time $\tau^{k^*}(P)$ of the backward ng-paths included in the set $\mathcal{B}(P)$ is computed as $k^* = \Gamma_p$.

EC.2.4. Computation of $lb(P)$ for a forward path P under uncertainty set $\mathcal{T}_C$

Under uncertainty set $\mathcal{T}_C$ a backward *rng*-path $\hat{P} = (\hat{i}_0, \hat{i}_1, ..., \hat{i}_p)$ is associated with a set of departure times $\tau_h^\gamma(\hat{P})$, $\forall h = 0, \dots, p-1$, $\forall \gamma = 0, \dots, \Gamma_{p-h+1} = \min\{\Gamma, p-h+1\}$, each representing the worst-case departure time from node $\hat{i}_h$ that is feasible with respect to a travel time vector $\mathbf{t} \in \mathcal{T}_C$ where γ arcs (i,j) of the subpath $(\hat{i}_h, ..., \hat{i}_p)$ have $t_{ij} = t_{ij}^0 + \delta_{ij}$. These times can be computed using recursion (EC.6) in a backward manner. Path $\hat{P}$ is robust feasible if $\tau_h^{\hat{\gamma}}(\hat{P}) \geq e_{\hat{i}_h}$, $\forall h = 0, \dots, p-1$, $\hat{\gamma} = \Gamma_{p-h+1}$.

Let $P = (i_0, i_1, ..., i_p)$ be a robust feasible forward path ending at node $i_p = j$. To compute $lb(P)$ with respect to $\mathcal{T}_C$ we can adapt Observation 4 in a straightforward way by replacing condition (ii) with the following:

$$\tau^\gamma(P) - \tau^{\bar{\gamma}}(\hat{P}) \geq 0, \quad \forall \gamma = 1, \dots, \Gamma_p, \tag{EC.7}$$

where $\bar{\gamma} = \Gamma - \gamma$ and $\tau^{\bar{\gamma}}(\hat{P}) = \tau_0^{\bar{\gamma}}(\hat{P})$ is the worst-case departure time from the first node $\hat{i}_0$ of the backward path $\hat{P}$ when $\bar{\gamma}$ of its arcs can have maximum delay.

Thus, a lower bound $lb(P)$ on the smallest cost of a tour containing P is obtained by adding to the cost of P the smallest cost of a backward *rng*-path $\hat{P}$ that starts from i_p and satisfies $N(P) \cap N(\hat{P}) = \{j\}$ (where in $N(\hat{P})$ denotes the *ng*-set of $\hat{P}$) plus condition (EC.7). However we actually use a weaker version of condition (EC.7) that only considers $\gamma = \Gamma_p$.

Accordingly, let $\mathcal{Q}$ be the set of all backward *rng*-paths $\hat{P}$, computed with respect to $\mathcal{T}_C$ using Algorithm 1, that have a modified cost (i.e., cost computed with respect to the modified arc costs $c_{ij}^{\mathbf{u}}$) less than *gap*. Let $\mathcal{Q}(P) \subseteq \mathcal{Q}$ be the subset of backward *rng*-paths $\hat{P}$ starting from $\hat{i}_0 = i_p$ and satisfying condition (ii) of Observation 4 plus condition (EC.7) for $\gamma = \Gamma_p$. Algorithm 1 computes the label $lb(P)$ of path P as follows:

$$lb(P) = c^{\mathbf{u}}(P) + \min_{\hat{P} \in \mathcal{Q}(P)} c^{\mathbf{u}}(\hat{P}). \tag{EC.8}$$

Note that the set $\mathcal{Q}$ must be pre-computed before running the DP Algorithm 1 in Phase 2 of the exact algorithm.

EC.3. Further algorithmic details

This section provides some algorithmic details that were omitted in the main paper for the sake of brevity. Specifically, the first two subsections detail the components of the lower bounding procedure used in Phase 1 by the exact algorithm of Section 5 (regardless of the uncertainty set considered). The last section describes heuristic speedups used by the DP algorithm of Section 6 for testing Dominance 1 and 2 with regard to uncertainty set $\mathcal{T}_K$ and $\mathcal{T}_C$, respectively.

EC.3.1. Description of Step 1 of the lower bounding procedure

The Lagrangean dual used at Step 1 is obtained from CSP by dualizing all constraints (8) except the one of node $i=0$, and is solved approximately by executing a limited number ν of iterations of the subgradient algorithm. Letting λ be a penalty vector associated with constraints (8) where $\lambda_0=0$, and defining $c^{\lambda}_{ij}=c_{ij}-\frac{1}{2}\lambda_i-\frac{1}{2}\lambda_j$, $\forall(i,j)\in A$, (with the convention $\lambda_{n+1}=0$), the Lagrangean problem solved at each iteration is to find a *rng*-tour of minimum cost with respect to costs c^{λ}_{ij}. The main operations at each iteration are the following.

The DP algorithm of Section 1 is run with input parameters $\mathbf{u}=\lambda$, $\eta=1$ and $gap=\infty$ to find a tour $P^{\lambda}=(i_0=0,i_1,...,i_p=n+1)$ of minimum modified cost $c^{\lambda}(P^{\lambda})=\sum_{k=0}^{p-1}c^{\lambda}_{i_k i_{k+1}}$. Let α_i be the number of times that P^{λ} visits node i. A lower bound on the optimal cost of CSP is computed as $L(\lambda)=c^{\lambda}(P^{\lambda})+\sum_{i=0}^{n}\lambda_i$, and tour P^{λ} is made elementary (removing eventual multiple visits to each node) and stored in a set $\mathcal{P}$. A subgradient $\mathbf{s}$ is calculated as $s_i=1-\alpha_i$, $\forall i=1,...,n$ and the penalties are updated as $\lambda_i:=\lambda_i+\theta s_i$, $i=1,...,n$, where θ is computed as (see, e.g., Baldacci et al. 2008):

$$\theta=\phi\frac{0.2\cdot lb}{\sum_{i=1}^{n}s_i^2}. \tag{EC.9}$$

The value of ϕ is initialized equal to 1.99 and multiplied by 0.999 at each iteration.

EC.3.2. Description of Step 2 of the lower bounding procedure

Step 2 is based on the following theorem from Baldacci et al. (2012) that we restate here. We refer to Baldacci et al. (2012, 2008) and references therein for a proof and the rationale behind the lower bounding procedure described below.

Theorem 1 *Let $\lambda_j\in\mathbb{R}$, $j=0,...,n$ and let $\bar{\mathcal{L}}\subseteq\mathcal{L}$ be the index-set of any subset of rng-tours that correspond to columns of CSP. The following is a feasible solution to the dual of CSP:*

$$u_j=\min_{\ell\in\bar{\mathcal{L}}_j}\left\{\frac{c^{\lambda}_{\ell}}{a(\ell)}\right\}+\lambda_j,\ \forall j=1,...,n \quad \textit{and} \quad u_0=\lambda_0 \tag{EC.10}$$

where $\bar{\mathcal{L}}_j \subseteq \mathcal{L}$ indexes the subset of tours visiting j, c^{λ}_{ℓ} is the cost of rng-tour P_ℓ with respect to costs c^{λ}_{ij}, $a_{j\ell}$ equals the number of times that P_ℓ visits j and $a(\ell) = \sum_{j=1}^{n} a_{j\ell}$. The cost of solution $\mathbf{u}$ computed as above equals $\bar{L}(\lambda) = \sum_{j=0}^{n} u_j$.

Step 2 executes a dual ascent procedure that starts with a vector $\lambda = (\lambda_0, ..., \lambda_n)$ of Lagrangean multipliers and the set $\mathcal{P}$ of tours collected at Step 1 (plus the best tour found by the GVNS). Let $\bar{\mathcal{L}}$ be the index set of the *rng*-tours in $\mathcal{P}$ and let $\bar{\texttt{CSP}}$ denote CSP where $\mathcal{L}$ is replaced with $\bar{\mathcal{L}}$. The procedure executes a pre-defined number ν_1 of macro-iterations.

At each macro-iteration, ν_2 iterations of the subgradient algorithm are executed to approximately maximize $\bar{L}(\lambda)$. At each such iteration, $\mathbf{u}$ is computed using (EC.10), and a subgradient at point λ is computed as $s_i = 1 - \sum_{j=1}^{n} \frac{a_{i\ell_j}}{a(\ell_j)}$, $\forall i = 0, ..., n$, where $\ell_j \in \bar{\mathcal{L}}_j$ is the index of the tour that minimizes the right hand side of (EC.10). The penalty vector λ is then updated as in Step 1 (see Section EC.3.1), but here the value of parameter ϕ is initialized equal to 1.5 and multiplied by 0.9 after any sequence of 60 iterations where the value $\bar{L}(\lambda)$ does not increase with respect to the largest found so far.

After the ν_2 iterations let $\bar{\mathbf{u}}$ be the best (i.e., with largest cost) dual solution found. The pricing problem is solved by the DP algorithm of Section 6 with input parameters $\mathbf{u} = \bar{\mathbf{u}}$, $\eta = 600$ and $gap = -0.00001$, and all the *rng*-tours it finds are added to $\mathcal{P}$. If no tours are found, then $\bar{\mathbf{u}}$ is feasible for the dual of CSP and its cost is a valid lower bound on $z(\texttt{CSP})$.

After the ν_1 macro-iterations, the best feasible dual solution of CSP that was found, say $\tilde{\mathbf{u}}$, is returned. The best lower bound found by Step 2 is the cost of $\tilde{\mathbf{u}}$.

EC.3.3. Heuristic speedup of Dominance 1 and 2

This section describes how the tests for Dominance 1 and 2 are heuristically made faster by the DP algorithm used at Step 2 of the lower bounding procedure (see Section EC.3.2).

1. When solving RTSPTW($\mathcal{T}_K$), Dominance 1 is used. Let $P = (i_0, ..., i_p)$ and $P' = (i'_0, ..., i'_{p'})$ be the two paths to be compared (P' being the candidate for being dominated) and suppose that conditions (i) – (iv) are satisfied. Let $k_1 = \arg\max_{k \in \mathcal{I}(P)} \{\delta(P,k,p) - w(P,k,p)\}$ be the scenario yielding maximum effective delay at i_p for path P. Let also $k_2 = \arg\min_{k \in \mathcal{I}(P)} \{w(P,k,p)\}$ be the scenario yielding minimum cumulated waiting time at i_p for path P.

   The heuristic dominance replaces condition (v) with:

   - $\tau(P) + \delta(P,k_1,p) - w(P,k_1,p) \leq \tau_{p'}(P') + \delta(P',k'_1,p') - w(P',k'_1,p')$ and

- $\tau(P) - w(P,k_2,p) \le \tau_{p'}(P') - w(P',k_2',p')$

2. When solving RTSPTW($\mathcal{T}_C$), Dominance 2 is used. Let $P = (i_0,...,i_p)$ and $P' = (i_0',...,i_p')$ be the two paths to be compared (P' being the candidate to be dominated) and suppose that conditions (i) – (iv) and (vi) are satisfied. The heuristic dominance replaces condition (v) with $\tau^{\bar{\gamma}}(P) \le \tau^{\bar{\gamma}}(P')$ where $\bar{\gamma} = \min\{\Gamma_p, \Gamma_{p'}\}$.

In both cases, at the first iteration in which the DP algorithm uses the heuristic dominance, but fails to find a *rng*-tour of negative reduced cost the heuristic is (permanently) disabled and the DP algorithm is executed again.

EC.4. Graph preprocessing

This section explains the preprocessing steps that we use to a-priori tighten time windows and remove infeasible arcs. Note that these preprocessing steps differ depending on the uncertainty set used, as is detailed below.

To pre-process the graph at the beginning of Phase 1 of the exact algorithm, the following steps are iteratively applied. Preprocessing stops after an iteration where no change to the graph G occurs (one iteration consists of executing all the steps below).

We use the following notation. For each arc $(i,j) \in A$ we denote by t_{ij}^0 its nominal travel time and by $\hat{t}_{ij} = t_{ij}^0 + \delta_{ij}$ its peak travel time (where we assume $\delta_{ij} \le \Delta$). Moreover, for any two nodes i and j (not necessarily adjacent), we denote by s_{ij} the minimum cost of a path in G from i to j that is computed using as arc costs the nominal travel times t_{ij}^0. Finally, we write $i \prec j$ to indicate that node i must precede j in any solution.

Time windows tightening:

1. Let $\bar{e}_i := \min_{\substack{(j,i)\in A \\ j\neq n+1}} \{e_j + t_{ji}^0\}$ and set $e_i := \max\{\bar{e}_i, e_i\}$, $\forall i \in N \setminus \{0, n+1\}$.
2. Let $\bar{e}_i := \min\{l_i, \min_{\substack{(i,j)\in A \\ j\neq 0,n+1}} \{e_j - \hat{t}_{ij}\}\}$ and set $e_i := \max\{\bar{e}_i, e_i\}$, $\forall i \in N \setminus \{0, n+1\}$.
3. Let $\bar{l}_i := \max\{e_i, \hat{t}_{0i}, \max_{\substack{(j,i)\in A \\ j\neq 0,n+1}} \{l_j + \hat{t}_{ji}\}\}$ and set $l_i := \min\{\bar{l}_i, l_i\}$, $\forall i \in N \setminus \{0\}$.
4. Let $\bar{l}_i := \max_{\substack{(i,j)\in A \\ j\neq 0}} \{l_j - t_{ij}^0\}$ and set $l_i := \min\{\bar{l}_i, l_i\}$, $\forall i \in N \setminus \{0, n+1\}$.

Simple arc eliminations:

1. Remove from A all arcs (i,j) such that $e_i + \hat{t}_{ij} > l_j$.

Minimum delay paths:

This step differs depending on the uncertainty set used. Its purpose is to compute, for each pair of nodes i, $j \in N$, a lower bound on the amount of delay that can be incurred in a worst-case scenario when traveling from i to j (not necessarily directly).

1. With uncertainty set $\mathcal{T}_K$, a lower bound $\hat{\delta}_{ij}$ on the amount of delay from i to j can be computed simply as $\hat{\delta}_{ij} = \min\{\Delta, \delta^*_{ij}\}$ where δ^*_{ij} is the cost of a shortest path from i to j in G that is computed using as arc costs the values δ_{ij}.
2. With uncertainty set $\mathcal{T}_C$, let the γ-delay of a path P_{ij} from i to j be the quantity $\max_{S\subseteq A(P_{ij}),|S|\leq\gamma}\{\sum_{(i,j)\in S}\delta_{ij}\}$, $\forall\gamma = 0,...,\min\{|A(P_{ij})|,\Gamma\}$, where $A(P_{ij})$ is the set of arcs traversed by P_{ij}. We denote by $\hat{\delta}_{ij}(\gamma)$ the minimum γ-delay of any path in G from i to j. Once fixed a start node s, the values $\hat{\delta}_{si}(\gamma)$ for all nodes $i \in N$ and all budget values γ can be computed by solving a dynamic programming recursion. Let $f_s(i,k,\gamma)$ be the γ-delay of a path P_{si} from s to i traversing k arcs. The recursion is the following:

$$f_s(i,k,\gamma) = \begin{cases} \min\limits_{(j,i)\in A} \{\max\{f_s(j,k-1,\gamma), f_s(j,k-1,\gamma-1)+\delta_{ji}\}\} & \texttt{if } 1 \leq \gamma \leq k-1 \\ \min\limits_{(j,i)\in A} \{f_s(j,k-1,\gamma-1)+\delta_{ji}\} & \texttt{if } \gamma = k \\ \min\limits_{(j,i)\in A} \{f_s(j,k-1,0)\} & \texttt{if } \gamma = 0 \end{cases}$$
$$\forall k = 1,...,|N|-1,\ \forall i \in N\setminus\{s\},\ \forall\gamma = 0,...,\min\{\Gamma,k\}.$$

   where we assume the initialization $f_s(s,0,0) = 0$, $f_s(s,0,\gamma) = \infty$, $\forall\gamma = 1,...,\Gamma$, and $f_s(i,0,\gamma) = \infty$, $\forall i \in N\setminus\{s\}$, $\forall\gamma = 0,...,\Gamma$. Then, $\hat{\delta}_{sj}(\gamma)$ equals $\min_{k=1,...,n} f(j,k,\gamma)$.

In the next two steps, first precedences between nodes are determined. Then, arcs are eliminated based on those precedences and by using conditions derived from time windows and the minimum delay paths determined in the previous step.

Precedence lists:

1. Compute the shortest path costs s_{ij} between all pairs of nodes.
2. For each pair of nodes i and j add precedence $i \prec j$ if either $e_j + s_{ji} + \hat{\delta}_{ji} > l_i$ and the uncertainty set $\mathcal{T}_K$ is considered, or $e_j + s_{ji} + \hat{\delta}_{ji}(\Gamma) > l_i$ and the set $\mathcal{T}_C$ is considered.
3. For each pair of nodes i and j such that $i \prec k$ and $k \prec j$ for some $k \in N$ add the precedence $i \prec j$. This step is iteratively repeated until no new precedences are detected.

Arc eliminations due to precedences:

1. Remove from A all arcs (i,j) such that $j \prec i$, or $i \prec k \prec j$ (k must be served between i and j) for some $k \in N$.
2. If using uncertainty set $\mathcal{T}_K$, then remove from A all arcs (i,j) such that:
   - $k \prec i$ or $k \prec j$ or $e_i + t^0_{ij} + s_{jk} + \min\{\Delta, \delta_{ij} + \hat{\delta}_{jk}\} > l_k$

   and

   - $i \prec k$ or $j \prec k$ or $e_k + s_{ki} + t^0_{ij} + \min\{\Delta, \hat{\delta}_{ki} + \delta_{ij}\} > l_j$

   for some $k \in N$.
3. If using uncertainty set $\mathcal{T}_C$, then remove from A all arcs (i,j) such that:
   - $k \prec i$ or $k \prec j$ or $e_i + \hat{t}_{ij} + s_{jk} + \hat{\delta}_{jk}(\max\{\Gamma - 1, 0\}) > l_k$ or $e_i + t^0_{ij} + s_{jk} + \hat{\delta}_{jk}(\Gamma) > l_k$

   and

   - $i \prec k$ or $j \prec k$ or $e_k + s_{ki} + \hat{t}_{ij} + \hat{\delta}_{ki}(\max\{\Gamma - 1, 0\}) > l_j$ or $e_k + s_{ki} + \hat{\delta}_{ki}(\Gamma) + t^0_{ij} > l_j$

   for some $k \in N$.

EC.5. Characteristics of the new instances

In this section, we give details on how the instances used in this paper were created. The next subsection explains the creation process of the new RTSPTW instances of sets GDE-D and GDE-I and provides some insight on their data. The following one describes how we generated the random instances used for the tradeoff analysis reported in Section 7.5.

EC.5.1. Robust instances of sets GDE-D and GDE-I

As mentioned before, the two sets of GDE-D and GDE-I instances differ with respect to the delay distribution pattern, and particularly for how the maximum travel time $\hat{t}_{ij}$ of each arc $(i,j) \in A$ is generated.

Starting from each TSPTW instance of Gendreau et al. (1998) two travel time matrices $[t^0_{ij}]$ and $[\hat{t}_{ij}]$ are generated where t^0_{ij} represents the nominal travel time and $\hat{t}_{ij}$ is the maximum or peak travel time of a corresponding RTSPTW instance of set GDE-D. The process is then repeated for the instances of set GDE-I.

In all cases nominal travel times t^0_{ij} are set equal to the travel times of the original TSPTW instance. The peak times $\hat{t}_{ij}$ are instead generated differently for the two sets:

- GDE-D: The value of $\hat{t}_{ij}$, $\forall (i,j) \in A$, is computed as $\hat{t}_{ij} = \lfloor (\alpha + 1) t^0_{ij} \rfloor$, where α is randomly drawn within the interval $[0,1]$.

- GDE-I: The value of $\hat{t}_{ij}$, $\forall(i,j) \in A$, is computed as $\hat{t}_{ij} = \lfloor t^0_{ij} + \delta \rfloor$, where δ is randomly drawn within the interval $[0, 30]$.

Each pair of travel time matrices $[t^0_{ij}]$ and $[\hat{t}_{ij}]$ generated in this way was then used to define three RTSPTW($\mathcal{T}_K$) instances and three RTSPTW($\mathcal{T}_C$) ones characterized by three different budget sizes as explained in Section EC.7. Note however that the three RTSPTW($\mathcal{T}_K$) instances derived in this way may actually end up having different peak travel times since these are further preprocessed by setting $\hat{t}_{ij} := \min\{\hat{t}_{ij}, t^0_{ij} + \Delta\}$.

The following Table EC.1 summarizes the characteristics ot the peak time matrices $[\hat{t}_{ij}]$ generated as above. Each row of this table reports average data for one group of five instances with the same number of customers and average time windows widths. Columns "α_{max}", "α_{min}" and "α_{avg}" report the maximum, minimum and average increase α_{ij} of the travel time $\hat{t}_{ij}$ with respect to the nominal time t^0_{ij} over all arcs (where $\alpha_{ij} = \frac{\hat{t}_{ij}}{t^0_{ij}} - 1$). Columns "$\delta_{max}$", "$\delta_{min}$" and "$\delta_{avg}$" report instead the minimum, maximum, and average deviation δ_{ij} of $\hat{t}_{ij}$ with respect to the nominal time t^0_{ij} over all arcs (where $\delta_{ij} = \hat{t}_{ij} - t^0_{ij}$).

Table EC.1 Travel time data of instances GDE-D and GDE-I

		GDE-D						GDE-I					
n	group	α_{max}	α_{min}	α_{avg}	δ_{max}	δ_{min}	δ_{avg}	α_{max}	α_{min}	α_{avg}	δ_{max}	δ_{min}	δ_{avg}
	w120	1	0	0.50	46.60	0	12.07	13.23	0	0.94	30	0	14.67
	w140	1	0	0.52	49.40	0	13.05	12.04	0	0.90	30	0	14.51
20	w160	1	0	0.50	43.00	0	12.57	14.13	0	0.93	30	0	14.90
	w180	1	0	0.51	47.00	0	12.86	17.90	0	0.96	30	0	14.85
	w200	1	0	0.52	47.80	0	12.72	13.93	0	0.95	30	0	15.39
	w120	1	0	0.50	53.40	0	13.22	26.40	0	0.92	30	0	14.83
	w140	1	0	0.51	50.40	0	12.88	21.00	0	0.90	30	0	14.69
40	w160	1	0	0.51	47.80	0	12.38	20.20	0	0.94	30	0	14.88
	w180	1	0	0.50	51.00	0	13.14	18.20	0	0.88	30	0	14.98
	w200	1	0	0.50	48.80	0	12.55	17.20	0	0.92	30	0	15.05
	w120	1	0	0.50	54.00	0	13.16	24.40	0	0.89	30	0	15.02
	w140	1	0	0.50	53.00	0	12.84	22.80	0	0.87	30	0	14.81
60	w160	1	0	0.50	57.00	0	13.18	23.80	0	0.88	30	0	15.05
	w180	1	0	0.49	54.00	0	12.64	28.40	0	0.90	30	0	14.94
	w200	1	0	0.50	52.80	0	12.74	25.80	0	0.90	30	0	15.01
	w100	1	0	0.50	53.80	0	12.53	27.00	0	0.91	30	0	14.87
	w120	1	0	0.50	55.40	0	12.79	28.60	0	0.89	30	0	15.03
80	w140	1	0	0.50	53.80	0	12.68	26.80	0	0.89	30	0	14.88
	w160	1	0	0.50	53.20	0	12.98	27.00	0	0.89	30	0	14.88
	w180	1	0	0.50	54.80	0	12.71	29.00	0	0.93	30	0	14.89
	w200	1	0	0.50	53.80	0	12.53	27.00	0	0.91	30	0	14.87

EC.5.2. Generation of random instances in simulation experiments

In our simulation experiments (see Section 7.5) random travel time vectors were generated following a given probability distribution which is either a discrete two-point distribution or a uniform distribution. Starting with a baseline TSPTW instance (either n60w120.001 or n60w200.001) we thus obtained a number of random TSPTW instances each defined by one of the travel time vectors generated. When sampling the travel time vectors we take the travel time $\tilde{t}_{ij}$ of each arc $(i,j) \in A$ in the baseline instance as the mean of the random travel time t_{ij}. In all cases, the arc costs c_{ij} are set equal to the mean travel times $\tilde{t}_{ij}$, while realizations of random travel times t_{ij} are generated as follows:

- Two-point distribution: Each travel time t_{ij}, $(i,j) \in A$ is treated as a two-point independently distributed random variable with $\mathbb{P}(t_{ij} = \lfloor (1-\lambda_{ij})\tilde{t}_{ij} \rfloor) = \mathbb{P}(t_{ij} = \lfloor (1+\lambda_{ij})\tilde{t}_{ij} \rfloor) = 0.5$. The value λ_{ij} is randomly and independently selected from the set $\{0.1, 0.2, ..., 0.8\}$ with equal probability.
- Uniform distribution: The travel time realization for each arc (i,j) is drawn uniformly from the interval $[\lfloor \alpha_{low}\tilde{t}_{ij} \rfloor, \lfloor \alpha_{high}\tilde{t}_{ij} \rfloor]$, where α_{low}, α_{high} are set as 0.5 and 2 respectively.

Each travel time vector generated in this way represents one sample. As explained in Section 7.5, a number of $|\Omega|$ samples simulating available historical data are used to generate a RTSPTW instance, while an additional $|\bar{\Omega}|$ samples are created to simulate future scenarios and evaluate the performance of the solutions obtained by solving the RTSPTW instance.

EC.6. Comparison of the two uncertainty sets

This section provides an example showing that the two uncertainty sets $\mathcal{T}_K$ and $\mathcal{T}_C$ defined in Section 2 give rise, in general, to different sets of travel time scenarios also if the budget value Γ defining $\mathcal{T}_C$ is permitted to be fractional. More precisely, given a budget value $\Delta \in \mathbb{N}$ it is generally not possible to find a value $0 \leq \Gamma \leq n$ such that the resulting polytopes $\mathcal{T}_K$ and $\mathcal{T}_C$ have the same extreme points, or equivalently such that $\mathcal{T}_C = \mathcal{T}_K$.

In view of the fact that RTSPTW($\mathcal{T}_K$) and RTSPTW($\mathcal{T}_C$) can be equivalently defined by replacing the sets $\mathcal{T}_K$ and $\mathcal{T}_C$ with the sets of their extreme points, this observation suggests that in general RTSPTW($\mathcal{T}_K$) and RTSPTW($\mathcal{T}_C$) model in effect different optimization problems also if Γ can be fractional. As a consequence, RTSPTW($\mathcal{T}_C$) may not generally be used to obtain a solution of RTSPTW($\mathcal{T}_K$).

These observations are summarized and illustrated below by an example. We will use the notation $\mathcal{T}_C(\bar{\Gamma})$ to indicate the set $\mathcal{T}_C$ defined by setting $\Gamma = \bar{\Gamma}$ for some given $\bar{\Gamma}$, $0 \leq \bar{\Gamma} \leq n$. Similarly, we will write $\mathcal{T}_K(\bar{\Delta})$ to indicate the set $\mathcal{T}_K$ defined by setting $\Delta = \bar{\Delta}$, for some given $\bar{\Delta} \in \mathbb{N}$.

Observation 5 *Consider a directed graph $G = (V, A)$ with n nodes and a set of arcs $(i, j) \in A$ each associated with an integer nominal travel time t^0_{ij} and an integer maximum delay δ_{ij}. In general, for a fixed $\bar{\Delta} \in \mathbb{N}$ there is no value $0 \leq \bar{\Gamma} \leq n$ such that $\mathcal{T}_K(\bar{\Delta}) = \mathcal{T}_C(\bar{\Gamma})$. Furthermore, there is in general no value $0 \leq \bar{\Gamma} \leq n$ such that RTSPTW($\mathcal{T}_C(\bar{\Gamma})$) admits an optimal solution which is also optimal for RTSPTW($\mathcal{T}_K(\bar{\Delta})$).*

It is enough to provide an example. Let $\mathcal{T}_K(\bar{\Delta})$ be defined by $\bar{\Delta} = 3$ and let $A = \{(1,2),$ $(1,3)$, $(2,1)$, $(2,3)$, $(4,2)$, $(3,4)$, $(4,1)$ $\}$, $\delta_{12} = \delta_{23} = 2$, and $\delta_{ij} = 1$ for other arcs. We assume for simplicity that node 1 must be both the start and end node of the tour.

Suppose now that the only node with a time window is node 1 with $e_1 = 0$ and $l_1 = 15$ and that the nominal travel times are $t^0_{12} = t^0_{34} = 2$, $t^0_{23} = t^0_{21} = 3$, and $t^0_{13} = t^0_{41} = t^0_{42} = 4$. There are only two Hamiltonian tours in G, that is, $P_1 = (1, 2, 3, 4, 1)$ and $P_2 = (1, 3, 4, 2, 1)$. These two tours are depicted in Figure EC.1, where below each arc of the tours it is shown its nominal travel time, and above its maximum delay. Suppose that P_2 has lower cost than P_1. Notice that if $\Delta = 3$ then P_1 is feasible for RTSPTW($\mathcal{T}_K$), but P_2 is not (the arrival time at the last node is 16). Therefore P_1 is optimal for this problem. Now consider RTSPTW($\mathcal{T}_C$) and note that if $\Gamma > 2$ then both P_1 and P_2 are infeasible for this problem because assigning full delay to the two arcs in bold yields an arrival time of 15 at the last node. On the other hand, if $\Gamma \leq 2$ then the tour P_2 is feasible, and thus optimal, for RTSPTW($\mathcal{T}_C$). Therefore, for any (possibly fractional) value of Γ either RTSPTW($\mathcal{T}_C$) is infeasible or its optimal solution is infeasible for RTSPTW($\mathcal{T}_K(3)$). Obviously, this also means that $\mathcal{T}_K(3) \neq \mathcal{T}_C(\Gamma)$ for all values of Γ.

EC.7. Detailed computational results

In this section, we report detailed results obtained by our algorithm on the new RTSPTW instances of sets GDE-I and GDE-D and on all TSPTW instances proposed by Gendreau et al. (1998) and Ohlmann and Thomas (2007). Each one of Tables EC.2–EC.18 shows the results obtained by solving RTSPTW($\mathcal{T}_K$) or RTSPTW($\mathcal{T}_C$) for instances of the same size. Tables EC.19–EC.21 report the results for the TSPTW instances.

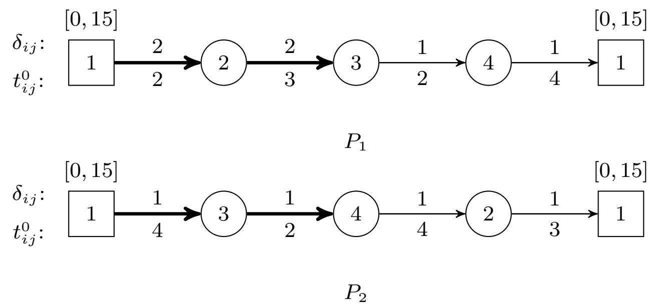

Figure EC.1 Illustration of Observation 5

The first column of each table identifies the instance. In Tables EC.2–EC.18, the remaining columns are divided into three blocks each reporting the results obtained for one of the three budget sizes. These columns report the following information. Column "ub^*" reports the best known upper bound. Column "$\%gap$" reports the percentage distance of the best upper bound ub found by the GVNS from the best known upper bound ub^* (computed as $100 \cdot \frac{ub^*}{ub-ub^*}$). Column "$\%lb$" reports the percentage of the lower bound lb computed by the exact algorithm with respect to ub^* (computed as $100 \cdot \frac{lb}{ub^*}$). Column "*opt*" indicates whether the instance was solved to optimality (i.e., either an optimal solution was found or the instance was proved infeasible). A check-mark indicates optimality.

Under heading GVNS, column "*time*" reports the total time spent by the GVNS. The same column reports the time spent by the lower bounding procedure, under heading CSP, and by the entire algorithm, under heading DP. Note that all these times include the time spent by the algorithm since the beginning until when they are measured.

Tables EC.19–EC.21 report the same columns as described above except that the time spent by the lower bounding procedure is not reported.

For instances that were proved infeasible we report the symbol "`inf`" in column "ub^*" whereas we report the symbol "?" to indicate that no feasible solution was found but the instance was not proved infeasible. Finally, in column "*time*" (under heading CSP or DP) we report the symbol "`t.l.`" to indicate that the algorithm stopped prematurely upon reaching the imposed time limit, whereas we report the symbol "`m.l.`" if the algorithm stopped due to the memory limit imposed to the DP algorithm.

Some instances were proved infeasible during preprocessing (i.e., either the precedence graph induced by the precedence lists contains a directed cycle, or the assignment problem solved in Phase 1 is infeasible). Additionally, if an instance is proved infeasible for a certain value of the budget, then it is not solved with higher values. For all these instances no values are reported in columns "%*gap*", "%*lb*" or "*time*". Note that in some cases the GVNS is unable to find a feasible solution, but an optimal solution was nevertheless found by the exact algorithm. In these cases no values are reported in column "%*gap*".

Finally, we note that for instances where Step 2 of Phase 1 reaches the time limit without finding any feasible dual solution the lower bound *lb* obtained at termination corresponds to the best (generally very weak) Lagrangean bound obtained at Step 1.

Table EC.2 RTSPTW($\mathcal{T}_K$): Results on the instances of set GDE-D with 80 customers.

	$\Delta = 20$							$\Delta = 40$							$\Delta = 60$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	%*gap*	*time*	%*lb*	*time*†	*opt*	*time*†	ub^*	%*gap*	*time*	%*lb*	*time*†	*opt*	*time*†	ub^*	%*gap*	*time*	%*lb*	*time*†	*opt*	*time*†
w100.001	?	-	1378	-	2593		2593	inf	-	1399	-	2592	✓	2592	inf	-	1367	-	2528	✓	2528
w100.002	590	0.34	748	99.49	804	✓	805	inf	-	1400	-	6044	✓	6044	inf	-	-	-	-	✓	-
w100.003	588	0.00	576	100.00	602	✓	602	inf	-	1353	-	1924	✓	1924	inf	-	1354	-	2374	✓	2374
w100.004	inf	-	212	-	337	✓	337	inf	-	-	-	-	✓	-	inf	-	-	-	-	✓	-
w100.005	554	0.00	448	100.00	546	✓	546	?	-	1385	-	t.l.		-	?	-	1409	-	t.l.		t.l.
w120.001	517	0.00	765	99.78	917	✓	918	519	0.00	665	100.00	986	✓	986	519	0.00	646	100.00	1044	✓	1044
w120.002	577	0.00	279	99.98	323	✓	323	577	0.00	378	99.98	493	✓	493	578	0.00	541	100.00	737	✓	737
w120.003	544	0.00	592	100.00	648	✓	648	579	0.00	989	100.00	1197	✓	1197	581	0.00	584	100.00	1267	✓	1267
w120.004	508	0.00	519	98.82	611	✓	614	517	0.00	733	99.03	1011	✓	1019	518	0.00	783	99.28	1187	✓	1656
w120.005	622	0.00	371	98.47	653	✓	672	622	0.00	518	99.19	976	✓	1032	627	0.00	838	99.62	3141	✓	3923
w140.001	515	0.00	701	100.00	862	✓	862	515	0.00	768	100.00	1037	✓	1037	515	0.00	560	100.00	1293	✓	1293
w140.002	518	0.00	575	99.42	3147	✓	3152	529	0.19	701	98.80	6435	✓	6686	531	0.00	948	79.87	t.l.		-
w140.003	603	0.00	433	99.04	678	✓	681	603	1.16	434	99.12	1336	✓	1426	608	0.49	577	98.61	2600	✓	3881
w140.004	440	0.00	342	98.95	933	✓	971	450	2.22	776	99.42	2059	✓	4143	474	0.00	883	98.83	4555		t.l.
w140.005	545	0.00	323	100.00	361	✓	361	545	0.00	488	100.00	581	✓	581	562	0.00	369	100.00	636	✓	636
w160.001	509	0.00	839	100.00	1094	✓	1094	516	0.00	1007	100.00	1972	✓	1972	516	0.19	1009	100.00	2869	✓	2869
w160.002	565	0.71	740	98.32	2573	✓	3672	583	0.00	848	97.13	5622		t.l.	583	0.00	1112	55.96	t.l.		-
w160.003	531	0.00	410	99.15	1518	✓	1536	533	0.00	549	99.78	1898	✓	2008	533	0.00	712	99.98	2303	✓	2303
w160.004	514	0.00	667	100.00	946	✓	946	517	0.00	679	100.00	1311	✓	1311	517	0.00	801	100.00	2168	✓	2168
w160.005	454	0.00	521	99.97	822	✓	822	454	2.20	499	100.00	1731	✓	1731	464	0.00	731	99.08	2628	✓	3632
w180.001	565	1.06	758	99.32	1321	✓	1341	573	0.00	829	99.95	1527	✓	1527	574	0.00	1124	99.84	2164	✓	2164
w180.002	510	0.00	626	99.62	1256	✓	1258	515	0.00	821	99.71	2266	✓	2277	515	0.00	912	100.00	2065	✓	2065
w180.003	537	0.00	550	99.44	2081	✓	2086	539	0.00	873	99.84	2605	✓	2605	539	0.00	1058	99.66	2742	✓	2824
w180.004	483	0.00	1351	99.76	1609	✓	1610	483	0.00	1633	99.84	2175	✓	2175	491	0.00	1720	99.92	2720	✓	2720
w180.005	473	0.00	434	99.79	664	✓	667	475	0.00	615	100.00	1053	✓	1053	475	0.00	696	100.00	1144	✓	1144
w200.001	497	0.20	644	99.50	1936	✓	1963	499	0.00	1059	99.60	2964	✓	2997	499	0.00	1123	99.72	2640	✓	2692
w200.002	508	0.00	1047	99.93	1246	✓	1246	508	0.00	1125	100.00	1494	✓	1494	508	0.00	855	100.00	1162	✓	1162
w200.003	464	0.00	758	99.71	1061	✓	1062	465	0.43	913	99.94	1418	✓	1423	467	0.64	1054	100.00	2446	✓	2532
w200.004	526	0.00	488	99.14	955	✓	957	535	0.00	789	99.81	1313	✓	1319	537	0.00	1033	100.00	2258	✓	2258
w200.005	439	0.00	493	100.00	1061	✓	1061	445	0.67	505	99.89	1609	✓	1622	449	0.89	675	100.00	4787	✓	4787

†: Includes the time of GVNS.

Table EC.3 RTSPTW($\mathcal{T}_K$): Results on the instances of set GDE-I with 80 customers.

	$\Delta = 20$							$\Delta = 40$							$\Delta = 60$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	*%gap*	*time*	*%lb*	$time^\dagger$	*opt*	$time^\dagger$	ub^*	*%gap*	*time*	*%lb*	$time^\dagger$	*opt*	$time^\dagger$	ub^*	*%gap*	*time*	*%lb*	$time^\dagger$	*opt*	$time^\dagger$
w100.001	inf	-	1434	-	1556	✓	1556	inf	0.00	-	-	1425	✓	1425	inf	-	1310	-	1390	✓	1390
w100.002	inf	-	1361	-	1521	✓	1521	inf	0.00	-	-	1456	✓	1456	inf	-	1343	-	1420	✓	1420
w100.003	inf	-	0	-	0	✓	0	inf	0.00	-	-	0	✓	0	inf	-	0	-	0	✓	0
w100.004	inf	-	0	-	0	✓	0	inf	0.00	-	-	0	✓	0	inf	-	0	-	0	✓	0
w100.005	inf	-	0	-	0	✓	0	inf	0.00	-	-	0	✓	0	inf	-	0	-	0	✓	0
w120.001	517	0.00	846	100.00	952	✓	952	519	0.00	1314	100.00	1409	✓	1409	531	0.00	527	100.00	721	✓	721
w120.002	578	0.00	362	99.90	399	✓	399	578	0.00	521	100.00	563	✓	563	581	0.00	529	100.00	571	✓	571
w120.003	544	0.00	881	100.00	943	✓	943	593	0.00	1934	100.00	2058	✓	2058	inf	0.00	1364	0.25	1594	✓	1594
w120.004	509	0.00	418	99.21	494	✓	494	518	0.00	782	99.42	874	✓	876	inf	0.00	1376	0.25	1469	✓	1469
w120.005	622	0.00	363	98.69	566	✓	568	650	0.00	678	98.91	1106	✓	1113	673	0.00	1161	99.26	1435	✓	1448
w140.001	512	0.00	1444	100.00	1566	✓	1566	512	0.00	1191	100.00	1359	✓	1359	518	0.00	886	100.00	1109	✓	1109
w140.002	520	0.00	406	99.76	2522	✓	2526	533	0.00	763	99.66	1839	✓	1841	557	0.18	876	99.41	1874	✓	1882
w140.003	603	0.00	403	99.37	564	✓	565	611	0.00	461	99.51	656	✓	658	623	0.00	749	100.00	956	✓	956
w140.004	444	0.00	343	99.57	559	✓	561	481	0.21	921	97.20	1379	✓	1490	504	0.00	1165	98.62	1542	✓	1649
w140.005	545	0.00	321	100.00	379	✓	379	547	0.00	417	100.00	498	✓	498	553	0.00	585	100.00	674	✓	674
w160.001	509	0.00	645	100.00	1061	✓	1061	523	0.00	1058	100.00	1966	✓	1966	533	0.00	1139	100.00	2113	✓	2113
w160.002	565	0.88	758	98.42	2183	✓	2350	585	0.00	697	98.72	2607	✓	2937	594	0.00	1065	99.99	2219	✓	2219
w160.003	533	0.00	406	98.97	1055	✓	1061	545	0.00	1135	100.00	1467	✓	1467	572	0.00	787	100.00	1304	✓	1304
w160.004	517	0.00	691	100.00	987	✓	987	527	0.00	1068	99.81	1285	✓	1292	543	0.00	1054	100.00	1443	✓	1443
w160.005	465	0.00	535	99.14	852	✓	856	466	0.00	610	100.00	812	✓	812	482	0.00	715	100.00	941	✓	941
w180.001	565	0.18	611	99.43	845	✓	847	573	0.00	891	99.97	1082	✓	1082	585	0.85	1200	100.00	1396	✓	1396
w180.002	510	0.00	630	99.90	1155	✓	1155	536	0.00	797	98.13	2600	✓	2710	539	0.00	819	99.32	1310	✓	1320
w180.003	539	0.00	615	99.76	1512	✓	1514	539	0.00	759	100.00	1181	✓	1181	541	0.00	1240	100.00	1664	✓	1664
w180.004	482	0.00	631	99.78	843	✓	844	483	0.00	1204	100.00	1459	✓	1459	489	0.20	1037	100.00	1356	✓	1368
w180.005	473	0.00	440	100.00	540	✓	540	490	1.02	727	100.00	1006	✓	1006	533	0.00	1296	99.98	2022	✓	2022
w200.001	497	0.20	661	99.58	1806	✓	1814	505	0.00	1001	99.61	1899	✓	1917	507	0.00	1132	99.97	1522	✓	1522
w200.002	508	0.00	1134	99.93	1282	✓	1282	512	0.00	1168	99.86	1311	✓	1311	513	0.00	963	99.98	1112	✓	1112
w200.003	465	0.00	789	99.97	968	✓	968	472	0.00	985	100.00	1207	✓	1207	503	0.00	1272	98.84	2080	✓	2121
w200.004	526	0.00	510	99.14	1008	✓	1009	535	0.00	689	99.81	1128	✓	1129	557	0.00	945	98.81	1796	✓	1812
w200.005	444	0.00	496	99.65	1105	✓	1106	465	0.43	744	98.70	1994	✓	2391	472	0.00	1172	99.36	2521	✓	2576

†: Includes the time of GVNS.

Table EC.4 RTSPTW($\mathcal{T}_K$): Results on the instances of set GDE-D with 80 customers and larger values of Δ.

	$\Delta = 80$							$\Delta = 100$						
		GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	*%gap*	*time*	*%lb*	$time^\dagger$	*opt*	$time^\dagger$	ub^*	*%gap*	*time*	*%lb*	$time^\dagger$	*opt*	$time^\dagger$
w100.001	inf	-	1228	-	3445	✓	3445	inf	-	1220	-	2599	✓	2599
w100.002	inf	-	1272	-	4636	✓	4636	inf	-	1256	-	3924	✓	3924
w100.003	inf	-	1236	-	2114	✓	2114	inf	-	1239	-	6321	✓	6321
w100.004	inf	-	0	-	0	✓	0	inf	-	0	-	0	✓	0
w100.005	?	-	1305	-	t.l.		-	?	-	1269	-	t.l.		-
w120.001	522	0.00	646	100.00	1330	✓	1330	522	0.00	864	100.00	1484	✓	1484
w120.002	586	0.00	564	100.00	1144	✓	1144	?	-	1291	-	t.l.		-
w120.003	582	0.00	579	100.00	1184	✓	1184	582	0.00	685	100.00	1513	✓	1513
w120.004	521	0.00	923	99.96	2344	✓	2344	521	0.00	1111	100.00	2528	✓	2528
w120.005	649	0.00	1091	90.28	t.l.		-	?	-	1272	-	t.l.		-
w140.001	516	0.00	546	100.00	1320	✓	1320	516	0.00	537	100.00	1843	✓	1843
w140.002	534	0.00	1126	75.71	t.l.		-	536	0.00	1144	79.40	t.l.		-
w140.003	618	0.00	898	-	t.l.		-	621	0.00	1228	-	t.l.		-
w140.004	?	-	1328	-	t.l.		-	?	-	1526	-	t.l.		-
w140.005	562	0.00	465	100.00	910	✓	910	562	0.00	543	100.00	1012	✓	1012
w160.001	537	0.00	1176	80.16	t.l.		-	549	0.00	1231	78.41	t.l.		-
w160.002	586	0.00	1085	55.67	t.l.		-	599	0.00	1249	54.46	t.l.		-
w160.003	533	0.00	782	99.97	2470	✓	2470	533	0.00	924	100.00	3858	✓	3858
w160.004	517	0.58	1029	100.00	1621	✓	1621	517	0.58	1239	100.00	1989	✓	1989
w160.005	464	0.00	837	99.62	2544	✓	4323	475	0.00	1046	97.51	9073		t.l.
w180.001	579	0.35	1234	100.00	2716	✓	2716	593	2.36	1281	100.00	7645	✓	7645
w180.002	521	0.00	981	99.25	4439		t.l.	521	0.00	1124	84.40	t.l.		-
w180.003	546	0.00	1202	99.92	6215	✓	6215	559	0.00	1218	-	t.l.		-
w180.004	491	0.00	1646	99.92	2458	✓	2458	491	0.00	1547	99.91	3381	✓	3381
w180.005	475	0.00	884	100.00	1528	✓	1528	476	0.00	1007	100.00	1614	✓	1614
w200.001	508	0.00	1293	77.52	t.l.		-	509	0.00	1320	84.05	t.l.		-
w200.002	510	0.39	796	100.00	1931	✓	1940	516	0.19	846	99.32	2359	✓	4640
w200.003	467	0.43	1119	100.00	8616	✓	9106	467	0.64	1210	100.00	7167	✓	9044
w200.004	537	0.00	1165	99.99	2462	✓	2462	537	0.00	1193	99.99	2587	✓	2587
w200.005	449	0.89	638	100.00	7495	✓	7495	449	0.89	796	100.00	5694	✓	5694

†: Includes the time of GVNS. In this table, an entry t.l. in column *time* of section DP indicates that $\mathcal{CG}$ timed out when precomputing the path set $\mathcal{Q}$ before running the DP algorithm.

Table EC.5 RTSPTW($\mathcal{T}_K$): Results on the instances of set GDE-D with 60 customers.

	$\Delta = 20$							$\Delta = 40$							$\Delta = 60$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$
w120.001	398	0.00	196	100.00	246	✓	246	401	0.00	270	100.00	315	✓	315	401	0.00	262	100.00	375	✓	375
w120.002	511	0.00	55	99.12	130	✓	130	512	0.00	212	100.00	298	✓	298	518	0.00	336	100.00	817	✓	817
w120.003	407	0.00	169	100.00	206	✓	206	409	0.00	395	100.00	485	✓	485	412	0.00	427	100.00	554	✓	554
w120.004	490	0.00	62	99.96	117	✓	117	492	0.00	68	100.00	150	✓	150	492	0.00	88	100.00	230	✓	230
w120.005	565	0.00	120	100.00	166	✓	166	566	0.00	124	100.00	175	✓	175	568	0.00	143	100.00	209	✓	209
w140.001	423	0.00	97	100.00	129	✓	129	427	0.00	137	100.00	209	✓	209	435	0.00	184	98.97	400	✓	474
w140.002	478	0.00	153	100.00	189	✓	189	478	0.00	116	100.00	206	✓	206	inf	-	1000	-	3031	✓	3031
w140.003	439	0.00	63	100.00	90	✓	90	440	0.00	69	100.00	119	✓	119	441	0.00	77	99.89	120	✓	120
w140.004	inf	-	995	-	1213	✓	1213	inf	-	982	-	1099	✓	1099	inf	-	988	-	1137	✓	1137
w140.005	468	0.00	80	99.55	195	✓	199	478	0.63	123	99.16	296	✓	303	483	1.24	572	100.00	731	✓	731
w160.001	563	0.00	186	100.00	268	✓	268	563	0.00	82	100.00	302	✓	302	563	0.00	108	100.00	402	✓	402
w160.002	442	0.00	307	100.00	343	✓	343	448	0.00	358	100.00	426	✓	426	448	0.00	252	100.00	376	✓	376
w160.003	434	0.00	84	99.56	198	✓	198	434	0.00	91	99.71	296	✓	297	435	0.00	123	99.85	452	✓	452
w160.004	462	0.00	66	100.00	145	✓	145	462	0.00	74	100.00	169	✓	169	462	0.00	81	100.00	346	✓	346
w160.005	501	0.00	80	100.00	122	✓	122	501	0.00	99	100.00	403	✓	403	501	0.00	115	100.00	427	✓	427
w180.001	420	0.00	124	97.92	858	✓	883	426	0.00	130	98.38	1164	✓	1339	431	0.00	129	97.46	2033	✓	2991
w180.002	412	0.00	139	99.61	189	✓	189	412	0.00	143	99.92	205	✓	205	414	0.00	140	99.92	256	✓	256
w180.003	446	0.00	76	99.40	134	✓	134	451	0.00	125	99.88	210	✓	210	451	0.00	142	99.88	251	✓	251
w180.004	463	0.00	86	100.00	138	✓	138	463	0.00	93	100.00	161	✓	161	463	0.00	104	100.00	215	✓	215
w180.005	395	0.00	91	100.00	162	✓	162	410	0.49	130	97.94	614	✓	932	413	0.00	494	98.23	2483		t.l.
w200.001	422	0.00	146	100.00	215	✓	215	423	0.00	203	100.00	292	✓	292	423	0.00	199	100.00	359	✓	359
w200.002	420	0.00	75	99.40	145	✓	146	420	0.00	101	99.40	202	✓	204	420	0.00	124	99.40	250	✓	256
w200.003	455	0.00	135	98.35	778	✓	793	455	0.00	142	99.56	1317	✓	1323	455	0.00	213	100.00	1060	✓	1060
w200.004	431	0.00	96	99.19	168	✓	169	431	0.00	125	99.54	254	✓	255	431	0.00	130	100.00	396	✓	396
w200.005	427	0.00	97	100.00	164	✓	164	427	0.00	116	100.00	199	✓	199	427	0.00	132	100.00	234	✓	234

†: Includes the time of GVNS.

Table EC.6 RTSPTW($\mathcal{T}_K$): Results on the instances of set GDE-I with 60 customers.

	$\Delta = 20$							$\Delta = 40$							$\Delta = 60$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$
w120.001	418	0.00	164	100.00	216	✓	216	443	0.00	171	99.77	211	✓	212	inf	-	988	-	1078	✓	1078
w120.002	514	0.00	88	99.12	145	✓	145	518	0.00	226	100.00	266	✓	266	inf	-	995	-	1047	✓	1047
w120.003	407	0.00	170	100.00	196	✓	196	414	0.00	240	100.00	301	✓	301	inf	-	985	-	1322	✓	1322
w120.004	490	0.00	65	99.91	89	✓	89	503	0.00	67	100.00	131	✓	131	inf	-	989	-	1104	✓	1104
w120.005	565	0.00	120	100.00	150	✓	150	566	0.00	162	100.00	187	✓	187	inf	-	983	-	1008	✓	1008
w140.001	423	0.00	108	100.00	136	✓	136	474	0.00	214	100.00	254	✓	254	inf	-	992	-	1037	✓	1037
w140.002	474	0.00	201	100.00	226	✓	226	477	5.66	145	100.00	350	✓	350	inf	-	999	-	1280	✓	1280
w140.003	439	0.00	66	100.00	90	✓	90	444	0.00	100	100.00	141	✓	141	inf	-	1005	-	1653	✓	1653
w140.004	inf	-	997	-	1117	✓	1117	inf	-	992	-	1027	✓	1027	inf	-	982	-	1022	✓	1022
w140.005	468	0.00	75	99.60	132	✓	133	484	0.00	133	98.97	216	✓	217	inf	-	992	-	1709	✓	1709
w160.001	577	0.00	139	100.00	210	✓	210	585	0.00	147	99.78	269	✓	270	597	0.00	128	100.00	283	✓	283
w160.002	453	0.00	261	99.99	284	✓	284	470	0.00	297	100.00	329	✓	329	490	0.20	150	98.87	319	✓	329
w160.003	434	0.00	81	99.58	144	✓	145	437	0.00	128	100.00	197	✓	197	448	0.00	145	98.55	304	✓	310
w160.004	464	0.00	101	99.97	151	✓	151	464	0.00	107	99.99	194	✓	194	465	0.00	150	100.00	216	✓	216
w160.005	501	0.00	90	100.00	120	✓	120	508	0.00	119	100.00	182	✓	182	513	0.00	107	100.00	157	✓	157
w180.001	423	0.00	113	98.98	474	✓	483	430	0.00	135	99.85	427	✓	427	436	0.23	187	100.00	445	✓	445
w180.002	412	0.00	152	99.39	207	✓	207	414	0.00	231	100.00	276	✓	276	429	0.00	195	100.00	262	✓	262
w180.003	450	0.00	83	99.89	127	✓	127	451	0.00	135	99.89	168	✓	168	464	0.00	187	99.95	244	✓	244
w180.004	459	0.00	119	100.00	167	✓	167	471	0.00	108	99.99	167	✓	167	481	0.00	102	98.86	342	✓	354
w180.005	398	0.00	101	100.00	148	✓	148	417	0.00	175	99.97	323	✓	323	428	0.00	557	100.00	627	✓	627
w200.001	422	0.00	129	100.00	180	✓	180	451	0.00	203	99.36	304	✓	305	451	0.00	302	100.00	360	✓	360
w200.002	421	0.00	119	99.52	179	✓	179	443	0.00	139	99.62	281	✓	282	450	0.00	286	100.00	420	✓	420
w200.003	455	0.00	133	98.46	637	✓	641	455	0.00	131	99.68	697	✓	700	459	0.00	154	100.00	286	✓	286
w200.004	431	0.00	102	99.59	163	✓	163	431	0.00	117	99.72	170	✓	170	443	0.00	106	100.00	181	✓	181
w200.005	427	0.00	106	99.99	161	✓	161	428	0.00	127	100.00	181	✓	181	433	0.00	169	100.00	257	✓	257

†: Includes the time of GVNS.

Table EC.7 RTSPTW($\mathcal{T}_K$): Results on the instances of set GDE-D with 40 customers.

	$\Delta = 20$							$\Delta = 40$							$\Delta = 60$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$
w120.001	446	0.00	7	100.00	14	✓	14	446	0.00	8	100.00	15	✓	15	446	0.00	9	100.00	31	✓	31
w120.002	463	0.00	6	100.00	14	✓	14	500	0.00	8	100.00	17	✓	17	504	0.00	11	100.00	27	✓	27
w120.003	379	0.26	11	99.87	31	✓	31	384	0.00	18	100.00	44	✓	44	385	0.00	18	100.00	45	✓	45
w120.004	307	0.00	9	100.00	16	✓	16	338	0.00	16	100.00	36	✓	36	338	0.00	46	100.00	66	✓	66
w120.005	350	0.00	9	100.00	14	✓	14	350	0.00	13	100.00	18	✓	18	350	0.00	11	100.00	16	✓	16
w140.001	364	0.00	9	99.99	35	✓	35	364	0.00	10	100.00	39	✓	39	364	0.00	10	100.00	43	✓	43
w140.002	383	0.00	10	100.00	18	✓	18	383	0.00	9	100.00	22	✓	22	383	0.00	10	100.00	20	✓	20
w140.003	416	0.00	9	100.00	28	✓	28	416	0.00	11	100.00	30	✓	30	416	0.00	14	100.00	38	✓	38
w140.004	352	0.00	8	99.99	17	✓	17	365	0.00	20	99.97	37	✓	37	365	0.00	19	100.00	42	✓	42
w140.005	375	0.00	10	100.00	26	✓	26	378	0.00	12	100.00	38	✓	38	382	0.00	16	100.00	55	✓	55
w160.001	359	0.00	34	100.00	45	✓	45	360	0.00	31	100.00	43	✓	43	360	0.00	28	100.00	43	✓	43
w160.002	345	0.00	28	100.00	36	✓	36	345	0.00	21	100.00	31	✓	31	345	2.90	17	100.00	70	✓	70
w160.003	368	0.00	11	100.00	61	✓	61	368	0.00	11	100.00	53	✓	53	368	0.00	16	100.00	87	✓	87
w160.004	290	0.00	13	99.77	44	✓	44	297	0.00	20	99.99	155	✓	155	297	0.00	18	100.00	268	✓	268
w160.005	315	0.00	10	100.00	50	✓	50	315	0.00	11	100.00	36	✓	36	315	0.00	10	100.00	124	✓	124
w180.001	339	0.00	9	100.00	23	✓	23	340	0.00	10	100.00	30	✓	30	365	0.00	29	97.02	162	✓	269
w180.002	358	0.00	10	99.55	45	✓	46	358	0.00	12	100.00	33	✓	33	378	0.00	48	100.00	183	✓	183
w180.003	282	0.00	12	100.00	25	✓	25	299	0.00	23	100.00	51	✓	51	299	0.00	21	100.00	62	✓	62
w180.004	372	0.00	11	100.00	22	✓	22	372	0.00	13	100.00	26	✓	26	372	0.00	16	100.00	39	✓	39
w180.005	335	0.00	12	100.00	59	✓	59	335	0.00	11	100.00	76	✓	76	335	0.00	12	100.00	45	✓	45
w200.001	330	0.00	16	100.00	27	✓	27	349	0.00	20	99.00	128	✓	132	349	0.00	21	100.00	89	✓	89
w200.002	314	0.00	40	99.46	85	✓	86	314	0.00	40	99.84	120	✓	120	314	0.00	35	99.84	222	✓	222
w200.003	342	0.00	11	93.64	83	✓	150	342	0.00	10	94.85	111	✓	237	342	0.00	11	95.76	143	✓	572
w200.004	301	0.00	12	100.00	27	✓	27	301	0.00	12	100.00	61	✓	61	302	0.00	14	100.00	74	✓	74
w200.005	310	0.00	16	99.42	77	✓	80	310	0.00	17	99.87	84	✓	84	310	0.00	23	100.00	93	✓	93

†: Includes the time of GVNS.

Table EC.8 RTSPTW($\mathcal{T}_K$): Results on the instances of set GDE-I with 40 customers.

	$\Delta = 20$							$\Delta = 40$							$\Delta = 60$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$
w120.001	446	0.00	7	100.00	13	✓	13	446	0.00	8	100.00	14	✓	14	inf	-	659	-	671	✓	671
w120.002	444	0.00	6	100.00	14	✓	14	450	0.00	11	100.00	18	✓	18	469	0.00	12	100.00	22	✓	22
w120.003	393	0.00	13	100.00	34	✓	34	429	0.00	23	100.00	53	✓	53	inf	-	659	-	684	✓	684
w120.004	325	0.00	17	100.00	36	✓	36	358	0.00	17	100.00	36	✓	36	inf	-	659	-	680	✓	680
w120.005	350	0.00	11	100.00	17	✓	17	381	0.00	33	100.00	40	✓	40	405	0.00	14	100.00	36	✓	36
w140.001	366	0.00	11	100.00	23	✓	23	366	0.00	10	100.00	25	✓	25	369	0.00	14	100.00	32	✓	32
w140.002	383	0.00	9	100.00	16	✓	16	383	0.00	9	100.00	21	✓	21	383	0.00	10	100.00	24	✓	24
w140.003	416	0.00	9	100.00	20	✓	20	416	0.00	9	100.00	16	✓	16	inf	-	659	-	669	✓	669
w140.004	352	0.00	8	100.00	17	✓	17	367	0.00	29	100.00	40	✓	40	399	0.00	63	100.00	83	✓	83
w140.005	375	0.00	8	100.00	25	✓	25	378	0.00	12	100.00	29	✓	29	386	0.00	14	100.00	34	✓	34
w160.001	360	0.00	42	100.00	50	✓	50	360	0.00	43	100.00	52	✓	52	370	0.00	32	100.00	42	✓	42
w160.002	351	0.00	18	100.00	32	✓	32	369	0.00	24	99.59	59	✓	59	372	0.00	19	100.00	38	✓	38
w160.003	368	0.00	12	100.00	58	✓	58	368	0.00	11	100.00	33	✓	33	381	0.00	16	100.00	43	✓	43
w160.004	297	0.00	12	99.86	76	✓	76	300	0.00	32	100.00	93	✓	93	308	0.00	19	99.90	54	✓	54
w160.005	315	0.00	10	100.00	31	✓	31	315	0.00	10	100.00	38	✓	38	315	0.00	10	100.00	54	✓	54
w180.001	353	0.00	10	98.18	40	✓	40	355	0.00	13	100.00	35	✓	35	380	0.00	17	99.13	86	✓	88
w180.002	358	0.00	10	99.77	35	✓	35	359	0.00	14	100.00	28	✓	28	378	0.00	19	100.00	49	✓	49
w180.003	285	0.00	13	99.96	26	✓	26	323	0.00	21	99.99	45	✓	45	348	0.00	22	100.00	44	✓	44
w180.004	372	0.00	12	99.93	25	✓	25	376	0.00	16	100.00	29	✓	29	392	0.00	16	99.87	34	✓	34
w180.005	335	0.00	12	100.00	53	✓	53	335	0.00	11	100.00	49	✓	49	335	0.00	20	100.00	45	✓	45
w200.001	335	0.00	13	100.00	31	✓	31	350	0.00	22	99.93	67	✓	67	350	0.00	24	100.00	54	✓	54
w200.002	317	0.00	52	99.86	93	✓	93	317	0.00	46	100.00	85	✓	85	318	0.00	27	100.00	76	✓	76
w200.003	342	0.00	10	93.64	80	✓	98	342	0.88	11	95.09	70	✓	88	342	0.00	13	98.92	74	✓	75
w200.004	301	0.00	13	100.00	26	✓	26	319	0.00	13	100.00	42	✓	42	inf	-	659	-	690	✓	690
w200.005	311	0.00	14	99.98	50	✓	50	329	0.30	27	99.42	92	✓	93	352	1.70	40	97.05	297	✓	456

†: Includes the time of GVNS.

Table EC.9 RTSPTW($\mathcal{T}_K$): Results on the instances of set GDE-D with 20 customers.

	$\Delta = 20$							$\Delta = 40$							$\Delta = 60$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	*%gap*	*time*	*%lb*	$time^\dagger$	*opt*	$time^\dagger$	ub^*	*%gap*	*time*	*%lb*	$time^\dagger$	*opt*	$time^\dagger$	ub^*	*%gap*	*time*	*%lb*	$time^\dagger$	*opt*	$time^\dagger$
w120.001	309	0.00	0	100.00	6	✓	6	313	0.00	0	100.00	6	✓	6	313	0.00	0	100.00	6	✓	6
w120.002	219	0.00	0	100.00	5	✓	5	221	0.00	0	100.00	5	✓	5	221	0.00	1	100.00	5	✓	5
w120.003	303	0.00	0	100.00	4	✓	4	303	0.00	0	100.00	4	✓	4	312	0.00	0	100.00	4	✓	4
w120.004	334	0.00	0	100.00	4	✓	4	377	0.00	0	100.00	5	✓	5	377	0.00	0	100.00	5	✓	5
w120.005	240	0.00	0	100.00	4	✓	4	281	0.00	0	100.00	4	✓	4	281	0.00	0	100.00	4	✓	4
w140.001	176	0.00	0	100.00	5	✓	5	181	0.00	0	100.00	5	✓	5	181	7.18	0	100.00	5	✓	5
w140.002	272	0.00	0	100.00	4	✓	4	280	0.00	0	100.00	5	✓	5	280	0.00	0	100.00	5	✓	5
w140.003	236	0.00	0	100.00	5	✓	5	236	0.00	0	100.00	5	✓	5	236	0.00	0	100.00	5	✓	5
w140.004	272	0.00	0	97.24	6	✓	7	289	0.00	0	99.65	10	✓	11	293	0.00	0	100.00	7	✓	7
w140.005	225	0.00	0	100.00	5	✓	5	225	0.00	0	100.00	5	✓	5	225	0.00	0	100.00	5	✓	5
w160.001	245	0.00	0	100.00	5	✓	5	245	0.00	0	100.00	5	✓	5	245	0.00	0	100.00	5	✓	5
w160.002	201	0.00	0	100.00	5	✓	5	201	0.00	0	100.00	4	✓	4	201	0.00	0	100.00	4	✓	4
w160.003	267	0.00	0	100.00	8	✓	8	270	0.00	0	96.67	10	✓	10	272	0.00	0	96.69	16	✓	16
w160.004	203	0.00	0	100.00	7	✓	7	203	0.00	0	100.00	7	✓	7	203	0.00	0	100.00	7	✓	7
w160.005	247	0.00	0	100.00	5	✓	5	247	0.00	0	100.00	5	✓	5	247	0.00	0	100.00	5	✓	5
w180.001	253	0.00	0	100.00	4	✓	4	264	0.00	0	100.00	5	✓	5	270	0.00	0	100.00	5	✓	5
w180.002	265	0.00	0	100.00	5	✓	5	266	0.00	0	100.00	5	✓	5	271	0.00	0	100.00	5	✓	5
w180.003	275	0.00	0	100.00	5	✓	5	275	0.00	0	100.00	5	✓	5	275	0.00	0	100.00	5	✓	5
w180.004	215	0.00	0	100.00	5	✓	5	242	0.00	0	100.00	9	✓	9	242	0.00	0	100.00	7	✓	7
w180.005	193	0.00	0	100.00	5	✓	5	206	0.00	0	100.00	5	✓	5	206	0.00	0	100.00	6	✓	6
w200.001	233	0.00	0	99.97	6	✓	6	234	0.00	0	100.00	6	✓	6	234	0.00	0	100.00	5	✓	5
w200.002	205	0.00	0	99.99	5	✓	5	205	0.00	0	99.96	6	✓	6	205	0.00	0	99.96	5	✓	5
w200.003	249	0.00	0	100.00	8	✓	8	249	0.00	0	100.00	7	✓	7	249	0.00	0	100.00	11	✓	11
w200.004	293	0.00	0	100.00	6	✓	6	320	0.31	0	99.14	14	✓	14	325	0.00	1	100.00	13	✓	13
w200.005	236	0.00	0	100.00	6	✓	6	236	0.00	0	100.00	7	✓	7	236	0.00	0	100.00	6	✓	6

†: Includes the time of GVNS.

Table EC.10 RTSPTW($\mathcal{T}_K$): Results on the instances of set GDE-I with 20 customers.

	$\Delta = 20$							$\Delta = 40$							$\Delta = 60$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	*%gap*	*time*	*%lb*	$time^\dagger$	*opt*	$time^\dagger$	ub^*	*%gap*	*time*	*%lb*	$time^\dagger$	*opt*	$time^\dagger$	ub^*	*%gap*	*time*	*%lb*	$time^\dagger$	*opt*	$time^\dagger$
w120.001	313	0.00	0	100.00	5	✓	5	313	0.00	0	100.00	4	✓	4	inf	-	419	-	424	✓	424
w120.002	222	0.00	0	100.00	5	✓	5	231	0.00	0	100.00	5	✓	5	248	0.00	0	100.00	6	✓	6
w120.003	303	0.00	0	100.00	4	✓	4	312	0.00	0	100.00	5	✓	5	inf	-	419	-	423	✓	423
w120.004	377	0.00	0	100.00	5	✓	5	389	0.00	0	100.00	5	✓	5	391	0.00	0	100.00	5	✓	5
w120.005	240	0.00	0	100.00	4	✓	4	293	0.00	0	100.00	5	✓	5	323	0.00	338	100.00	343	✓	343
w140.001	176	0.00	0	100.00	4	✓	4	207	0.00	0	100.00	5	✓	5	210	0.00	0	100.00	5	✓	5
w140.002	272	0.00	0	100.00	5	✓	5	280	0.00	0	100.00	5	✓	5	280	0.00	0	100.00	5	✓	5
w140.003	236	0.00	0	100.00	5	✓	5	244	0.00	0	100.00	5	✓	5	250	0.00	0	100.00	5	✓	5
w140.004	272	0.00	0	97.24	7	✓	7	293	0.00	0	98.98	8	✓	8	inf	-	419	-	424	✓	424
w140.005	225	0.00	0	100.00	4	✓	4	243	0.00	0	100.00	5	✓	5	inf	-	419	-	424	✓	424
w160.001	245	0.00	0	100.00	5	✓	5	245	0.00	0	100.00	5	✓	5	270	0.00	0	100.00	6	✓	6
w160.002	201	0.00	0	100.00	4	✓	4	201	0.00	0	100.00	4	✓	4	201	0.00	0	100.00	5	✓	5
w160.003	270	0.00	0	100.00	6	✓	6	278	0.00	0	99.94	6	✓	6	295	0.00	1	100.00	7	✓	7
w160.004	204	0.00	0	100.00	5	✓	5	204	0.00	0	100.00	6	✓	6	204	0.00	0	100.00	4	✓	4
w160.005	247	0.00	0	100.00	5	✓	5	247	0.00	0	100.00	5	✓	5	247	0.00	0	100.00	4	✓	4
w180.001	253	0.00	0	100.00	4	✓	4	253	0.00	0	100.00	4	✓	4	262	0.00	0	100.00	5	✓	5
w180.002	276	0.00	0	100.00	5	✓	5	276	0.00	0	100.00	5	✓	5	276	0.00	0	100.00	5	✓	5
w180.003	275	0.00	0	100.00	5	✓	5	292	0.00	0	100.00	5	✓	5	292	0.00	0	100.00	5	✓	5
w180.004	215	0.00	0	100.00	5	✓	5	243	0.00	0	100.00	7	✓	7	243	0.00	0	100.00	7	✓	7
w180.005	193	0.00	0	100.00	5	✓	5	206	0.00	0	100.00	5	✓	5	207	0.00	0	100.00	5	✓	5
w200.001	233	0.00	0	99.99	5	✓	5	234	0.00	0	100.00	5	✓	5	234	0.00	0	100.00	5	✓	5
w200.002	205	0.00	0	99.99	5	✓	5	205	0.00	0	99.97	5	✓	5	211	0.00	0	100.00	6	✓	6
w200.003	249	0.00	0	100.00	16	✓	16	267	0.00	0	100.00	15	✓	15	271	0.00	0	100.00	9	✓	9
w200.004	293	0.00	0	100.00	6	✓	6	322	0.00	0	99.84	11	✓	11	337	0.00	0	98.96	11	✓	11
w200.005	236	0.00	0	99.87	6	✓	6	236	0.00	0	100.00	6	✓	6	236	0.00	0	100.00	6	✓	6

†: Includes the time of GVNS.

Table EC.11 RTSPTW($\mathcal{T}_C$): Results on the instances of set GDE-D with 80 customers.

	$\Gamma=1$							$\Gamma=7$							$\Gamma=12$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	%gap	time	%lb	time†	opt	time†	ub^*	%gap	time	%lb	time†	opt	time†	ub^*	%gap	time	%lb	time†	opt	time†
w100.001	587	0.00	599	100.00	633	✓	633	inf	-	1303	-	3987	✓	3987	inf	-	1304	-	2803	✓	2803
w100.002	575	0.35	576	99.91	595	✓	595	?	-	1304	-	4089		4089	inf	-	1304	-	4171	✓	4171
w100.003	586	0.00	253	100.00	276	✓	276	inf	-	1302	-	1865	✓	1865	inf	-	1306	-	2043	✓	2043
w100.004	661	0.00	591	100.00	609	✓	609	inf	-	1303	-	1600	✓	1600	inf	-	1305	-	1749	✓	1749
w100.005	557	0.00	674	100.00	939	✓	939	inf	-	1302	-	3510	✓	3510	inf	-	1305	-	4758		4758
w120.001	517	0.00	152	99.53	328	✓	328	519	0.00	169	100.00	454	✓	454	519	0.00	299	100.00	660	✓	660
w120.002	577	0.00	92	99.91	148	✓	148	577	0.00	169	99.93	250	✓	250	577	0.00	234	100.00	381	✓	381
w120.003	544	0.00	386	100.00	437	✓	437	583	0.00	465	100.00	793	✓	793	613	0.00	1058	99.99	1840	✓	1840
w120.004	506	0.00	257	99.09	340	✓	341	515	0.00	529	99.57	818	✓	820	518	0.00	426	99.85	791	✓	791
w120.005	615	0.00	663	99.19	830	✓	832	622	0.00	798	99.39	1391	✓	1396	661	0.00	1142	89.37	t.l.		-
w140.001	515	0.00	231	100.00	332	✓	332	515	0.00	374	100.00	780	✓	780	515	0.00	562	100.00	1146	✓	1146
w140.002	501	0.00	260	96.85	4195	✓	4697	526	0.00	810	99.33	3083	✓	3095	530	0.00	992	84.87	t.l.		-
w140.003	603	0.00	461	98.62	670	✓	696	603	0.00	420	99.37	990	✓	993	613	0.33	472	99.43	2818	✓	2834
w140.004	429	0.70	405	98.33	689	✓	692	449	0.45	494	97.89	1453	✓	1465	474	0.00	841	96.41	3393		3488
w140.005	558	0.00	360	100.00	446	✓	446	573	0.00	385	100.00	585	✓	585	574	0.00	285	100.00	633	✓	633
w160.001	506	0.00	483	100.00	1520	✓	1520	512	0.39	507	100.00	1276	✓	1276	520	0.77	784	100.00	3768	✓	3768
w160.002	556	0.00	382	97.99	1525	✓	2773	585	0.00	604	75.78	t.l.		-	590	0.00	1250	0.00	t.l.		-
w160.003	531	0.00	168	98.62	1136	✓	1142	533	0.00	236	98.78	1898	✓	1909	533	0.00	135	99.44	2258	✓	2272
w160.004	514	0.00	385	99.68	916	✓	919	517	0.00	495	100.00	1470	✓	1470	517	0.58	549	100.00	1795	✓	1795
w160.005	444	0.00	262	99.27	543	✓	545	454	2.42	438	100.00	1543	✓	1543	455	2.42	328	100.00	1337	✓	1337
w180.001	551	0.00	152	99.51	460	✓	461	574	0.17	357	99.96	1773	✓	1778	582	0.52	460	100.00	2903	✓	2903
w180.002	508	0.00	423	99.15	1230	✓	1234	515	0.00	497	99.80	1691	✓	1695	518	0.00	484	99.52	2597	✓	2613
w180.003	533	0.38	52	99.04	921	✓	944	539	0.00	236	99.99	2462	✓	2462	541	0.00	364	99.76	2890	✓	2899
w180.004	480	0.00	159	99.65	398	✓	398	488	0.00	205	100.00	732	✓	732	491	0.00	186	99.92	1587	✓	1587
w180.005	473	0.00	538	99.33	765	✓	766	475	0.00	322	100.00	747	✓	747	475	0.00	585	100.00	894	✓	894
w200.001	493	0.00	47	99.47	1010	✓	1015	499	0.00	405	99.71	2926	✓	2937	502	0.20	478	99.60	4813	✓	4892
w200.002	508	0.00	164	99.47	366	✓	367	508	0.00	118	100.00	383	✓	383	511	0.20	60	99.93	561	✓	562
w200.003	464	0.00	162	99.53	475	✓	476	464	0.00	144	100.00	544	✓	544	467	0.00	227	99.99	1031	✓	1031
w200.004	526	0.00	167	99.14	548	✓	548	535	0.00	197	99.66	1350	✓	1355	537	0.00	533	99.99	1987	✓	1987
w200.005	439	0.00	304	99.70	745	✓	746	444	0.00	267	100.00	1205	✓	1205	444	0.68	288	100.00	1506	✓	1506

†: Includes the time of GVNS.

Table EC.12 RTSPTW($\mathcal{T}_C$): Results on the instances of set GDE-I with 80 customers.

	$\Gamma=1$							$\Gamma=2$							$\Gamma=3$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	%gap	time	%lb	time†	opt	time†	ub^*	%gap	time	%lb	time†	opt	time†	ub^*	%gap	time	%lb	time†	opt	time†
w100.001	inf	-	1300	-	1550	✓	1550	inf	-	1300	-	1498	✓	1498	inf	-	1301	-	1389	✓	1389
w100.002	inf	-	1299	-	1986	✓	1986	inf	-	1301	-	1398	✓	1398	inf	-	1301	-	1363	✓	1363
w100.003	inf	-	1302	-	1514	✓	1514	inf	-	1300	-	1435	✓	1435	inf	-	1301	-	1428	✓	1428
w100.004	inf	-	0	-	0	✓	0	inf	-	0	-	0	✓	0	inf	-	0	-	0	✓	0
w100.005	inf	-	1299	-	1728	✓	1728	inf	-	0	-	0	✓	0	inf	-	0	-	0	✓	0
w120.001	517	0.00	264	100.00	391	✓	391	526	0.00	468	100.00	716	✓	716	538	0.00	687	100.00	1081	✓	1081
w120.002	578	0.00	157	99.91	199	✓	199	581	0.00	569	100.00	665	✓	665	inf	-	1301	-	1538	✓	1538
w120.003	548	0.00	390	100.00	576	✓	576	603	0.00	520	100.00	748	✓	748	inf	-	1301	-	2234	✓	2234
w120.004	514	0.39	418	99.32	516	✓	517	524	0.00	746	99.81	900	✓	901	inf	-	1301	-	1520	✓	1520
w120.005	624	0.00	594	99.27	846	✓	849	658	0.30	1173	99.83	1836	✓	1840	677	0.15	1245	98.97	1792	✓	1796
w140.001	512	0.00	364	100.00	533	✓	533	512	0.00	506	100.00	652	✓	652	?	-	1301	-	t.l.		-
w140.002	526	0.19	412	98.63	3135	✓	3153	545	0.00	625	99.72	6792	✓	6803	?	-	1301	-	t.l.		-
w140.003	609	0.16	726	98.95	1019	✓	1022	621	0.16	788	99.38	1376	✓	1382	634	-	1303	100.00	4694	✓	4694
w140.004	445	2.02	431	99.66	758	✓	761	502	0.00	859	97.97	1750	✓	1790	inf	-	1301	-	1992	✓	1992
w140.005	546	0.00	456	100.00	552	✓	552	546	0.00	666	100.00	820	✓	820	560	0.00	731	100.00	1059	✓	1059
w160.001	514	0.00	307	100.00	873	✓	873	530	0.00	557	100.00	1640	✓	1640	?	-	1303	-	t.l.		-
w160.002	583	0.00	405	97.16	2447		m.l.	591	0.00	743	99.82	2695	✓	2701	?	-	1302	-	t.l.		-
w160.003	533	0.00	221	99.50	764	✓	766	545	0.00	201	100.00	644	✓	644	577	0.00	393	100.00	1261	✓	1261
w160.004	518	0.00	614	100.00	1058	✓	1058	527	0.00	703	99.53	1401	✓	1406	?	-	1301	-	t.l.		-
w160.005	465	0.00	538	99.35	1053	✓	1059	480	0.00	795	99.87	1465	✓	1465	495	0.00	894	99.39	1505	✓	1509
w180.001	570	0.18	169	99.96	557	✓	558	577	0.00	152	100.00	420	✓	420	inf	-	1303	-	6110	✓	6110
w180.002	526	0.00	667	99.17	2102	✓	2109	538	0.00	621	99.16	1477	✓	1485	540	0.00	805	99.98	1852	✓	1852
w180.003	539	0.00	234	99.91	1144	✓	1144	540	0.00	526	100.00	1186	✓	1186	?	-	1306	-	t.l.		-
w180.004	482	0.00	261	99.93	629	✓	629	487	0.00	385	99.99	810	✓	810	?	-	1305	-	t.l.		-
w180.005	475	0.00	536	100.00	652	✓	652	499	0.00	607	99.61	1353	✓	1357	inf	-	1308	-	3684	✓	3684
w200.001	497	0.20	111	99.89	1212	✓	1219	507	0.00	192	99.65	1507	✓	1516	?	-	1311	-	t.l.		-
w200.002	512	0.00	271	99.75	477	✓	478	513	0.00	348	99.86	594	✓	594	524	2.29	684	99.62	1792	✓	1808
w200.003	467	0.00	34	99.57	283	✓	285	471	0.00	334	100.00	612	✓	612	507	0.20	720	99.31	4037	✓	4069
w200.004	529	0.00	476	99.15	1017	✓	1020	537	0.00	375	100.00	901	✓	901	inf	-	1303	-	7958	✓	7958
w200.005	448	0.89	413	99.71	1538	✓	1542	472	0.00	546	98.48	2714	✓	2805	489	0.20	484	97.86	3447	✓	5695

m.l.: DP terminates prematurely after reaching the path limit M.
†: Includes the time of GVNS.

Table EC.13 RTSPTW($\mathcal{T}_C$): Results on the instances of set GDE-D with 60 customers.

	$\Gamma=1$							$\Gamma=7$							$\Gamma=12$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$
w120.001	393	0.00	78	99.87	95	✓	95	401	0.00	20	100.00	64	✓	64	401	0.00	17	100.00	109	✓	109
w120.002	500	0.00	10	99.90	43	✓	43	512	0.00	204	99.99	295	✓	295	518	0.00	525	99.98	772	✓	772
w120.003	407	0.00	8	100.00	47	✓	47	411	0.00	64	100.00	110	✓	110	413	0.00	174	100.00	260	✓	260
w120.004	492	0.00	9	99.96	58	✓	58	492	0.00	65	100.00	166	✓	166	492	0.00	84	100.00	200	✓	200
w120.005	547	0.00	11	100.00	27	✓	27	inf	-	980	-	5684	✓	5684	inf	-	-	-	-	✓	-
w140.001	423	0.00	9	99.76	38	✓	38	423	0.00	22	100.00	58	✓	58	426	0.00	22	100.00	86	✓	86
w140.002	478	0.00	24	99.90	60	✓	60	478	0.00	13	100.00	101	✓	101	?	-	980	-	3235		3235
w140.003	434	0.00	9	100.00	35	✓	35	440	0.00	27	100.00	62	✓	62	441	0.00	15	99.77	54	✓	55
w140.004	545	0.00	597	99.90	653	✓	653	inf	-	980	-	1184	✓	1184	inf	-	981	-	1196	✓	1196
w140.005	462	0.00	28	99.86	90	✓	90	478	1.05	189	100.00	331	✓	331	486	0.00	781	99.63	923	✓	925
w160.001	563	0.00	17	100.00	84	✓	84	594	0.00	57	100.00	297	✓	297	599	0.00	406	100.00	1185	✓	1185
w160.002	423	0.00	8	99.92	25	✓	25	448	0.00	13	100.00	77	✓	77	448	0.00	16	100.00	72	✓	72
w160.003	434	0.00	12	99.32	111	✓	111	435	0.00	27	99.72	322	✓	323	435	0.00	127	100.00	479	✓	479
w160.004	462	0.00	9	99.58	100	✓	100	462	0.00	15	100.00	202	✓	202	462	0.00	110	99.99	276	✓	276
w160.005	501	0.00	10	100.00	47	✓	47	501	0.00	92	100.00	295	✓	295	501	0.00	75	100.00	414	✓	414
w180.001	414	0.48	9	98.41	439	✓	445	423	0.00	16	98.21	1001	✓	1017	431	0.00	37	97.88	1477	✓	1501
w180.002	411	0.00	12	99.07	78	✓	78	412	0.00	19	99.92	87	✓	87	414	0.00	34	99.98	132	✓	132
w180.003	446	0.00	10	98.59	52	✓	52	451	0.00	62	99.65	174	✓	174	451	0.89	93	99.89	207	✓	208
w180.004	463	0.00	20	100.00	94	✓	94	463	0.00	18	100.00	125	✓	125	463	0.00	23	100.00	130	✓	130
w180.005	395	0.00	18	98.76	85	✓	86	408	0.25	21	97.75	362	✓	389	412	0.00	221	98.12	1311	✓	1361
w200.001	422	0.00	14	99.62	105	✓	106	423	0.00	27	100.00	144	✓	144	423	0.00	257	100.00	389	✓	389
w200.002	414	0.00	10	100.00	87	✓	87	420	0.48	16	99.40	117	✓	118	420	0.00	20	99.40	98	✓	99
w200.003	455	0.00	60	97.87	800	✓	843	455	0.00	72	99.79	926	✓	926	455	0.00	34	100.00	1033	✓	1033
w200.004	431	0.00	11	99.19	107	✓	107	431	0.00	63	99.54	208	✓	209	431	0.00	115	99.70	293	✓	294
w200.005	427	0.00	12	100.00	182	✓	182	427	0.00	25	100.00	127	✓	127	427	0.00	28	100.00	92	✓	92

†: Includes the time of GVNS.

Table EC.14 RTSPTW($\mathcal{T}_C$): Results on the instances of set GDE-I with 60 customers.

	$\Gamma=1$							$\Gamma=2$							$\Gamma=3$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$
w120.001	424	2.12	85	100.00	130	✓	130	448	0.00	117	99.40	184	✓	184	456	0.00	200	100.00	264	✓	264
w120.002	516	0.00	104	99.98	212	✓	212	521	0.00	125	100.00	164	✓	164	inf	-	979	-	1056	✓	1056
w120.003	407	0.00	20	100.00	69	✓	69	418	0.00	73	100.00	183	✓	183	449	0.22	212	100.00	540	✓	540
w120.004	492	0.00	9	100.00	52	✓	52	504	0.00	63	100.00	112	✓	112	inf	-	980	-	1223	✓	1223
w120.005	566	0.00	14	100.00	51	✓	51	568	0.00	65	100.00	104	✓	104	inf	-	980	-	1091	✓	1091
w140.001	423	0.00	8	100.00	34	✓	34	468	0.00	111	100.00	173	✓	173	inf	-	980	-	1217	✓	1217
w140.002	465	0.00	31	100.00	60	✓	60	?	-	980	-	2155		2155	inf	-	979	-	1521	✓	1521
w140.003	436	0.00	11	100.00	35	✓	35	458	0.22	62	99.78	149	✓	150	504	-	980	100.00	3696	✓	3696
w140.004	inf	-	979	-	1136	✓	1136	inf	-	979	-	1042	✓	1042	inf	-	979	-	1034	✓	1034
w140.005	472	0.21	42	100.00	129	✓	130	489	0.20	324	100.00	415	✓	415	inf	-	979	-	1656	✓	1656
w160.001	577	0.00	16	100.00	113	✓	113	597	0.00	79	99.12	606	✓	607	603	0.00	188	100.00	524	✓	524
w160.002	455	0.00	9	100.00	52	✓	52	473	0.00	63	100.00	133	✓	133	496	0.00	100	97.92	360	✓	365
w160.003	434	0.00	28	99.79	121	✓	121	437	0.00	69	100.00	244	✓	244	?	-	979	-	6624		6624
w160.004	464	0.00	15	99.92	91	✓	91	465	0.00	71	100.00	175	✓	175	inf	-	979	-	1822	✓	1822
w160.005	501	0.00	17	100.00	71	✓	71	512	0.00	62	100.00	164	✓	164	522	0.00	76	100.00	207	✓	207
w180.001	430	0.00	12	98.62	904	✓	913	436	0.00	20	99.40	774	✓	781	442	0.00	111	99.98	586	✓	586
w180.002	414	0.00	9	99.03	101	✓	101	422	0.00	13	99.76	82	✓	82	449	0.00	63	100.00	364	✓	364
w180.003	451	0.00	11	99.88	48	✓	48	451	2.88	206	99.89	312	✓	313	501	1.20	408	100.00	918	✓	918
w180.004	460	0.00	13	100.00	70	✓	70	468	0.00	14	99.97	92	✓	92	471	3.18	36	100.00	504	✓	504
w180.005	410	0.00	12	99.16	267	✓	269	423	0.00	277	100.00	375	✓	375	inf	-	979	-	6470	✓	6470
w200.001	438	0.00	19	99.60	103	✓	104	451	0.00	21	99.41	171	✓	171	476	0.00	464	100.00	950	✓	950
w200.002	421	0.00	9	99.52	75	✓	76	433	0.00	16	100.00	134	✓	134	465	4.09	577	100.00	1515	✓	1515
w200.003	455	0.00	60	98.99	654	✓	657	455	0.00	60	100.00	480	✓	480	?	-	980	-	3174		3174
w200.004	431	0.00	11	99.69	95	✓	96	431	0.00	109	100.00	206	✓	206	467	0.00	527	99.93	1079	✓	1079
w200.005	428	0.00	13	100.00	103	✓	103	428	0.00	17	100.00	147	✓	147	441	0.00	82	99.76	430	✓	433

†: Includes the time of GVNS.

Table EC.15 RTSPTW($\mathcal{T}_C$): Results on the instances of set GDE-D with 40 customers.

	$\Gamma=1$							$\Gamma=7$							$\Gamma=12$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	*ub**	*%gap*	*time*	*%lb*	*time*†	*opt*	*time*†	*ub**	*%gap*	*time*	*%lb*	*time*†	*opt*	*time*†	*ub**	*%gap*	*time*	*%lb*	*time*†	*opt*	*time*†
w120.001	446	0.00	1	100.00	9	✓	9	457	0.00	3	100.00	17	✓	17	inf	-	659	-	737	✓	737
w120.002	499	0.00	1	100.00	11	✓	11	inf	-	659	-	698	✓	698	inf	-	660	-	687	✓	687
w120.003	374	0.00	1	100.00	12	✓	12	383	0.00	2	99.86	29	✓	29	384	0.00	3	100.00	30	✓	30
w120.004	307	0.00	1	100.00	8	✓	8	338	0.00	160	100.00	185	✓	185	345	0.29	336	100.00	364	✓	364
w120.005	350	0.00	1	100.00	7	✓	7	350	0.00	2	100.00	7	✓	7	350	0.00	2	100.00	7	✓	7
w140.001	363	0.00	1	99.86	18	✓	18	364	0.00	2	100.00	36	✓	36	368	0.00	3	100.00	46	✓	46
w140.002	383	0.00	1	100.00	11	✓	11	383	0.00	3	100.00	13	✓	13	383	0.00	36	100.00	47	✓	47
w140.003	406	0.00	1	99.96	11	✓	11	416	0.00	4	100.00	26	✓	26	423	0.00	64	100.00	105	✓	105
w140.004	343	0.00	1	100.00	8	✓	8	365	0.00	2	100.00	18	✓	18	365	0.00	3	100.00	24	✓	24
w140.005	371	0.00	1	100.00	12	✓	12	392	0.00	87	100.00	130	✓	130	?	-	660	-	t.l.		-
w160.001	359	0.00	1	100.00	11	✓	11	360	0.00	3	100.00	17	✓	17	360	0.00	3	100.00	18	✓	18
w160.002	337	0.00	1	100.00	8	✓	8	345	0.00	2	100.00	17	✓	17	345	0.00	4	100.00	39	✓	39
w160.003	368	0.00	1	98.91	68	✓	68	368	0.00	3	100.00	72	✓	72	368	0.00	4	100.00	65	✓	65
w160.004	288	0.00	1	100.00	37	✓	37	296	0.00	3	100.00	85	✓	85	297	0.00	3	100.00	120	✓	120
w160.005	315	0.00	1	100.00	49	✓	49	315	0.00	2	100.00	55	✓	55	315	0.00	3	100.00	69	✓	69
w180.001	339	0.00	1	99.80	27	✓	27	343	0.00	2	100.00	23	✓	23	367	0.00	130	97.18	293	✓	306
w180.002	352	0.00	2	99.99	46	✓	46	358	0.00	4	100.00	25	✓	25	378	0.00	9	100.00	153	✓	153
w180.003	279	0.00	1	100.00	17	✓	17	299	0.00	2	100.00	35	✓	35	299	0.00	3	100.00	36	✓	36
w180.004	370	0.00	1	100.00	14	✓	14	372	0.00	5	100.00	22	✓	22	372	0.00	8	100.00	31	✓	31
w180.005	335	0.00	1	100.00	46	✓	46	335	0.00	3	100.00	52	✓	52	335	0.00	4	100.00	42	✓	42
w200.001	330	0.00	2	100.00	13	✓	13	349	0.00	4	100.00	80	✓	80	351	0.00	8	99.72	161	✓	162
w200.002	303	0.00	1	99.59	50	✓	50	314	0.00	2	99.84	124	✓	124	314	0.00	3	99.84	109	✓	109
w200.003	342	0.00	2	93.57	94	✓	135	343	1.17	3	96.50	228	✓	283	344	0.29	4	97.47	401	✓	465
w200.004	301	0.00	1	99.98	30	✓	30	301	0.00	2	100.00	36	✓	36	302	0.00	3	100.00	92	✓	92
w200.005	301	0.00	2	100.00	16	✓	16	310	0.00	3	99.91	70	✓	70	311	0.00	4	100.00	85	✓	85

†: Includes the time of GVNS.

Table EC.16 RTSPTW($\mathcal{T}_C$): Results on the instances of set GDE-I with 40 customers.

	$\Gamma=1$							$\Gamma=2$							$\Gamma=3$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	*ub**	*%gap*	*time*	*%lb*	*time*†	*opt*	*time*†	*ub**	*%gap*	*time*	*%lb*	*time*†	*opt*	*time*†	*ub**	*%gap*	*time*	*%lb*	*time*†	*opt*	*time*†
w120.001	446	0.00	1	100.00	7	✓	7	446	0.00	2	100.00	10	✓	10	inf	-	659	-	686	✓	686
w120.002	445	0.00	1	100.00	8	✓	8	450	0.00	2	100.00	11	✓	11	486	0.00	2	100.00	15	✓	15
w120.003	395	0.00	1	100.00	33	✓	33	432	0.00	2	100.00	40	✓	40	inf	-	659	-	785	✓	785
w120.004	342	0.00	1	100.00	20	✓	20	366	0.00	4	99.18	49	✓	49	inf	-	659	-	682	✓	682
w120.005	350	0.00	1	100.00	6	✓	6	366	0.00	2	100.00	37	✓	37	417	0.00	3	100.00	36	✓	36
w140.001	366	0.00	1	100.00	12	✓	12	366	0.00	1	100.00	13	✓	13	392	0.00	2	100.00	31	✓	31
w140.002	383	0.00	1	100.00	10	✓	10	383	0.00	2	100.00	12	✓	12	394	0.00	2	100.00	18	✓	18
w140.003	416	0.00	1	100.00	12	✓	12	417	0.00	2	100.00	8	✓	8	inf	-	660	-	674	✓	674
w140.004	366	0.00	1	100.00	12	✓	12	384	0.00	13	100.00	29	✓	29	419	0.00	162	99.28	232	✓	233
w140.005	376	0.00	1	100.00	19	✓	19	382	0.00	2	100.00	31	✓	31	393	0.00	55	100.00	80	✓	80
w160.001	360	0.00	1	100.00	10	✓	10	360	0.00	2	100.00	12	✓	12	inf	-	659	-	689	✓	689
w160.002	355	0.00	1	100.00	17	✓	17	370	0.00	2	100.00	23	✓	23	inf	-	659	-	696	✓	696
w160.003	368	0.00	2	100.00	57	✓	57	374	0.00	2	100.00	47	✓	47	inf	-	659	-	751	✓	751
w160.004	297	0.00	1	100.00	88	✓	88	303	0.00	2	100.00	118	✓	118	312	0.00	2	100.00	93	✓	93
w160.005	315	0.00	1	100.00	66	✓	66	315	0.00	1	100.00	39	✓	39	316	0.00	2	100.00	58	✓	58
w180.001	354	0.00	1	98.59	35	✓	35	356	0.00	2	100.00	28	✓	28	389	0.00	35	100.00	79	✓	79
w180.002	358	0.00	2	100.00	24	✓	24	378	0.00	67	100.00	137	✓	137	386	0.00	200	100.00	231	✓	231
w180.003	300	0.00	1	99.76	20	✓	20	328	0.00	2	100.00	36	✓	36	350	3.43	3	100.00	260	✓	260
w180.004	376	1.60	2	100.00	20	✓	20	386	0.00	2	100.00	23	✓	23	422	0.00	198	99.29	250	✓	250
w180.005	335	0.00	2	100.00	39	✓	39	335	0.00	2	100.00	28	✓	28	349	0.00	3	100.00	61	✓	61
w200.001	332	0.00	2	100.00	15	✓	15	349	0.00	2	100.00	37	✓	37	365	0.00	8	99.18	239	✓	241
w200.002	317	0.00	2	99.98	61	✓	61	318	0.00	2	100.00	99	✓	99	329	0.00	3	100.00	132	✓	132
w200.003	342	0.00	1	94.42	77	✓	104	342	0.00	2	97.83	81	✓	82	348	0.29	2	99.84	111	✓	112
w200.004	301	0.00	1	100.00	20	✓	20	312	2.24	2	99.68	77	✓	79	321	0.00	2	100.00	42	✓	42
w200.005	319	0.00	2	98.87	57	✓	57	331	0.00	3	99.54	110	✓	110	348	0.00	3	99.92	221	✓	221

†: Includes the time of GVNS.

Table EC.17 RTSPTW($\mathcal{T}_C$): Results on the instances of set GDE-D with 20 customers.

	$\Delta = 1$								$\Gamma = 7$								$\Gamma = 12$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$
w120.001	297	0.00	0	100.00	5	✓	5	313	0.00	0	100.00	5	✓	5	inf	-	419	-	427	✓	427
w120.002	218	0.00	0	99.67	5	✓	5	221	0.00	0	100.00	4	✓	4	inf	-	419	-	424	✓	424
w120.003	303	0.00	0	100.00	4	✓	4	325	0.00	0	100.00	5	✓	5	339	0.00	0	100.00	5	✓	5
w120.004	321	0.00	0	100.00	5	✓	5	inf	-	419	-	425	✓	425	inf	-	419	-	424	✓	424
w120.005	278	0.00	0	100.00	4	✓	4	287	0.00	0	100.00	5	✓	5	inf	-	420	-	426	✓	426
w140.001	176	0.00	0	100.00	4	✓	4	181	7.18	0	100.00	5	✓	5	181	0.00	0	100.00	5	✓	5
w140.002	272	0.00	0	100.00	4	✓	4	286	0.00	0	100.00	4	✓	4	286	0.00	0	100.00	5	✓	5
w140.003	236	0.00	0	100.00	5	✓	5	236	0.00	0	100.00	5	✓	5	236	0.00	0	100.00	5	✓	5
w140.004	273	0.00	0	98.72	8	✓	8	309	0.00	63	100.00	72	✓	72	inf	-	419	-	431	✓	431
w140.005	225	0.00	0	100.00	5	✓	5	228	0.44	0	100.00	4	✓	4	243	0.00	0	100.00	4	✓	4
w160.001	241	0.00	0	100.00	5	✓	5	245	0.00	0	100.00	5	✓	5	246	0.00	0	100.00	5	✓	5
w160.002	201	0.00	0	100.00	4	✓	4	201	0.00	0	100.00	4	✓	4	201	0.00	0	100.00	4	✓	4
w160.003	243	0.00	0	98.35	6	✓	6	270	0.00	0	97.41	10	✓	10	272	2.21	0	97.43	13	✓	13
w160.004	203	0.00	0	100.00	8	✓	8	203	0.00	0	100.00	7	✓	7	203	0.00	0	100.00	7	✓	7
w160.005	247	0.00	0	100.00	5	✓	5	247	0.00	0	100.00	4	✓	4	247	0.00	0	100.00	5	✓	5
w180.001	253	0.00	0	100.00	4	✓	4	270	0.00	0	100.00	5	✓	5	270	0.00	0	100.00	5	✓	5
w180.002	265	0.00	0	100.00	5	✓	5	271	0.00	0	100.00	4	✓	4	276	0.00	0	100.00	5	✓	5
w180.003	275	0.00	0	100.00	5	✓	5	275	0.00	0	100.00	5	✓	5	278	0.00	0	100.00	5	✓	5
w180.004	215	0.00	0	100.00	5	✓	5	242	0.00	0	100.00	6	✓	6	242	0.00	0	100.00	8	✓	8
w180.005	193	0.00	0	100.00	5	✓	5	206	0.00	0	100.00	5	✓	5	206	0.00	0	100.00	6	✓	6
w200.001	233	0.00	0	99.74	6	✓	6	234	0.00	0	100.00	5	✓	5	234	0.00	0	100.00	5	✓	5
w200.002	205	0.00	0	99.97	5	✓	5	205	0.00	0	99.96	5	✓	5	205	0.00	0	99.96	5	✓	5
w200.003	249	0.00	0	100.00	7	✓	7	249	0.00	0	100.00	6	✓	6	249	0.00	0	100.00	10	✓	10
w200.004	293	0.00	0	98.12	7	✓	7	337	0.00	0	100.00	10	✓	10	inf	-	419	-	437	✓	437
w200.005	236	0.00	0	99.97	6	✓	6	236	0.00	0	100.00	6	✓	6	236	0.00	0	100.00	9	✓	9

†: Includes the time of GVNS.

Table EC.18 RTSPTW($\mathcal{T}_C$): Results on the instances of set GDE-I with 20 customers.

	$\Gamma = 1$								$\Gamma = 2$								$\Gamma = 3$						
		GVNS		CSP		DP			GVNS		CSP		DP			GVNS		CSP		DP	
Instance	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	$time^\dagger$
w120.001	313	0.00	0	100.00	5	✓	5	316	0.00	0	100.00	4	✓	4	inf	-	419	-	424	✓	424
w120.002	224	0.00	0	100.00	5	✓	5	244	0.00	0	100.00	5	✓	5	inf	-	419	-	424	✓	424
w120.003	303	0.00	0	100.00	4	✓	4	inf	-	419	-	424	✓	424	inf	-	419	-	423	✓	423
w120.004	350	0.00	4	100.00	9	✓	9	389	0.00	0	100.00	4	✓	4	inf	-	419	-	424	✓	424
w120.005	250	0.00	0	100.00	5	✓	5	301	0.00	0	100.00	5	✓	5	inf	-	419	-	424	✓	424
w140.001	178	0.00	0	100.00	5	✓	5	207	0.00	0	100.00	5	✓	5	213	0.47	0	100.00	5	✓	5
w140.002	272	0.00	0	100.00	4	✓	4	280	0.00	0	100.00	4	✓	4	inf	-	419	-	424	✓	424
w140.003	236	0.00	0	100.00	4	✓	4	244	0.00	0	100.00	4	✓	4	inf	-	419	-	424	✓	424
w140.004	286	0.00	0	97.00	7	✓	8	321	0.00	43	100.00	50	✓	50	inf	-	419	-	424	✓	424
w140.005	225	0.00	0	100.00	4	✓	4	225	0.00	0	100.00	4	✓	4	253	0.00	0	100.00	5	✓	5
w160.001	245	0.00	0	100.00	5	✓	5	261	0.00	0	100.00	5	✓	5	inf	-	419	-	429	✓	429
w160.002	201	0.00	0	100.00	4	✓	4	201	0.00	0	100.00	4	✓	4	201	0.00	0	100.00	4	✓	4
w160.003	261	0.00	0	100.00	7	✓	7	275	0.00	0	100.00	5	✓	5	inf	-	419	-	425	✓	425
w160.004	204	0.00	0	100.00	5	✓	5	204	0.00	0	100.00	5	✓	5	204	0.00	0	100.00	5	✓	5
w160.005	247	0.00	0	100.00	4	✓	4	247	0.00	0	100.00	5	✓	5	248	0.00	0	100.00	4	✓	4
w180.001	253	0.00	0	100.00	4	✓	4	262	0.00	0	100.00	4	✓	4	287	0.00	0	100.00	5	✓	5
w180.002	276	0.00	0	100.00	4	✓	4	276	0.00	0	100.00	4	✓	4	276	0.00	0	100.00	4	✓	4
w180.003	275	0.00	0	100.00	5	✓	5	292	0.00	0	100.00	4	✓	4	inf	-	419	-	425	✓	425
w180.004	233	0.00	0	100.00	6	✓	6	243	0.00	0	100.00	7	✓	7	243	0.00	0	100.00	7	✓	7
w180.005	193	0.00	0	100.00	4	✓	4	206	0.00	0	100.00	5	✓	5	207	0.00	0	100.00	5	✓	5
w200.001	233	0.00	0	99.95	6	✓	6	234	0.00	0	100.00	5	✓	5	237	0.00	0	100.00	5	✓	5
w200.002	205	0.00	0	99.99	5	✓	5	205	0.00	0	100.00	5	✓	5	219	0.00	0	100.00	7	✓	7
w200.003	251	0.00	0	100.00	10	✓	10	271	0.00	0	100.00	11	✓	11	271	0.00	0	100.00	8	✓	8
w200.004	293	0.00	0	100.00	5	✓	5	322	0.00	0	100.00	10	✓	10	337	0.00	0	100.00	7	✓	7
w200.005	236	0.00	0	100.00	5	✓	5	236	0.00	0	100.00	5	✓	5	236	0.00	0	100.00	7	✓	7

†: Includes the time of GVNS.

Table EC.19 TSPTW: Results on instances of Gendreau et al. (1998) with up to 60 customers.

	$n=20$						$n=40$						$n=60$					
		GVNS		CSP+DP				GVNS		CSP+DP				GVNS		CSP+DP		
Instance	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt
w120.001	267	0.00	0	100.00	1	✓	434	0.00	1	100.00	6	✓	384	0.00	36	100.00	57	✓
w120.002	218	0.00	0	100.00	1	✓	444	0.00	1	100.00	6	✓	426	0.00	9	100.00	26	✓
w120.003	303	0.00	0	100.00	1	✓	357	0.00	1	100.00	5	✓	407	0.00	7	100.00	28	✓
w120.004	300	0.00	0	100.00	1	✓	303	0.00	1	100.00	7	✓	490	0.00	7	100.00	19	✓
w120.005	240	0.00	0	100.00	1	✓	350	0.00	1	100.00	3	✓	547	0.00	7	100.00	27	✓
w140.001	176	0.00	0	100.00	1	✓	328	0.00	1	100.00	5	✓	423	0.00	7	99.64	28	✓
w140.002	272	0.00	0	100.00	1	✓	383	0.00	1	100.00	6	✓	462	0.00	7	99.78	40	✓
w140.003	236	0.00	0	100.00	1	✓	398	0.00	1	100.00	7	✓	427	0.00	8	100.00	22	✓
w140.004	255	0.00	0	100.00	2	✓	342	0.00	1	100.00	7	✓	488	0.00	14	100.00	41	✓
w140.005	225	0.00	0	100.00	1	✓	371	0.00	1	100.00	10	✓	460	0.00	17	99.35	56	✓
w160.001	241	0.00	0	100.00	1	✓	348	0.00	1	100.00	6	✓	560	0.54	8	99.35	41	✓
w160.002	201	0.00	0	100.00	1	✓	337	0.00	1	100.00	7	✓	423	0.00	6	100.00	28	✓
w160.003	201	0.00	0	100.00	1	✓	346	0.00	1	100.00	8	✓	434	0.00	9	99.82	32	✓
w160.004	203	0.00	0	99.98	1	✓	288	0.00	1	100.00	11	✓	401	0.00	7	100.00	24	✓
w160.005	245	0.00	0	100.00	1	✓	315	0.00	1	100.00	10	✓	501	0.00	9	100.00	25	✓
w180.001	253	0.00	0	100.00	1	✓	337	0.00	1	100.00	13	✓	411	0.00	7	98.84	97	✓
w180.002	265	0.00	0	100.00	1	✓	347	0.00	1	100.00	16	✓	399	0.00	7	100.00	19	✓
w180.003	271	0.00	0	99.76	1	✓	279	0.00	1	100.00	8	✓	444	0.00	10	99.28	42	✓
w180.004	201	0.00	0	100.00	1	✓	354	0.00	1	99.72	13	✓	456	0.00	17	99.89	33	✓
w180.005	193	0.00	0	100.00	1	✓	335	0.00	1	100.00	10	✓	395	0.00	7	98.41	71	✓
w200.001	233	0.00	0	100.00	4	✓	330	0.00	1	100.00	12	✓	410	0.00	9	100.00	33	✓
w200.002	203	0.00	0	100.00	1	✓	303	0.00	1	100.00	21	✓	414	0.00	13	100.00	28	✓
w200.003	249	0.00	0	100.00	2	✓	339	0.00	1	94.43	53	✓	455	0.00	12	97.86	218	✓
w200.004	293	0.00	0	98.81	8	✓	301	0.00	1	100.00	19	✓	431	0.00	9	99.82	52	✓
w200.005	227	0.00	0	99.73	1	✓	296	1.35	1	100.00	18	✓	427	0.00	10	99.87	42	✓

†: Includes the time of GVNS.

Table EC.20 TSPTW: Results on instances of Gendreau et al. (1998) with 80 and 100 customers.

	$n=80$						$n=100$					
		GVNS		CSP+DP				GVNS		CSP+DP		
Instance	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt
w100.001	541	0.00	275	100.00	290	✓	643	0.00	271	100.00	308	✓
w100.002	567	0.00	421	100.00	439	✓	618	0.00	405	100.00	443	✓
w100.003	578	0.00	387	100.00	403	✓	685	0.00	358	100.00	395	✓
w100.004	648	0.00	409	100.00	436	✓	684	0.00	511	99.96	540	✓
w100.005	532	0.00	533	100.00	557	✓	572	0.00	419	100.00	450	✓
w120.001	498	0.00	252	99.89	276	✓	629	0.32	217	99.89	266	✓
w120.002	577	0.00	23	99.91	48	✓	540	0.00	274	98.94	344	✓
w120.003	540	0.00	200	100.00	226	✓	615	0.00	167	100.00	239	✓
w120.004	501	0.00	298	98.20	367	✓	662	0.00	275	98.94	324	✓
w120.005	591	0.00	242	99.41	284	✓	537	0.00	221	100.00	250	✓
w140.001	511	0.00	256	100.00	291	✓	603	0.00	217	100.00	310	✓
w140.002	470	0.64	211	99.89	295	✓	613	0.00	302	100.00	355	✓
w140.003	580	0.17	303	99.14	393	✓	481	0.00	258	99.99	318	✓
w140.004	422	0.00	319	99.64	370	✓	533	0.00	224	100.00	271	✓
w140.005	545	0.00	174	100.00	197	✓	509	0.00	396	98.98	477	✓
w160.001	506	0.00	149	100.00	213	✓	582	0.00	180	99.91	246	✓
w160.002	548	0.00	207	99.88	376	✓	530	0.00	52	99.90	152	✓
w160.003	521	0.00	69	99.99	119	✓	495	0.00	220	100.00	267	✓
w160.004	509	0.00	260	100.00	301	✓	580	0.00	237	99.94	362	✓
w160.005	438	0.00	181	100.00	226	✓	586	0.00	244	99.83	321	✓
w180.001	551	0.18	105	99.94	191	✓	732	0.00	598	99.11	826	✓
w180.002	478	0.00	502	100.00	582	✓	677	0.59	779	98.79	1285	✓
w180.003	524	1.53	151	100.00	243	✓	747	0.00	766	99.96	983	✓
w180.004	479	0.00	104	99.79	187	✓	762	0.00	443	99.95	629	✓
w180.005	470	0.00	260	100.00	319	✓	689	0.15	494	99.37	693	✓
w200.001	490	0.41	155	99.28	348	✓	762	0.13	603	98.95	2608	✓
w200.002	488	0.00	122	99.80	215	✓	753	0.13	670	99.94	996	✓
w200.003	464	0.00	28	99.54	115	✓	613	2.94	946	99.27	1861	✓
w200.004	526	0.00	209	99.14	315	✓	676	0.00	945	100.00	1126	✓
w200.005	439	0.00	205	99.85	263	✓	663	0.15	735	99.87	1211	✓

†: Includes the time of GVNS.

Table EC.21 TSPTW: Results on instances of Ohlmann and Thomas (2007) with 150 and 200 customers.

	$n = 150$						$n = 200$					
		GVNS		CSP+DP				GVNS		CSP+DP		
Instance	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt	ub^*	$\%gap$	$time$	$\%lb$	$time^\dagger$	opt
w120.001	732	0.00	598	99.11	826	✓	795	0.00	1109	99.66	1461	✓
w120.002	677	0.59	779	98.79	1285	✓	721	0.14	1120	99.71	1648	✓
w120.003	747	0.00	766	99.96	983	✓	879	2.39	1196	99.70	2008	✓
w120.004	762	0.00	443	99.95	629	✓	777	0.00	1084	99.98	1304	✓
w120.005	689	0.15	494	99.37	693	✓	840	0.12	1139	99.34	4142	✓
w140.001	762	0.13	603	98.95	2608	✓	830	0.00	1179	99.52	2250	✓
w140.002	753	0.13	670	99.94	996	✓	760	1.05	1221	99.38	2594	✓
w140.003	613	2.94	946	99.27	1861	✓	758	0.92	1180	99.73	1925	✓
w140.004	676	0.00	945	100.00	1126	✓	816	0.00	1238	98.98	m.l.	
w140.005	663	0.15	735	99.87	1211	✓	822	0.49	1148	99.77	2128	✓
w160.001	704	0.00	708	99.71	954	✓						
w160.002	711	0.00	673	99.79	952	✓						
w160.003	608	0.16	734	99.26	1467	✓						
w160.004	672	0.15	710	99.99	1144	✓						
w160.005	658	0.61	563	99.58	887	✓						

m.l.: DP terminates prematurely after reaching the path limit M.
†: Includes the time of GVNS.

References

Agra, A., M. Christiansen, R. Figueiredo, L. M. Hvattum, M. Poss, C. Requejo. 2013. The robust vehicle routing problem with time windows. *Computers & Operations Research* **40** 856–866.

Baldacci, R., A. Mingozzi., N. Christofides. 2008. An exact algorithm for the vehicle routing problem based on the set partitioning formulation with additional cuts. *Mathematical Programming, Series A* **115** 351–385.

Baldacci, R., A. Mingozzi., R. Roberti. 2012. New state space relaxations for solving the traveling salesman problem with time windows. *INFORMS Journal on Computing* **24** 356–371.

Gendreau, M., A. Hertz, G. Laporte, M. Stan. 1998. A generalized insertion heuristic for the traveling salesman problem with time windows. *Operations Research* **46** 330–335.

Munari, P., A. Moreno, J. De La Vega, D. Alem, J, Gondzio, R. Morabito. 2019. The robust vehicle routing problem with time windows: Compact formulation and branch-price-and-cut method. *Transportation Science*, https://doi.org/10.1287/trsc.2018.0886.

Ohlmann, J. W., B. W. Thomas. 2007. A compressed-annealing heuristic for the traveling salesman problem with time windows. *INFORMS Journal on Computing* **19** 80–90.