# Online Supplement

## The Undirected Team Orienteering Arc Routing Problem: Formulations, Valid Inequalities, and Exact Algorithms

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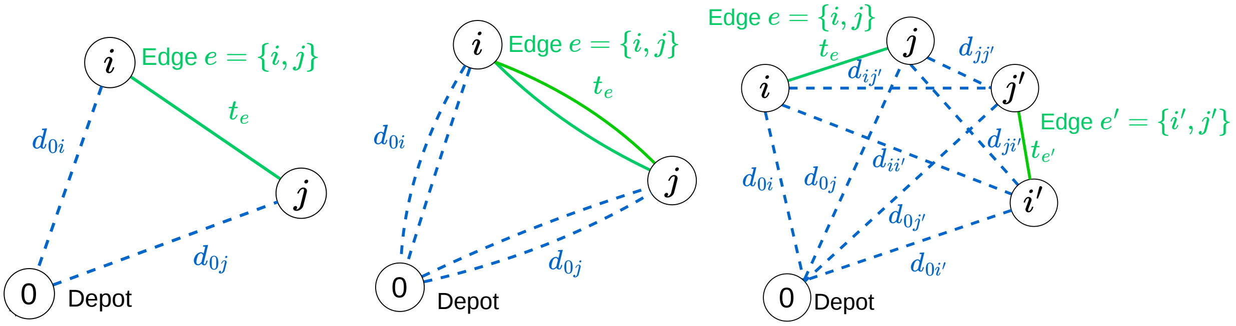
## A Inaccessible Traversal Inequalities and Edges in Conflict

We demonstrate the minimum travel time used in inaccessible traversal inequalities and the definition of edges in conflict. Figure 1a illustrates the minimum travel time $l^1_{0e} = d_{0i} + t_e + d_{j0}$ for edge $e = \{i, j\}$, where the dashed edges represent shortest paths between pairs of vertices. Figure 1b visualizes the possible tours contributing to the minimum travel time $l^2_{0e} = \min\{d_{0i} + 2t_e + d_{i0}, d_{0j} + 2t_e + d_{j0}\}$ for edge $e = \{i, j\}$. Since the graph is undirected, we can simplify it as $2t_e + 2\min\{d_{0i}, d_{0j}\}$. Starting from the depot 0, a vehicle can travel either from vertex $i$, covering a distance of $d_{0i}$, or via vertex $j$, covering a distance of $d_{0j}$. After that, the vehicle can traverse edge $e$ twice, and finally, follow the original path (either $d_{i0}$ or $d_{j0}$) back to the depot. Figure 1c depicts the possible tours contributing to the minimum travel time $L_{\min}(e, e') = \min\{d_{0i} + t_e + d_{ji'} + t_{e'} + d_{j'0}, d_{0i} + t_e + d_{jj'} + t_{e'} + d_{i'0}, d_{0j} + t_e + d_{ii'} + t_{e'} + d_{j'0}, d_{0j} + t_e + d_{ij'} + t_{e'} + d_{i'0}\}$ for edges $e = \{i, j\}$ and $e' = \{i', j'\}$. Starting from the depot 0, a vehicle can reach edge $e$ by arriving at either vertex $i$ or $j$. After traversing edge $e$, it departs from the opposite vertex and proceeds to edge $e'$, entering through either vertex $i'$ or $j'$. The vehicle then traverses edge $e'$ and returns to the depot from opposite vertex of $e'$.



(a) $l^1_{0e}$ (b) $l^2_{0e}$ (c) $L_{\min}(e, e')$

Figure 1: Minimum Travel Time
(a) Tour for Traversing Edge $e$ Once from the Depot; (b) Tours for Traversing Edge $e$ Twice from the Depot; (c) Tours for Traversing Two Edges $e$ and $e'$ Once from the Depot

## B MIP Start Heuristic

The pseudocode is presented in Algorithm 1.

To better explain the pseudocode, we introduce more notation. Let $\tau^k$ be the travel time of the current tour $k \in K$. Let $w_e$ be the maximum weight defined as the profit $r_e$ of unserved edge $e \in E_D \setminus H^k$ divided by the minimum travel time $l^1_{ie}$ over all vertices $i \in V_{H^k}$, provided that (i) the edge $e$ can be served within the travel time and the capacity limits based on the current tour's travel time $\tau^k$ and cumulative served demand $\delta^k$, and (ii) the number of times the edge has been served $\sigma_e$ is strictly less than its upper bound $u_e$, i.e., $w_e = \max_{i \in V_{H^k}} \{\frac{r_e}{l^1_{ie}} | \tau^k + l^1_{ie} \le T_{\max}, \delta^k + q_e \le Q, \sigma_e + 1 \le u_e\}$. Let $\mathcal{W}$ be the set of candidate

**Algorithm 1:** MIP Start Heuristic

```
Input: the travel time limit $T_{\max}$, fraction of candidates $\gamma$ for the candidate list
Output: a candidate solution $\psi$
$\boldsymbol{\sigma} = (\sigma_e)_{e \in E_D}$, $\boldsymbol{\sigma} \leftarrow \mathbf{0}$;
for $k \in K$ do
    $\tau^k \leftarrow 0$, $\delta^k \leftarrow 0$, $H^k \leftarrow \emptyset$, $\mathcal{V}_{H^k} \leftarrow \{0\}$, $\bar{\psi}^k \leftarrow \emptyset$;
    repeat
        $SolutionChange \leftarrow False$;
        repeat                                                          // Search for a candidate
            $\mathcal{W} \leftarrow \{w_e \mid e \in E_D \setminus H^k\}$ where $w_e = \max_{i \in V_{H^k}}\{\frac{r_e}{l^1_{ie}} | \tau^k + l^1_{ie} \le T_{\max},\ \delta^k + q_e \le Q,\ \sigma_e + 1 \le u_e\}$, and let
              $i_e \in \arg\max_{i \in V_{H^k}}\{\frac{r_e}{l^1_{ie}} | \tau^k + l^1_{ie} \le T_{\max},\ \delta^k + q_e \le Q,\ \sigma_e + 1 \le u_e\}$;
            if $\mathcal{W} \neq \emptyset$ then                                            // Select a candidate
                Sort edges from $E_D \setminus H^k$ in non-increasing order according to $w \in \mathcal{W}$;
                Randomly choose one $e' = \{i', j'\}$ from the top $\gamma$ fraction of the sequence of $E_D \setminus H^k$;
                Update $H^k \leftarrow H^k \cup \{e'\}$, $\tau^k \leftarrow \tau^k + l^1_{i_{e'}e'}$, $\delta^k \leftarrow \delta^k + q_{e'}$, $\sigma_{e'} \leftarrow \sigma_{e'} + 1$, $\mathcal{V}_{H^k} \leftarrow \mathcal{V}_{H^k} \cup \{i'\} \cup \{j'\}$,
                  $\bar{\psi}^k \leftarrow \bar{\psi}^k \cup (e', L_{i_{e'}e'})$;
                $SolutionChange \leftarrow True$;
        until $\mathcal{W} = \emptyset$;
        if $SolutionChange \leftarrow True$ then
            Solve a URPP of $H^k$ with $\bar{\psi}^k$ as initial solultion, and let $\psi^k = (H^k, L^k)$ be a feasible solution obtained from
              the URPP and $T^*(H^k)$ the corresponding objective value;
            $\tau^k \leftarrow T^*(H^k)$;
            for $e \in L^k$ do                                                  // Improvement Heuristic
                if $e = \{i, j\} \in E_D \setminus H^k$ and $\delta^k + q_e \le Q$ and $\sigma_e + 1 \le u_e$ then $H^k \leftarrow H^k \cup \{e\}$, $L^k \leftarrow L^k \setminus \{e\}$,
                  $\psi^k \leftarrow (H^k, L^k)$, $\delta^k \leftarrow \delta^k + q_e$, $\sigma_e \leftarrow \sigma_e + 1$, $\mathcal{V}_{H^k} \leftarrow \mathcal{V}_{H^k} \cup \{i\} \cup \{j\}$;
    until $SolutionChange = False$;
    $\psi = \psi \cup \{\psi^k\}$;
Return the candidate UTOARP solution $\psi$.
```

|  | $\lvert K \rvert = 2$ |  |  |  |  |  | $\lvert K \rvert = 3$ |  |  |  |  |  | $\lvert K \rvert = 4$ |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | LBBD |  |  |  | B&P |  | LBBD |  |  |  | B&P |  | LBBD |  |  |  | B&P |  |
| Instance | LB | UB | Gap (%) | Time (s) | LB | Gap (%) | LB | UB | Gap (%) | Time (s) | LB | Gap (%) | LB | UB | Gap (%) | Time (s) | LB | Gap (%) |
| val1A | 175 | 175 | 0 | 1.99 | 175 | 0 | 251 | 251 | 0 | 2.45 | 251 | 0 | 323 | 323 | 0 | 3.82 | 323 | 0 |
| val1B | 175 | 175 | 0 | 1.69 | 175 | 0 | 252 | 252 | 0 | 2.29 | 252 | 0 | 324 | 324 | 0 | 3.6 | 324 | 0 |
| val1C | 122 | 122 | 0 | 1.87 | 122 | 0 | 179 | 179 | 0 | 1.94 | 179 | 0 | 233 | 233 | 0 | 3.23 | 233 | 0 |
| val2A | 125 | 125 | 0 | 0.22 | 125 | 0 | 168 | 168 | 0 | 0.28 | 168 | 0 | 183 | 183 | 0 | 0.27 | 183 | 0 |
| val2B | 125 | 125 | 0 | 0.25 | 125 | 0 | 168 | 168 | 0 | 0.29 | 168 | 0 | 183 | 183 | 0 | 0.31 | 183 | 0 |
| val2C | 85 | 85 | 0 | 0.3 | 85 | 0 | 115 | 115 | 0 | 0.28 | 115 | 0 | 125 | 125 | 0 | 0.24 | 125 | 0 |
| val3A | 143 | 143 | 0 | 0.06 | 143 | – | 196 | 196 | 0 | 0.07 | 196 | – | 236 | 236 | 0 | 0.16 | 236 | – |
| val3B | 133 | 133 | 0 | 0.11 | 133 | – | 182 | 182 | 0 | 0.12 | 182 | – | 222 | 222 | 0 | 0.17 | 222 | – |
| val3C | 92 | 92 | 0 | 0.06 | 92 | – | 127 | 127 | 0 | 0.07 | 127 | – | 154 | 154 | 0 | 0.21 | 154 | – |
| val4A | 165 | 165 | 0 | 3.23 | 165 | 0 | 240 | 240 | 0 | 3.54 | 240 | 0 | 308 | 308 | 0 | 4.86 | 308 | 0 |
| val4B | 166 | 166 | 0 | 3.32 | 166 | 0 | 241 | 241 | 0 | 3.51 | 241 | 0 | 309 | 309 | 0 | 4.34 | 309 | 0 |
| val4C | 155 | 155 | 0 | 3.32 | 155 | 0 | 226 | 226 | 0 | 3.77 | 226 | 0 | 291 | 291 | 0 | 4.26 | 291 | 0 |
| val4D | 125 | 125 | 0 | 3.43 | 125 | 0 | 182 | 182 | 0 | 3.5 | 182 | 0 | 235 | 235 | 0 | 4.06 | 235 | 0 |
| val5A | 166 | 166 | 0 | 1.68 | 166 | 0 | 227 | 227 | 0 | 1.9 | 227 | 0 | 285 | 285 | 0 | 2.27 | 285 | 0 |
| val5B | 166 | 166 | 0 | 1.69 | 166 | 0 | 227 | 227 | 0 | 1.93 | 227 | 0 | 285 | 285 | 0 | 2.27 | 285 | 0 |
| val5C | 166 | 166 | 0 | 1.76 | 166 | 0 | 227 | 227 | 0 | 1.84 | 227 | 0 | 285 | 285 | 0 | 2.29 | 285 | 0 |
| val5D | 133 | 133 | 0 | 1.78 | 133 | 0 | 183 | 183 | 0 | 1.74 | 183 | 0 | 229 | 229 | 0 | 2.16 | 229 | 0 |
| val6A | 208 | 208 | 0 | 2.48 | 208 | 0 | 286 | 286 | 0 | 3.94 | 286 | 0 | 355 | 355 | 0 | 6.17 | 355 | 0 |
| val6B | 208 | 208 | 0 | 2.65 | 208 | 0 | 286 | 286 | 0 | 4.01 | 286 | 0 | 355 | 355 | 0 | 6.2 | 355 | 0 |
| val6C | 137 | 137 | 0 | 2.48 | 137 | 0 | 192 | 192 | 0 | 3.43 | 192 | 0 | 244 | 244 | 0 | 5.98 | 244 | 0 |
| val7A | 181 | 181 | 0 | 10.89 | 181 | 0 | 263 | 263 | 0 | 11.85 | 263 | 0 | 342 | 342 | 0 | 17.62 | 342 | 0 |
| val7B | 181 | 181 | 0 | 10.14 | 181 | 0 | 263 | 263 | 0 | 12.56 | 263 | 0 | 344 | 344 | 0 | 15.36 | 344 | 0 |
| val7C | 154 | 154 | 0 | 10.05 | 154 | 0 | 223 | 223 | 0 | 12.66 | 223 | 0 | 291 | 291 | 0 | 34.03 | 291 | 0 |
| val8A | 163 | 163 | 0 | 2.17 | 163 | 0 | 233 | 233 | 0 | 2.83 | 233 | 0 | 300 | 300 | 0 | 3.7 | 300 | 0 |
| val8B | 164 | 164 | 0 | 2.48 | 164 | 0 | 234 | 234 | 0 | 2.79 | 234 | 0 | 301 | 301 | 0 | 3.35 | 301 | 0 |
| val8C | 129 | 129 | 0 | 2.21 | 129 | 0 | 186 | 186 | 0 | 2.67 | 186 | 0 | 240 | 240 | 0 | 3.06 | 240 | 0 |
| val9A | 176 | 176 | 0 | 11.05 | 176 | – | 257 | 257 | 0 | 14.94 | 253 | – | 333 | 333 | 0 | 25.56 | 330 | – |
| val9B | 175 | 175 | 0 | 16.16 | 175 | – | 256 | 256 | 0 | 20.8 | 253 | – | 332 | 332 | 0 | 22.09 | 329 | – |
| val9C | 176 | 176 | 0 | 11.07 | 176 | – | 257 | 257 | 0 | 15.07 | 253 | – | 333 | 333 | 0 | 25.26 | 330 | – |
| val9D | 144 | 144 | 0 | 9.83 | 144 | – | 210 | 210 | 0 | 17.14 | 208 | – | 273 | 273 | 0 | 28.72 | 273 | 0 |
| val10A | 170 | 170 | 0 | 13.63 | 170 | 0 | 244 | 244 | 0 | 19.89 | 244 | 0 | 317 | 317 | 0 | 49.56 | 317 | 0 |
| val10B | 171 | 171 | 0 | 14.54 | 171 | 0 | 245 | 245 | 0 | 23.31 | 245 | 0 | 318 | 318 | 0 | 41.45 | 318 | 0 |
| val10C | 169 | 169 | 0 | 13.77 | 169 | 0 | 243 | 243 | 0 | 24.38 | 243 | 0 | 316 | 316 | 0 | 34.95 | 316 | 0 |
| val10D | 154 | 154 | 0 | 14.13 | 154 | 0 | 221 | 221 | 0 | 22.4 | 221 | 0 | 288 | 288 | 0 | 44.06 | 288 | 0 |

Table 1: The First Scenario: Performance of Strengthened LBBD and B&P

weights $w_e$ for unserved edge $e \in E_D \setminus H^k$. Let $i_e$ be the corresponding vertex in $V_{H^k}$ that achieves the maximum feasible weight $\frac{r_e}{l^1_{ie}}$ of edge $e$, i.e., $i_e \in \arg\max_{i \in V_{H^k}} \{\frac{r_e}{l^1_{ie}} | \tau^k + l^1_{ie} \le T_{\max},\ \delta^k + q_e \le Q,\ \sigma_e + 1 \le u_e\}$. Let $\bar{\psi}^k = (H^k, \bar{L}^k)$ be a trivial feasible solution for the URPP of $H^k$, constructed from the subtour $(e, L_{ie})$, where edge $e$ is served from vertex $i$ and $L_{ie}$ is the set of edges deadheaded to serve edge $e$ from vertex $i$. Let $\gamma$ be the fraction of candidates kept in the candidate set, which is set to 0.25 in our tests.

For each tour $k \in K$, we initialize the vertex set $V_{H^k}$ with only the depot and choose the candidates from all unserved demand edges of this vehicle $e \in E_D \setminus H^k$. For each such edge $e$, we calculate the weight $w_e$ as defined above, and add it to the candidate set $\mathcal{W}$ and record the corresponding vertex $i_e$. We then randomly choose the next demand edge $e' \in E_D \setminus H^k$ to visit from the candidate set $\mathcal{W}$ based on the fraction $\gamma$, and update all related sets $H^k, \tau^k, V_{H^k}, \delta^k, \boldsymbol{\sigma}$. A feasible solution $\bar{\psi}^k$ of tour $k$ is constructed by inserting the chosen demand edge $e'$ into the tour at vertex $i_{e'}$, along with the deadhead edges $L_{i_{e'}e'}$ (i.e., $\bar{\psi}^k = \bar{\psi}^k \cup (e', L_{i_{e'}e'})$). We repeat this procedure until no candidate is found. For the required-edge setting, the above process applies only to required edges $E_R$ in order to increase the likelihood of generating feasible solutions. We then solve a URPP for $H^k$ with $\bar{\psi}^k$ as an initial feasible solution, which enables us to find the minimum travel time $T^*(H^k)$, and hence gives us the chance to continue the previous search procedure. The feasible solution $\psi^k$ found by the URPP will be improved by seeking edges satisfying the two properties: (i) they are deadheaded but not served in the current tour; (ii) serving them in the current tour does not exceed the capacity limit $Q$ and the upper bound $u_e$. This improvement step, again, applies only to required edges in the required-edge setting. The algorithm stops when no candidate is found after solving the URPP.

# C Comparison to B&P for the Capacitated-Vehicle Setting

In Tables 1 and 2, we report the computational results of the strengthened LBBD approach without an initial feasible solution and the B&P approach from Archetti et al. (2010) for the first and second parameter scenarios, respectively. The B&P approach was tested on an Intel Pentium 4 CPU 1.60 GHz and 256 MB RAM. The code was written in $C++$ and the exact solver used is CPLEX 9.0. A time limit of 3600 seconds was imposed. For each instance (column *Instance*) and each number of vehicles ($|K| = \{2, 3, 4\}$), we present the lower bound (column *LB*), upper bound (column *UB*), gap in percentage at the termination (column *Gap (%)*), runtime in seconds (column *Time (s)*) for the strengthened LBBD approach, and the lower bound (column *LB*) and the gap in percentage at the termination (column *Gap (%)*) for the B&P approach. Note that in column *Time (s)*, "TL" indicates that LBBD reached the time limit, whereas in column *Gap (%)* for B&P "–" indicates that no valid upper bound was obtained for the corresponding instance.

|  | $\lvert K \rvert = 2$ |  |  |  |  |  | $\lvert K \rvert = 3$ |  |  |  |  |  | $\lvert K \rvert = 4$ |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | LBBD |  |  |  | B&P |  | LBBD |  |  |  | B&P |  | LBBD |  |  |  | B&P |  |
| Instance | LB | UB | Gap (%) | Time (s) | LB | Gap (%) | LB | UB | Gap (%) | Time (s) | LB | Gap (%) | LB | UB | Gap (%) | Time (s) | LB | Gap (%) |
| val1A | 713 | 728.00 | 2.06 | TL | 713 | – | 728 | 728.00 | 0.00 | 4.94 | 728 | – | 728 | 728.00 | 0.00 | 1.42 | 728 | 0 |
| val1B | 516 | 516.00 | 0.00 | 582.77 | 516 | 1.2 | 682 | 682.00 | 0.00 | 1255.86 | 682 | 2.62 | 731 | 731.00 | 0.00 | 189.13 | 731 | 0 |
| val1C | 179 | 179.00 | 0.00 | 2.78 | 179 | 0 | 256 | 256.00 | 0.00 | 6.26 | 256 | 0 | 328 | 328.00 | 0.00 | 18.42 | 328 | 0 |
| val2A | 585 | 585.00 | 0.00 | 301.12 | 585 | – | 605 | 605.00 | 0.00 | 5.88 | 605 | 0 | 605 | 605.00 | 0.00 | 4.36 | 605 | 0 |
| val2B | 409 | 409.00 | 0.00 | 42.04 | 409 | 0 | 481 | 481.00 | 0.00 | 25.84 | 481 | 0 | 541 | 541.00 | 0.00 | 28.78 | 541 | 0 |
| val2C | 146 | 146.00 | 0.00 | 2.50 | 146 | 0 | 209 | 209.00 | 0.00 | 2.99 | 209 | 0 | 261 | 261.00 | 0.00 | 4.62 | 261 | 0 |
| val3A | 245 | 245.00 | 0.00 | 710.04 | 245 | – | 253 | 253.00 | 0.00 | 2.59 | 253 | 0 | 253 | 253.00 | 0.00 | 2.40 | 253 | 0 |
| val3B | 186 | 186.00 | 0.00 | 52.08 | 186 | – | 227 | 227.00 | 0.00 | 38.23 | 227 | 0 | 237 | 237.00 | 0.00 | 15.30 | 237 | 0 |
| val3C | 65 | 65.00 | 0.00 | 1.07 | 65 | 0 | 92 | 92.00 | 0.00 | 1.73 | 92 | 0 | 116 | 116.00 | 0.00 | 2.00 | 116 | 0 |
| val4A | 915 | 1020.00 | 10.29 | TL | 923 | – | 1152 | 1242.00 | 7.25 | TL | 1211 | – | 1242 | 1242.00 | 0.00 | 37.59 | 1242 | – |
| val4B | 708 | 802.08 | 11.73 | TL | 718 | – | 972 | 1115.00 | 12.83 | TL | 978 | – | 1098 | 1248.00 | 12.02 | TL | 1195 | – |
| val4C | 556 | 581.20 | 4.34 | TL | 566 | – | 785 | 837.15 | 6.23 | TL | 798 | – | 938 | 1056.75 | 11.24 | TL | 964 | – |
| val4D | 300 | 300.00 | 0.00 | 23.52 | 300 | – | 432 | 432.00 | 0.00 | 88.11 | 426 | – | 555 | 555.00 | 0.00 | 203.09 | 547 | – |
| val5A | 909 | 1013.43 | 10.30 | TL | 948 | – | 1151 | 1221.00 | 5.73 | TL | 1191 | – | 1221 | 1221.00 | 0.00 | 66.74 | 1221 | – |
| val5B | 708 | 811.13 | 12.71 | TL | 725 | – | 929 | 1092.00 | 14.93 | TL | 978 | – | 1074 | 1221.00 | 12.04 | TL | 1137 | – |
| val5C | 585 | 597.26 | 2.05 | TL | 592 | – | 772 | 905.84 | 14.78 | TL | 773 | – | 888 | 1117.86 | 20.56 | TL | 925 | – |
| val5D | 326 | 326.00 | 0.00 | 34.27 | 326 | – | 465 | 465.00 | 0.00 | 290.48 | 464 | – | 585 | 599.89 | 2.48 | TL | 588 | – |
| val6A | 677 | 748.00 | 9.49 | TL | 700 | – | 850 | 891.00 | 4.60 | TL | 871 | – | 891 | 891.00 | 0.00 | 191.89 | 891 | – |
| val6B | 508 | 508.00 | 0.00 | 3081.48 | 504 | – | 684 | 737.80 | 7.29 | TL | 684 | – | 786 | 861.00 | 8.71 | TL | 804 | 3.41 |
| val6C | 207 | 207.00 | 0.00 | 9.52 | 207 | 0 | 291 | 291.00 | 0.00 | 22.35 | 291 | 0.82 | 371 | 371.00 | 0.00 | 68.41 | 371 | 0.64 |
| val7A | 800 | 922.50 | 13.28 | TL | 848 | – | 1000 | 1110.00 | 9.91 | TL | 1081 | – | 1103 | 1110.00 | 0.63 | TL | 1110 | – |
| val7B | 621 | 722.47 | 14.04 | TL | 633 | – | 842 | 1000.00 | 15.80 | TL | 911 | – | 1019 | 1118.00 | 8.86 | TL | 1082 | – |
| val7C | 286 | 286.00 | 0.00 | 43.32 | 286 | 0 | 418 | 418.00 | 0.00 | 71.77 | 418 | 0 | 541 | 541.00 | 0.00 | 649.35 | 541 | 0 |
| val8A | 831 | 889.00 | 6.52 | TL | 856 | – | 1033 | 1099.00 | 6.01 | TL | 1074 | – | 1099 | 1099.00 | 0.00 | 61.03 | 1099 | – |
| val8B | 636 | 718.25 | 11.45 | TL | 665 | – | 836 | 966.71 | 13.52 | TL | 893 | – | 1012 | 1103.00 | 8.25 | TL | 1058 | – |
| val8C | 270 | 270.00 | 0.00 | 30.29 | 270 | – | 389 | 389.00 | 0.00 | 360.65 | 389 | – | 493 | 503.80 | 2.14 | TL | 496 | – |
| val9A | 922 | 1044.33 | 11.71 | TL | 996 | – | 1124 | 1265.00 | 11.15 | TL | 1229 | – | 1265 | 1265.00 | 0.00 | 864.14 | 1265 | – |
| val9B | 742 | 832.00 | 10.82 | TL | 774 | – | 974 | 1122.22 | 13.21 | TL | 1033 | – | 1077 | 1262.00 | 14.66 | TL | 1216 | – |
| val9C | 608 | 686.88 | 11.48 | TL | 627 | – | 824 | 961.33 | 14.29 | TL | 876 | – | 976 | 1171.67 | 16.70 | TL | 1066 | – |
| val9D | 298 | 298.00 | 0.00 | 1032.40 | 296 | – | 437 | 437.00 | 0.00 | 3007.84 | 426 | – | 554 | 571.25 | 3.02 | TL | 555 | – |
| val10A | 980 | 1111.00 | 11.79 | TL | 1038 | – | 1270 | 1348.00 | 5.79 | TL | 1302 | – | 1348 | 1348.00 | 0.00 | 350.93 | 1348 | – |
| val10B | 803 | 917.00 | 12.43 | TL | 829 | – | 1032 | 1209.30 | 14.66 | TL | 1104 | – | 1212 | 1349.00 | 10.16 | TL | 1307 | – |
| val10C | 655 | 760.54 | 13.88 | TL | 658 | – | 848 | 1033.00 | 17.91 | TL | 912 | – | 1043 | 1244.00 | 16.16 | TL | 1129 | – |
| val10D | 327 | 327.00 | 0.00 | 389.94 | 322 | – | 465 | 478.91 | 2.90 | TL | 458 | – | 572 | 645.82 | 11.43 | TL | 591 | – |

Table 2: The Second Scenario: Performance of Strengthened LBBD and B&P

# References

C. Archetti, D. Feillet, A. Hertz, and M. G. Speranza. The undirected capacitated arc routing problem with profits. *Computers & Operations Research*, 37(11):1860–1869, 2010.