# Appendix A

# Artificial test instances

In Section 4.4.1 three different base scenarios were described. In the following, the complete data of the resulting serial, convergent, and general instance will be given (q.v. Seeanner and Meyr, 2013).

## A.1 Serial instance

| | |
|---|---|
| $\mathbf{L}$ | 4 |
| $\mathbf{J}$ | 6 |
| $\mathbf{T}$ | 4 |
| $\mathbf{S}$ | 12 (3 micros per macro) |
| $\mathbf{\Lambda}$ | {3,6,9,12} |
| $\mathbf{\Phi}$ | {1,4,7,10,13} |
| $\overline{\mathbf{w}}_\mathbf{s}$ | {0,-,-,80,-,-,160,-,-,240,-,-,320} |

Table A.1: Number of lines, products, macroperiods, microperiods as well as set of all last microperiods and all fixed microperiods with their respective starting times.

| | $\mathbf{I_{j0}}$ | $\mathbf{I_j^{max}}$ | $\mathbf{h_{js}}$ $(\mathbf{s} \in \mathbf{\Lambda})$ | $\mathbf{c_j^e}$ | $\mathbf{e_j^{max}}$ | $\mathcal{N}_j$ |
|---|---|---|---|---|---|---|
| $\mathbf{j = 1}$ | 0.0 | 15.0 | 8.0 | 100.0 | 100.0 | $\emptyset$ |
| $\mathbf{j = 2}$ | 0.0 | 10.0 | 8.0 | 100.0 | 100.0 | $\emptyset$ |
| $\mathbf{j = 3}$ | 0.0 | 10.0 | 2.0 | 0.0 | 0.0 | {1} |
| $\mathbf{j = 4}$ | 0.0 | 10.0 | 2.0 | 0.0 | 0.0 | {2} |
| $\mathbf{j = 5}$ | 0.0 | 100.0 | 1.0 | 4.0 | 100.0 | {3} |
| $\mathbf{j = 6}$ | 0.0 | 100.0 | 1.0 | 4.0 | 100.0 | {4} |

Table A.2: Initial and maximum inventory, holding and purchasing costs as well as maximum purchase and sets of immediate and all successors.

F. Seeanner, *Multi-Stage Simultaneous Lot-Sizing and Scheduling,* Produktion und Logistik,
DOI 10.1007/978-3-658-02089-7, © Springer Fachmedien Wiesbaden 2013

| | |
|---|---|
| $\mathcal{D}$ | { (3,5,2,3), (3,6,2,4), (4,5,2,3), (4,6,2,4), (2,3,1,1), (2,4,1,2) } |

Table A.3: Index sets for line synchronization constraints.

| | |
|---|---|
| $\mathbf{c^o}$ | 200 |
| $\mathbf{o^{max}}$ | 80 |

Table A.4: Overtime costs and maximum overtime.

| $\mathbf{a_{lj}}$ | $\mathbf{j=1}$ | $\mathbf{j=2}$ | $\mathbf{j=3}$ | $\mathbf{j=4}$ | $\mathbf{j=5}$ | $\mathbf{j=6}$ |
|---|---|---|---|---|---|---|
| $\mathbf{l=1}$ | 3.0 | 3.0 | - | - | - | - |
| $\mathbf{l=2}$ | - | - | 1.0 | 1.0 | - | - |
| $\mathbf{l=3,4}$ | - | - | - | - | 4.0 | 3.0 |

Table A.5: Production coefficients.

| | $\mathbf{f_t}$ | $\mathbf{S_t}$ |
|---|---|---|
| $\mathbf{t=1}$ | 1 | {1,2,3} |
| $\mathbf{t=2}$ | 4 | {4,5,6} |
| $\mathbf{t=3}$ | 7 | {7,8,9} |
| $\mathbf{t=4}$ | 10 | {10,11,12} |

Table A.6: First microperiod and set of microperiods belonging to a macroperiod.

| $\mathbf{d_{js}}$ | $\mathbf{s=3}$ | $\mathbf{s=6}$ | $\mathbf{s=9}$ | $\mathbf{s=12}$ |
|---|---|---|---|---|
| $\mathbf{j=1}$ | 3.0 | 5.0 | 5.0 | 5.0 |
| $\mathbf{j=2}$ | 2.0 | 4.0 | 6.0 | 8.0 |

Table A.7: Demand.

| $\mathbf{WIP_{lj}^{max}}$ | $\mathbf{j=1}$ | $\mathbf{j=2}$ | $\mathbf{j=3}$ | $\mathbf{j=4}$ | $\mathbf{j=5}$ | $\mathbf{j=6}$ |
|---|---|---|---|---|---|---|
| $\mathbf{l=1}$ | 100.0 | 100.0 | - | - | - | - |
| $\mathbf{l=2}$ | - | - | 10.0 | 10.0 | - | - |
| $\mathbf{l=3,4}$ | - | - | - | - | 0.0 | 0.0 |

Table A.8: Maximum WIP.

| $\mathbf{s_{lij}/st_{lij}}$ | | $\mathbf{j=1}$ | $\mathbf{j=2}$ | $\mathbf{j=3}$ | $\mathbf{j=4}$ | $\mathbf{j=5}$ | $\mathbf{j=6}$ |
|---|---|---|---|---|---|---|---|
| $\mathbf{l=1}$ | $\mathbf{i=1}$ | 0.0 | 6.0 | - | - | - | - |
| | $\mathbf{i=2}$ | 8.0 | 0.0 | - | - | - | - |
| $\mathbf{l=2}$ | $\mathbf{i=3}$ | - | - | 0.0 | 2.0 | - | - |
| | $\mathbf{i=4}$ | - | - | 12.0 | 0.0 | - | - |
| $\mathbf{l=3,4}$ | $\mathbf{i=5}$ | - | - | - | - | 0.0 | 8.0 |
| | $\mathbf{i=6}$ | - | - | - | - | 8.0 | 0.0 |

Table A.9: Setup costs and times.

| $c^p_{lj}$ | j = 1 | j = 2 | j = 3 | j = 4 | j = 5 | j = 6 |
|---|---|---|---|---|---|---|
| l = 1 | 1.0 | 1.0 | - | - | - | - |
| l = 2 | - | - | 1.0 | 1.0 | - | - |
| l = 3 | - | - | - | - | 1.0 | 1.0 |
| l = 4 | - | - | - | - | 2.0 | 2.0 |

Table A.10: Production costs.

| $m_{lj}$ | j = 1 | j = 2 | j = 3 | j = 4 | j = 5 | j = 6 |
|---|---|---|---|---|---|---|
| l = 1 | 1.0 | 1.0 | - | - | - | - |
| l = 2 | - | - | 10.0 | 10.0 | - | - |
| l = 3, 4 | - | - | - | - | 1.0 | 1.0 |

Table A.11: Minimum lot-sizes.

| $y_{lj0}$ | j = 1 | j = 2 | j = 3 | j = 4 | j = 5 | j = 6 |
|---|---|---|---|---|---|---|
| l = 1 | 1 | 0 | - | - | - | - |
| l = 2 | - | - | 1 | 0 | - | - |
| l = 3 | - | - | - | - | 1 | 0 |
| l = 4 | - | - | - | - | 0 | 1 |

Table A.12: Initial setup.

| $p_{ij}$ | j = 1 | j = 2 | j = 3 | j = 4 |
|---|---|---|---|---|
| i = 3 | 6.0 | - | | - |
| i = 4 | - | 6.0 | - | |
| i = 5 | 6.0 | - | 1.0 | - |
| i = 6 | - | 6.0 | - | 1.0 |

Table A.13: Gozinto factors.

| | $\mathcal{J}_l$ | $\Pi_l$ | $b_l$ |
|---|---|---|---|
| l = 1 | {1,2} | {1,2,...,12} | 0.0 |
| l = 2 | {3,4} | {1,2,...,12} | 0.0 |
| l = 3, 4 | {5,6} | {1,2,...,12} | 0.0 |

Table A.14: Allowed products and microperiods as well as standby costs.

## A.2 Divergent instance

| | |
|---|---|
| $\mathbf{L}$ | 3 |
| $\mathbf{J}$ | 6 |
| $\mathbf{T}$ | 3 |
| $\mathbf{S}$ | 12 (4 micros per macro) |
| $\mathbf{\Lambda}$ | {4,8,12} |
| $\mathbf{\Phi}$ | {1,5,9,13} |
| $\overline{\mathbf{w}}_\mathbf{s}$ | {0,-,-,-,80,-,-,-,160,-,-,-,240} |

Table A.15: Number of lines, products, macroperiods, microperiods as well as set of all last microperiods and all fixed microperiods with their respective starting times.

| | $\mathbf{I_{j0}}$ | $\mathbf{I_j^{max}}$ | $\mathbf{h_{js}}$ ($\mathbf{s \in \Lambda}$) | $\mathbf{c_j^e}$ | $\mathbf{e_j^{max}}$ | $\mathcal{N}_j$ |
|---|---|---|---|---|---|---|
| $\mathbf{j = 1}$ | 0.0 | 100.0 | 3.0 | 100.0 | 100.0 | $\emptyset$ |
| $\mathbf{j = 2}$ | 0.0 | 100.0 | 3.0 | 100.0 | 100.0 | $\emptyset$ |
| $\mathbf{j = 3}$ | 0.0 | 100.0 | 3.0 | 100.0 | 100.0 | $\emptyset$ |
| $\mathbf{j = 4}$ | 0.0 | 100.0 | 3.0 | 100.0 | 100.0 | $\emptyset$ |
| $\mathbf{j = 5}$ | 0.0 | 0.0 | - | 100.0 | 100.0 | {1,2} |
| $\mathbf{j = 6}$ | 0.0 | 0.0 | - | 100.0 | 100.0 | {3,4} |

Table A.16: Initial and maximum inventory, holding and purchasing costs as well as maximum purchase and sets of immediate and all successors.

| | |
|---|---|
| $\mathcal{D}$ | { (3,5,1,1), (3,5,1,2), (3,5,2,2), (3,6,1,3), (3,6,1,4), (3,6,2,4) } |

Table A.17: Index sets for line synchronization constraints.

| | |
|---|---|
| $\mathbf{c^o}$ | 200 |
| $\mathbf{o^{max}}$ | 80 |

Table A.18: Overtime costs and maximum overtime.

| $\mathbf{a_{lj}}$ | **j = 1** | **j = 2** | **j = 3** | **j = 4** | **j = 5** | **j = 6** |
|---|---|---|---|---|---|---|
| **l = 1** | 3.0 | 4.0 | 3.0 | 4.0 | - | - |
| **l = 2** | - | 8.0 | - | 8.0 | - | - |
| **l = 3** | - | - | - | - | 4.0 | 2.0 |

Table A.19: Production coefficients.

| | $\mathbf{f_t}$ | $\mathbf{S_t}$ |
|---|---|---|
| **t=1** | 1 | {1,2,3,4} |
| **t=2** | 5 | {5,6,7,8} |
| **t=3** | 9 | {9,10,11,12} |

Table A.20: First microperiod and set of microperiods belonging to a macroperiod.

| $\mathbf{d_{js}}$ | **s = 4** | **s = 8** | **s = 12** |
|---|---|---|---|
| **j = 1** | 0.0 | 6.0 | 6.0 |
| **j = 2** | 0.0 | 6.0 | 6.0 |
| **j = 3** | 2.0 | 6.0 | 6.0 |
| **j = 4** | 3.0 | 6.0 | 6.0 |

Table A.21: Demand.

| $\mathbf{WIP_{lj}^{max}}$ | **j = 1** | **j = 2** | **j = 3** | **j = 4** | **j = 5** | **j = 6** |
|---|---|---|---|---|---|---|
| **l = 1** | 100.0 | 100.0 | 100.0 | 100.0 | - | - |
| **l = 2** | - | 100.0 | - | 100.0 | - | - |
| **l = 3** | - | - | - | - | 0.0 | 0.0 |

Table A.22: Maximum WIP.

| $\mathbf{s_{lij}/st_{lij}}$ | | **j = 1** | **j = 2** | **j = 3** | **j = 4** | **j = 5** | **j = 6** |
|---|---|---|---|---|---|---|---|
| **l = 1** | **i = 1** | 0.0 | 1.0 | 1.0 | 2.0 | - | - |
| | **i = 2** | 2.0 | 0.0 | 3.0 | 1.0 | - | - |
| | **i = 3** | 3.0 | 4.0 | 0.0 | 1.0 | - | - |
| | **i = 4** | 5.0 | 3.0 | 2.0 | 0.0 | - | - |
| **l = 2** | **i = 2** | - | 0.0 | - | 2.0 | - | - |
| | **i = 4** | - | 4.0 | - | 0.0 | - | - |
| **l = 3** | **i = 5** | - | - | - | - | 0.0 | 2.0 |
| | **i = 6** | - | - | - | - | 6.0 | 0.0 |

Table A.23: Setup costs and times.

| $\mathbf{c^P_{lj}}$ | **j = 1** | **j = 2** | **j = 3** | **j = 4** | **j = 5** | **j = 6** |
|---|---|---|---|---|---|---|
| **l = 1** | 1.0 | 1.0 | 1.0 | 1.0 | - | - |
| **l = 2** | - | 2.0 | - | 2.0 | - | - |
| **l = 3** | - | - | - | - | 1.0 | 1.0 |

Table A.24: Production costs.

| $\mathbf{m_{lj}}$ | **j = 1** | **j = 2** | **j = 3** | **j = 4** | **j = 5** | **j = 6** |
|---|---|---|---|---|---|---|
| **l = 1** | 1.0 | 1.0 | 1.0 | 1.0 | - | - |
| **l = 2** | - | 1.0 | - | 1.0 | - | - |
| **l = 3** | - | - | - | - | 1.0 | 1.0 |

Table A.25: Minimum lot-sizes.

| $\mathbf{y_{lj0}}$ | **j = 1** | **j = 2** | **j = 3** | **j = 4** | **j = 5** | **j = 6** |
|---|---|---|---|---|---|---|
| **l = 1** | 1 | 0 | 0 | 0 | - | - |
| **l = 2** | - | 1 | - | 0 | - | - |
| **l = 3** | - | - | - | - | 0 | 1 |

Table A.26: Initial setup.

| $\mathbf{p_{ij}}$ | **j = 1** | **j = 2** | **j = 3** | **j = 4** |
|---|---|---|---|---|
| **i = 5** | 2.0 | 1.0 | - | - |
| **i = 6** | - | - | 2.0 | 1.0 |

Table A.27: Gozinto factors.

| | $\mathcal{J}_l$ | $\Pi_l$ | $b_l$ |
|---|---|---|---|
| **l = 1** | {1,2,3,4} | {1,2,...,12} | 0.0 |
| **l = 2** | {2,4} | {1,2,...,12} | 0.0 |
| **l = 3** | {5,6} | {1,2,...,12} | 0.0 |

Table A.28: Allowed products and microperiods as well as standby costs.

## A.3 General instance

| | |
|---|---|
| $\mathbf{L}$ | 3 |
| $\mathbf{J}$ | 8 |
| $\mathbf{T}$ | 3 |
| $\mathbf{S}$ | 12 (4 micros per macro) |
| $\mathbf{\Lambda}$ | {4,8,12} |
| $\mathbf{\Phi}$ | {1,5,9,13} |
| $\overline{\mathbf{w}}_\mathbf{s}$ | {0,-,-,-,80,-,-,-,160,-,-,-,240} |

Table A.29: Number of lines, products, macroperiods, microperiods as well as set of all last microperiods and all fixed microperiods with their respective starting times.

| | $\mathbf{I_{j0}}$ | $\mathbf{I_j^{max}}$ | $\mathbf{h_{js}}$ $(\mathbf{s} \in \mathbf{\Lambda})$ | $\mathbf{c_j^e}$ | $\mathbf{e_j^{max}}$ | $\mathcal{N}_j$ |
|---|---|---|---|---|---|---|
| $\mathbf{j = 1}$ | 0.0 | 100.0 | 8.0 | 200.0 | 100.0 | $\emptyset$ |
| $\mathbf{j = 2}$ | 0.0 | 100.0 | 8.0 | 200.0 | 100.0 | $\emptyset$ |
| $\mathbf{j = 3}$ | 0.0 | 100.0 | 7.0 | 200.0 | 100.0 | $\emptyset$ |
| $\mathbf{j = 4}$ | 0.0 | 100.0 | 12.0 | 200.0 | 100.0 | $\emptyset$ |
| $\mathbf{j = 5}$ | 0.0 | 100.0 | 1.0 | 200.0 | 100.0 | {1,2} |
| $\mathbf{j = 6}$ | 0.0 | 0.0 | - | 200.0 | 100.0 | {1,3} |
| $\mathbf{j = 7}$ | 0.0 | 0.0 | - | 200.0 | 100.0 | {2,4} |
| $\mathbf{j = 8}$ | 0.0 | 100.0 | 2.0 | 200.0 | 100.0 | {3,4} |

Table A.30: Initial and maximum inventory, holding and purchasing costs as well as maximum purchase and sets of immediate and all successors.

| | |
|---|---|
| $\mathcal{D}$ | { (2,6,1,1), (2,6,1,3), (2,7,1,2), (2,7,1,4), (3,5,1,1), (3,5,1,2), (3,8,1,3), (3,8,1,4) } |

Table A.31: Index sets for line synchronization constraints.

| | |
|---|---|
| $\mathbf{c^o}$ | 0 |
| $\mathbf{o^{max}}$ | 0 |

Table A.32: Overtime costs and maximum overtime.

| $\mathbf{a_{lj}}$ | **j = 0** | **j = 1** | **j = 2** | **j = 3** | **j = 4** | **j = 5** | **j = 6** | **j = 7** | **j = 8** |
|---|---|---|---|---|---|---|---|---|---|
| **l = 1** | 1.0 | 6.0 | 6.0 | 3.0 | 3.0 | - | - | - | - |
| **l = 2** | 1.0 | - | - | - | - | - | 6.0 | 6.0 | - |
| **l = 3** | 1.0 | - | - | - | - | 8.0 | - | - | 2.0 |

Table A.33: Production coefficients.

| | $\mathbf{f_t}$ | $\mathbf{S_t}$ |
|---|---|---|
| **t=1** | 1 | {1,2,3,4} |
| **t=2** | 5 | {5,6,7,8} |
| **t=3** | 9 | {9,10,11,12} |

Table A.34: First microperiod and set of microperiods belonging to a macroperiod.

| $\mathbf{d_{js}}$ | **s = 4** | **s = 8** | **s = 12** |
|---|---|---|---|
| **j = 1** | 0.0 | 0.0 | 7.0 |
| **j = 2** | 0.0 | 5.0 | 5.0 |
| **j = 3** | 0.0 | 5.0 | 6.0 |
| **j = 4** | 0.0 | 4.0 | 5.0 |

Table A.35: Demand.

| $\mathbf{WIP_{lj}^{max}}$ | **j = 1** | **j = 2** | **j = 3** | **j = 4** | **j = 5** | **j = 6** | **j = 7** | **j = 8** |
|---|---|---|---|---|---|---|---|---|
| **l = 1** | 200.0 | 200.0 | 200.0 | 200.0 | - | - | - | - |
| **l = 2** | - | - | - | - | - | 200.0 | 200.0 | - |
| **l = 3** | - | - | - | - | 200.0 | - | - | 200.0 |

Table A.36: Maximum WIP.

| $s_{lij}/st_{lij}$ | | j = 0 | j = 1 | j = 2 | j = 3 | j = 4 | j = 5 | j = 6 | j = 7 | j = 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| l = 1 | i = 0 | 0.0 | 999.0 | 999.0 | 999.0 | 999.0 | - | - | - | - |
| | i = 1 | 999.0 | 0.0 | 4.0 | 8.0 | 8.0 | - | - | - | - |
| | i = 2 | 999.0 | 4.0 | 0.0 | 8.0 | 8.0 | - | - | - | - |
| | i = 3 | 999.0 | 6.0 | 6.0 | 0.0 | 4.0 | - | - | - | - |
| | i = 4 | 999.0 | 6.0 | 6.0 | 4.0 | 0.0 | - | - | - | - |
| l = 2 | i = 0 | 0.0 | - | - | - | - | - | 999.0 | 999.0 | - |
| | i = 6 | 999.0 | - | - | - | - | - | 0.0 | 4.0 | - |
| | i = 7 | 999.0 | - | - | - | - | - | 4.0 | 0.0 | - |
| l = 3 | i = 0 | 0.0 | - | - | - | - | 12.0 | - | - | 12.0 |
| | i = 5 | 0.0 | - | - | - | - | 0.0 | - | - | 8.0 |
| | i = 8 | 0.0 | - | - | - | - | 6.0 | - | - | 0.0 |

Table A.37: Setup costs and times.

| $c^p_{lj}$ | j = 0 | j = 1 | j = 2 | j = 3 | j = 4 | j = 5 | j = 6 | j = 7 | j = 8 |
|---|---|---|---|---|---|---|---|---|---|
| l = 1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | - | - | - | - |
| l = 2 | 1.0 | - | - | - | - | - | 1.0 | 1.0 | - |
| l = 3 | 1.0 | - | - | - | - | 1.0 | - | - | 1.0 |

Table A.38: Production costs.

| $m_{lj}$ | j = 0 | j = 1 | j = 2 | j = 3 | j = 4 | j = 5 | j = 6 | j = 7 | j = 8 |
|---|---|---|---|---|---|---|---|---|---|
| l = 1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | - | - | - | - |
| l = 2 | 1.0 | - | - | - | - | - | 1.0 | 1.0 | - |
| l = 3 | 1.0 | - | - | - | - | 1.0 | - | - | 1.0 |

Table A.39: Minimum lot-sizes.

| $y_{ljo}$ | j = 0 | j = 1 | j = 2 | j = 3 | j = 4 | j = 5 | j = 6 | j = 7 | j = 8 |
|---|---|---|---|---|---|---|---|---|---|
| l = 1 | 0 | 1 | 0 | 0 | 0 | - | - | - | - |
| l = 2 | 0 | - | - | - | - | - | 1 | 0 | - |
| l = 3 | 0 | - | - | - | - | 1 | - | - | 0 |

Table A.40: Initial setup.

| $p_{ij}$ | j = 1 | j = 2 | j = 3 | j = 4 |
|---|---|---|---|---|
| i = 5 | 1.0 | 1.0 | - | - |
| i = 6 | 1.0 | - | 0.5 | - |
| i = 7 | - | 1.0 | - | 0.5 |
| i = 8 | - | - | 1.0 | 1.0 |

Table A.41: Gozinto factors.

| | $\mathcal{J}_l$ | $\Pi_l$ | $b_l$ |
|---|---|---|---|
| $\mathbf{l = 1}$ | {0,1,2,3,4} | {1,2,...,12} | 0.0 |
| $\mathbf{l = 2}$ | {0,6,7} | {1,2,...,12} | 0.0 |
| $\mathbf{l = 3}$ | {0,5,8} | {1,2,...,12} | 1.0 |

Table A.42: Allowed products and microperiods as well as standby costs.

# Appendix B

# Computational results of the heuristics

The following three selected figures show the development of the objective values for Truncated MIP, the tailored Fix&Optimize, and the new VNDS+E heuristic with parameter scenario 5. For each point in time the best, the worst, and the mean value is determined for the VNDS+E. These representatives are chosen in a way that for each product structure either the GLSPMS tailored Fix&Optimize or Truncated MIP performs well. Note that the tailored Fix&Optimize performed very bad for problem 17. That is why the corresponding curve cannot be seen in Figure B.2.

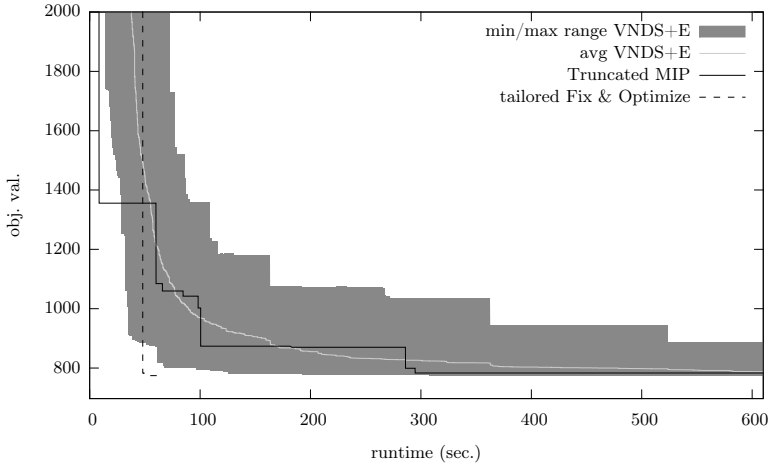


Figure B.1: Comparison of the solution procedures for problem 8.

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DOI 10.1007/978-3-658-02089-7, © Springer Fachmedien Wiesbaden 2013

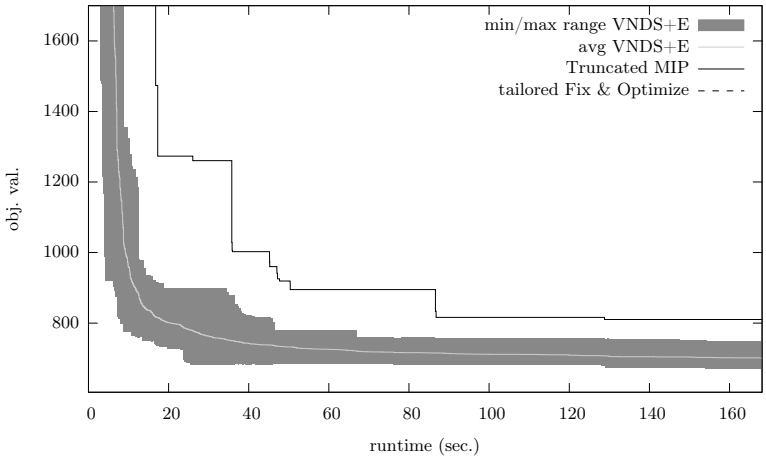


Figure B.2: Comparison of the solution procedures for problem 17.

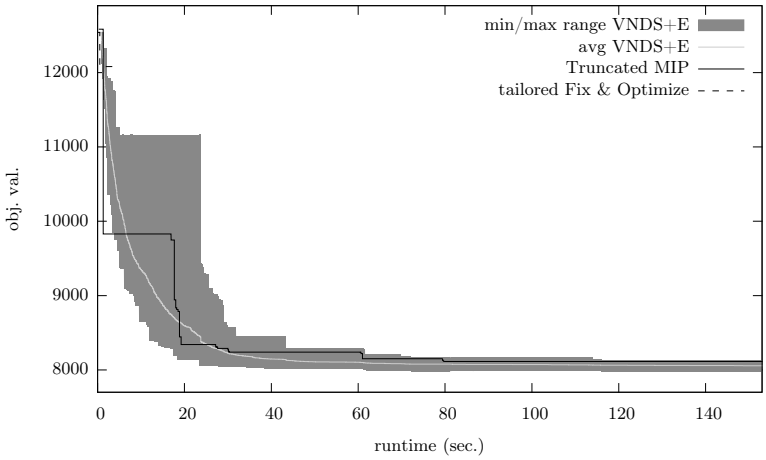


Figure B.3: Comparison of the solution procedures for problem 29.

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