

# APPENDIX 4

## RESULTS OF THE EQUAL PILES ALGORITHM

**GUNTHER** instance is composed of 35 operations and the total process time is 483. The results are given in Table A4.1. The balancing is given in Table A4.2 while Figure A4.1 gives the balancing for different number of stations.

| N  | CT      | Min 1 | Max 1 | Min 2 | Max 2 | Min 3 | Max 3 | Min 4 | Max 4 | Min 5 | Max 5 |
|----|---------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 6  | 80.5000 | 72    | 84    | 72    | 84    | 72    | 84    | 74    | 84    | 74    | 84    |
| 7  | 69.0000 | 57    | 73    | 57    | 73    | 57    | 73    | 57    | 73    | 57    | 73    |
| 8  | 60.3750 | 51    | 64    | 47    | 64    | 51    | 64    | 54    | 64    | 57    | 64    |
| 9  | 53.6667 | 53    | 54    | 53    | 54    | 53    | 54    | 53    | 54    | 53    | 54    |
| 10 | 48.3000 | 42    | 51    | 45    | 51    | 44    | 51    | 43    | 51    | 45    | 51    |
| 11 | 43.9091 | 35    | 48    | 35    | 48    | 35    | 49    | 35    | 49    | 35    | 48    |
| 12 | 40.2500 | 29    | 45    | 29    | 45    | 29    | 45    | 29    | 44    | 29    | 45    |
| 13 | 37.1538 | 28    | 44    | 23    | 44    | 28    | 44    | 22    | 44    | 22    | 44    |

Table A4.1. GUNTHER's minimal/maximal workload of stations.

| N  | Balance 1 | Balance 2 | Balance 3 | Balance 4 | Balance 5 | Avg Run Time | Std Deviation |
|----|-----------|-----------|-----------|-----------|-----------|--------------|---------------|
| 6  | 0.1201    | 0.1201    | 0.1201    | 0.0974    | 0.0942    | 10.76        | 1.553         |
| 7  | 0.1944    | 0.1944    | 0.1944    | 0.1944    | 0.1944    | 52.48        | 13.341        |
| 8  | 0.1931    | 0.2445    | 0.1931    | 0.1570    | 0.1019    | 54           | 17.070        |
| 9  | 0.0264    | 0.0264    | 0.0264    | 0.0264    | 0.0264    | 3.12         | 0.907         |
| 10 | 0.1709    | 0.1244    | 0.1494    | 0.1578    | 0.1244    | 48.1         | 13.559        |
| 11 | 0.3029    | 0.3029    | 0.2977    | 0.2871    | 0.3012    | 19.8         | 5.015         |
| 12 | 0.4348    | 0.4305    | 0.4305    | 0.3962    | 0.4262    | 19.934       | 10.763        |
| 13 | 0.4533    | 0.5644    | 0.5019    | 0.5846    | 0.6591    | 39.1         | 7.080         |

Table A4.2. GUNTHER's balancing.

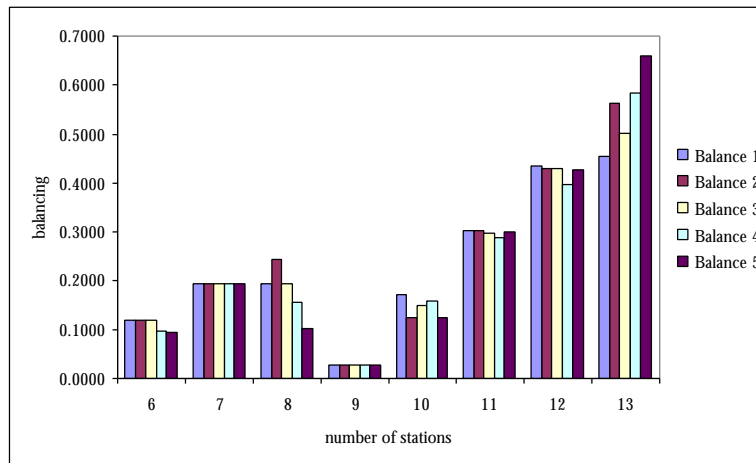


Figure A4.1. The balancing versus the number of stations (GUNTHER).

**HAHN** instance is composed of 53 operations and the total process time is 14026. The results are given in Table A4.3. The balancing of the solutions is given in Table A4.4 while Figure A4.2 gives the balancing for different number of stations.

| N | CT        | Min 1 | Max 1 | Min 2 | Max 2 | Min 3 | Max 3 | Min 4 | Max 4 | Min 5 | Max 5 |
|---|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 3 | 4675.3333 | 4471  | 4787  | 4471  | 4787  | 4471  | 4787  | 4471  | 4787  | 4471  | 4787  |
| 4 | 3506.5000 | 3012  | 3677  | 3012  | 3677  | 3012  | 3677  | 3012  | 3677  | 3012  | 3677  |
| 5 | 2805.2000 | 2778  | 2823  | 2778  | 2823  | 2778  | 2823  | 2778  | 2823  | 2778  | 2823  |
| 6 | 2337.6667 | 2201  | 2400  | 2249  | 2400  | 2113  | 2400  | 2270  | 2400  | 2281  | 2400  |
| 7 | 2003.7143 | 1085  | 2336  | 1085  | 2336  | 1085  | 2336  | 1085  | 2336  | 1085  | 2336  |
| 8 | 1753.2500 | 1085  | 1927  | 1085  | 1927  | 1145  | 1976  | 1085  | 1927  | 1085  | 1940  |

Table A4.3. HAHN's minimal/maximal workload of stations.

| N | Balance 1 | Balance 2 | Balance 3 | Balance 4 | Balance 5 | Avg Run Time | Std Deviation |
|---|-----------|-----------|-----------|-----------|-----------|--------------|---------------|
| 3 | 0.0536    | 0.0536    | 0.0536    | 0.0536    | 0.0536    | 0            | 0.000         |
| 4 | 0.1629    | 0.1629    | 0.1629    | 0.1629    | 0.1629    | 4.5          | 1.660         |
| 5 | 0.0118    | 0.0118    | 0.0118    | 0.0118    | 0.0118    | 2.64         | 0.502         |
| 6 | 0.0707    | 0.0592    | 0.1062    | 0.0556    | 0.0528    | 3.04         | 0.000         |
| 7 | 0.5410    | 0.5339    | 0.5500    | 0.5333    | 0.5346    | 2.62         | 1.085         |
| 8 | 0.4237    | 0.4237    | 0.3926    | 0.4238    | 0.4234    | 302.58       | 30.226        |

Table A4.4. HAHN's balancing.

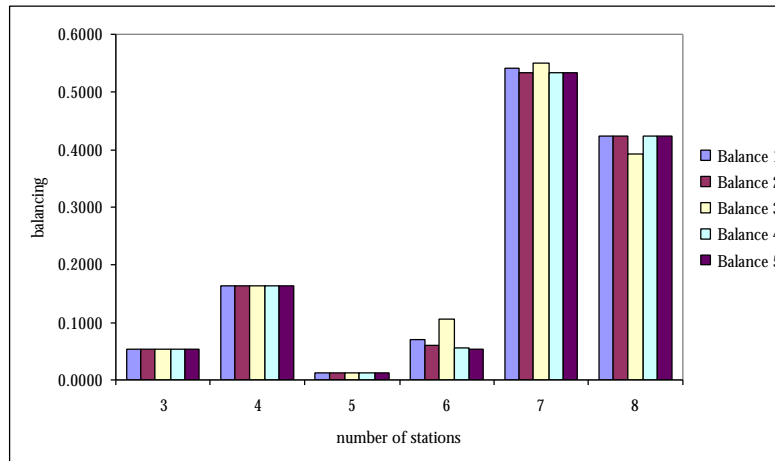


Figure A4.2. Evolution of the balancing with the number of stations (HAHN).

**KILBRIDGE** instance is composed of 45 operations and the total process time is 552. The results are given in Table A4.5. The balancing of the solutions is given in Table A4.6 while Figure A4.3 gives the balancing for different number of stations.

| N  | CT       | Min 1 | Max 1 | Min 2 | Max 2 | Min 3 | Max 3 | Min 4 | Max 4 | Min 5 | Max 5 |
|----|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 3  | 184.0000 | 184   | 184   | 184   | 184   | 184   | 184   | 184   | 184   | 184   | 184   |
| 4  | 138.0000 | 138   | 138   | 138   | 138   | 138   | 138   | 138   | 138   | 138   | 138   |
| 5  | 110.4000 | 110   | 111   | 110   | 111   | 110   | 111   | 110   | 111   | 110   | 111   |
| 6  | 92.0000  | 92    | 92    | 92    | 92    | 92    | 92    | 92    | 92    | 92    | 92    |
| 7  | 78.8571  | 78    | 79    | 78    | 79    | 78    | 79    | 78    | 79    | 78    | 79    |
| 8  | 69.0000  | 69    | 69    | 69    | 69    | 69    | 69    | 69    | 69    | 69    | 69    |
| 9  | 61.3333  | 60    | 62    | 60    | 62    | 60    | 62    | 60    | 62    | 59    | 62    |
| 10 | 55.2000  | 53    | 56    | 54    | 56    | 53    | 56    | 54    | 56    | 53    | 56    |
| 11 | 50.1818  | 40    | 55    | 36    | 56    | 38    | 55    | 34    | 55    | 39    | 55    |

Table A4.5. KILBRIDGE's minimal/maximal workload of stations.

| N  | Balance 1 | Balance 2 | Balance 3 | Balance 4 | Balance 5 | Avg Run Time | Std Deviation |
|----|-----------|-----------|-----------|-----------|-----------|--------------|---------------|
| 3  | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.000        | 0.000         |
| 4  | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.000        | 0.000         |
| 5  | 0.0099    | 0.0099    | 0.0099    | 0.0099    | 0.0099    | 0.000        | 0.000         |
| 6  | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.000        | 0.000         |
| 7  | 0.0117    | 0.0117    | 0.0117    | 0.0117    | 0.0117    | 0.000        | 0.000         |
| 8  | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.000        | 0.000         |
| 9  | 0.0326    | 0.0399    | 0.0326    | 0.0399    | 0.0461    | 22.180       | 5.901         |
| 10 | 0.0561    | 0.0499    | 0.0561    | 0.0429    | 0.0499    | 36.720       | 14.176        |
| 11 | 0.3020    | 0.4355    | 0.3747    | 0.4043    | 0.3308    | 38.720       | 12.817        |

Table A4.6. KILBRIDGE's balancing.

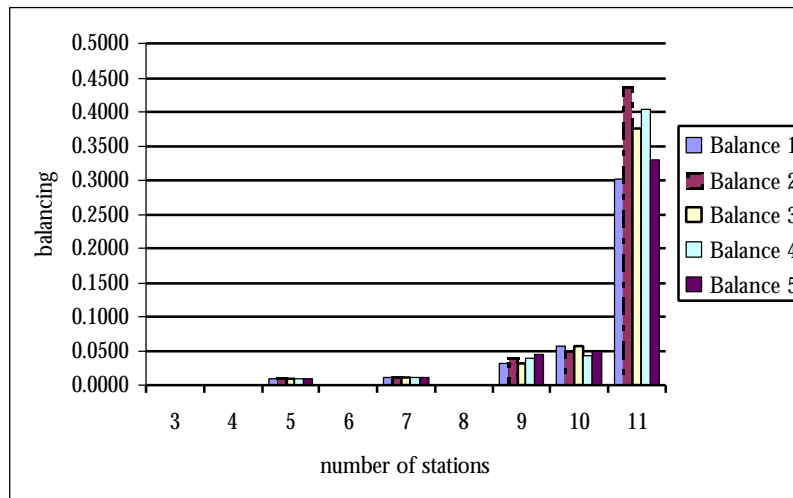


Figure A4.3. Evolution of the balancing with the number of stations (KILBRIDGE).

**LUTZ** instance is composed of 32 operations and the total process time is 14140. The results are given in Table A4.7. The balancing of the solutions is given in Table A4.8 while Figure A4.4 gives the balancing for different number of stations.

| N  | CT        | Min 1 | Max 1 | Min 2 | Max 2 | Min 3 | Max 3 | Min 4 | Max 4 | Min 5 | Max 5 |
|----|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 8  | 1767.5000 | 1598  | 1864  | 1400  | 1860  | 1598  | 1864  | 1598  | 1864  | 1598  | 1864  |
| 9  | 1571.1111 | 1240  | 1680  | 1240  | 1680  | 1236  | 1702  | 1240  | 1680  | 1240  | 1680  |
| 10 | 1414.0000 | 954   | 1586  | 1216  | 1662  | 1240  | 1534  | 954   | 1562  | 1022  | 1602  |
| 11 | 1285.4545 | 1158  | 1402  | 954   | 1406  | 1120  | 1400  | 1158  | 1402  | 1166  | 1402  |

Table A4.7. LUTZ's minimal/maximal workload of stations.

| N  | Balance 1 | Balance 2 | Balance 3 | Balance 4 | Balance 5 | Avg Run Time | Std Deviation |
|----|-----------|-----------|-----------|-----------|-----------|--------------|---------------|
| 8  | 0.1634    | 0.2253    | 0.1634    | 0.1634    | 0.1634    | 83.3         | 12.077        |
| 9  | 0.2356    | 0.2356    | 0.2450    | 0.2356    | 0.2356    | 80.2         | 34.264        |
| 10 | 0.4130    | 0.2920    | 0.1968    | 0.4106    | 0.3709    | 57.62        | 10.984        |
| 11 | 0.2177    | 0.3370    | 0.2702    | 0.2286    | 0.2284    | 40.82        | 11.612        |

Table A4.8. LUTZ's balancing.

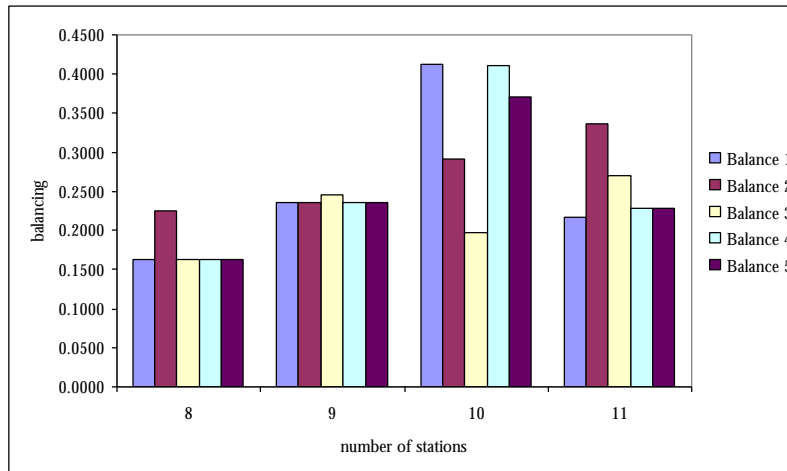


Figure A4.4. Evolution of the balancing with the number of stations (LUTZ).

**WARNEKEE** instance is composed of 58 operations and the total process time is 1548. The results are given in Table A4.9. The balancing of the solutions is given in Table A4.10 while Figure A4.5 gives the balancing for different number of stations.

| N  | CT       | Min 1 | Max 1 | Min 2 | Max 2 | Min 3 | Max 3 | Min 4 | Max 4 | Min 5 | Max 5 |
|----|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 3  | 516.0000 | 516   | 516   | 516   | 516   | 516   | 516   | 516   | 516   | 516   | 516   |
| 4  | 387.0000 | 387   | 387   | 387   | 387   | 387   | 387   | 387   | 387   | 387   | 387   |
| 5  | 309.6000 | 309   | 310   | 309   | 310   | 309   | 310   | 309   | 310   | 309   | 310   |
| 6  | 258.0000 | 258   | 258   | 258   | 258   | 258   | 258   | 258   | 258   | 258   | 258   |
| 7  | 221.1429 | 220   | 222   | 220   | 222   | 220   | 222   | 220   | 222   | 220   | 222   |
| 8  | 193.5000 | 191   | 195   | 191   | 195   | 191   | 195   | 191   | 195   | 191   | 195   |
| 9  | 172.0000 | 172   | 172   | 172   | 172   | 172   | 172   | 172   | 172   | 172   | 172   |
| 10 | 154.8000 | 154   | 155   | 154   | 155   | 154   | 156   | 154   | 155   | 154   | 155   |
| 11 | 140.7273 | 137   | 143   | 137   | 143   | 137   | 143   | 137   | 143   | 136   | 143   |
| 12 | 129.0000 | 125   | 132   | 125   | 131   | 125   | 132   | 126   | 132   | 126   | 132   |
| 13 | 119.0769 | 115   | 122   | 113   | 122   | 116   | 122   | 115   | 122   | 115   | 122   |
| 14 | 110.5714 | 109   | 112   | 108   | 112   | 109   | 112   | 109   | 113   | 109   | 111   |
| 15 | 103.2000 | 99    | 107   | 99    | 106   | 99    | 106   | 99    | 107   | 99    | 107   |
| 16 | 96.7500  | 91    | 101   | 89    | 101   | 87    | 101   | 89    | 100   | 91    | 101   |
| 17 | 91.0588  | 78    | 97    | 82    | 97    | 82    | 99    | 82    | 99    | 83    | 99    |
| 18 | 86.0000  | 77    | 91    | 81    | 92    | 75    | 95    | 77    | 96    | 76    | 93    |
| 19 | 81.4737  | 65    | 90    | 45    | 91    | 50    | 90    | 62    | 90    | 62    | 90    |
| 20 | 77.4000  | 52    | 84    | 64    | 86    | 54    | 87    | 54    | 86    | 54    | 86    |
| 21 | 73.7143  | 50    | 81    | 60    | 88    | 57    | 86    | 58    | 87    | 58    | 87    |
| 22 | 70.3636  | 50    | 81    | 53    | 76    | 57    | 79    | 57    | 79    | 55    | 79    |

Table A4.9. WARNEKEE's minimal/maximal workload of stations.

| N  | Balance 1 | Balance 2 | Balance 3 | Balance 4 | Balance 5 | Avg Run Time | Std Deviation |
|----|-----------|-----------|-----------|-----------|-----------|--------------|---------------|
| 3  | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.000        | 0.000         |
| 4  | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.380        | 0.137         |
| 5  | 0.0035    | 0.0035    | 0.0035    | 0.0035    | 0.0035    | 0.700        | 0.254         |
| 6  | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.000        | 0.000         |
| 7  | 0.0076    | 0.0076    | 0.0076    | 0.0076    | 0.0076    | 23.984       | 13.413        |
| 8  | 0.0163    | 0.0163    | 0.0163    | 0.0163    | 0.0163    | 2.260        | 0.822         |
| 9  | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 0.0000    | 44.080       | 14.258        |
| 10 | 0.0082    | 0.0082    | 0.0123    | 0.0082    | 0.0082    | 29.080       | 14.462        |
| 11 | 0.0427    | 0.0503    | 0.0450    | 0.0439    | 0.0439    | 74.16        | 3.851         |
| 12 | 0.0502    | 0.0537    | 0.0537    | 0.0478    | 0.0490    | 32.89        | 13.162        |
| 13 | 0.0550    | 0.0634    | 0.0510    | 0.0563    | 0.0510    | 30.364       | 14.218        |
| 14 | 0.0278    | 0.0355    | 0.0331    | 0.0331    | 0.0246    | 72.46        | 31.288        |
| 15 | 0.0753    | 0.0847    | 0.0765    | 0.0847    | 0.0813    | 101.6        | 31.493        |
| 16 | 0.1210    | 0.1270    | 0.1352    | 0.1227    | 0.1108    | 127.12       | 29.868        |
| 17 | 0.1961    | 0.1587    | 0.1967    | 0.1936    | 0.1760    | 129.62       | 56.609        |
| 18 | 0.1846    | 0.1386    | 0.2007    | 0.1960    | 0.2014    | 213.4        | 21.509        |
| 19 | 0.3720    | 0.5631    | 0.4758    | 0.4020    | 0.4020    | 128.48       | 43.281        |
| 20 | 0.4828    | 0.3469    | 0.4220    | 0.4176    | 0.4017    | 155.64       | 40.559        |
| 21 | 0.4368    | 0.4034    | 0.4438    | 0.4204    | 0.4204    | 130.42       | 18.566        |
| 22 | 0.4368    | 0.3811    | 0.4318    | 0.4318    | 0.4341    | 143.3        | 41.244        |

Table A4.10. WARNEKEE's balancing.

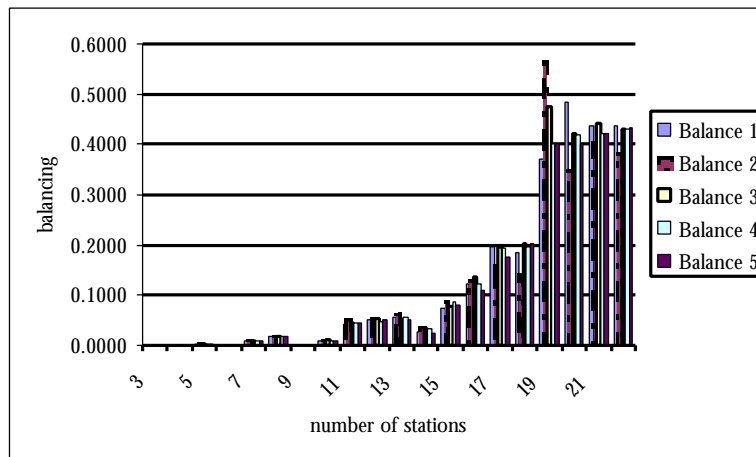


Figure A4.5. Evolution of the balancing with the number of stations (WARNEKEE).

**WEE-MAG** instance is composed of 75 operations and the total process time is 1499. The results are given in Table A4.11. The balancing of the solutions is given in Table A4.12 while Figure A4.6 gives the balancing for different number of stations.

| N  | CT       | Min 1 | Max 1 | Min 2 | Max 2 | Min 3 | Max 3 | Min 4 | Max 4 | Min 5 | Max 5 |
|----|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 3  | 499.6667 | 499   | 500   | 499   | 500   | 499   | 500   | 499   | 500   | 499   | 500   |
| 4  | 374.7500 | 374   | 375   | 374   | 375   | 374   | 375   | 374   | 375   | 374   | 375   |
| 5  | 299.8000 | 299   | 300   | 299   | 300   | 299   | 300   | 299   | 300   | 299   | 300   |
| 6  | 249.8333 | 249   | 250   | 249   | 250   | 249   | 250   | 249   | 250   | 249   | 250   |
| 7  | 214.1429 | 213   | 215   | 213   | 215   | 213   | 215   | 213   | 215   | 213   | 215   |
| 8  | 187.3750 | 187   | 188   | 186   | 188   | 186   | 188   | 186   | 188   | 186   | 188   |
| 9  | 166.5556 | 166   | 167   | 166   | 167   | 166   | 167   | 166   | 167   | 166   | 167   |
| 10 | 149.9000 | 149   | 150   | 149   | 150   | 149   | 150   | 149   | 150   | 149   | 150   |
| 11 | 136.2727 | 134   | 137   | 133   | 137   | 134   | 138   | 134   | 138   | 135   | 137   |
| 12 | 124.9167 | 124   | 125   | 124   | 125   | 124   | 125   | 124   | 125   | 124   | 125   |
| 13 | 115.3077 | 113   | 117   | 112   | 118   | 112   | 116   | 113   | 117   | 113   | 117   |
| 14 | 107.0714 | 96    | 112   | 96    | 111   | 100   | 116   | 100   | 110   | 102   | 115   |
| 15 | 99.9333  | 99    | 101   | 99    | 101   | 99    | 100   | 99    | 100   | 99    | 101   |
| 16 | 93.6875  | 91    | 94    | 92    | 95    | 92    | 96    | 92    | 97    | 91    | 95    |
| 17 | 88.1765  | 77    | 96    | 83    | 92    | 76    | 93    | 80    | 95    | 78    | 92    |

Table A4.11. WEE-MAG's minimal/maximal workload of stations.

| N  | Balance 1 | Balance 2 | Balance 3 | Balance 4 | Balance 5 | Avg Run Time | Std Deviation |
|----|-----------|-----------|-----------|-----------|-----------|--------------|---------------|
| 3  | 0.00163   | 0.00163   | 0.00163   | 0.00163   | 0.00163   | 0            | 0.000         |
| 4  | 0.00231   | 0.00231   | 0.00231   | 0.00231   | 0.00231   | 0.0000       | 0.000         |
| 5  | 0.00298   | 0.00298   | 0.00298   | 0.00298   | 0.00298   | 0.0000       | 0.000         |
| 6  | 0.00365   | 0.00365   | 0.00365   | 0.00365   | 0.00365   | 0.0000       | 0.000         |
| 7  | 0.01029   | 0.00789   | 0.01029   | 0.01029   | 0.00789   | 14.84        | 4.683         |
| 8  | 0.00731   | 0.01051   | 0.01051   | 0.01051   | 0.01051   | 30.32        | 8.324         |
| 9  | 0.00895   | 0.00895   | 0.00895   | 0.00895   | 0.00895   | 54.7         | 10.512        |
| 10 | 0.00633   | 0.00633   | 0.00633   | 0.00633   | 0.00633   | 2.52         | 10.512        |
| 11 | 0.02763   | 0.02952   | 0.02763   | 0.02763   | 0.02099   | 22.82        | 5.677         |
| 12 | 0.00766   | 0.00766   | 0.00766   | 0.00766   | 0.00766   | 8.52         | 1.283         |
| 13 | 0.03551   | 0.04316   | 0.03952   | 0.04316   | 0.04138   | 112.6        | 53.817        |
| 14 | 0.14007   | 0.12139   | 0.12973   | 0.09475   | 0.11550   | 115.84       | 33.752        |
| 15 | 0.01714   | 0.02223   | 0.00967   | 0.00967   | 0.02223   | 89.26        | 34.942        |
| 16 | 0.03279   | 0.03279   | 0.04457   | 0.04706   | 0.04194   | 107.7        | 44.894        |
| 17 | 0.17732   | 0.13537   | 0.17440   | 0.15896   | 0.16609   | 131.96       | 57.610        |

Table A4.12. WEE-MAG's balancing.

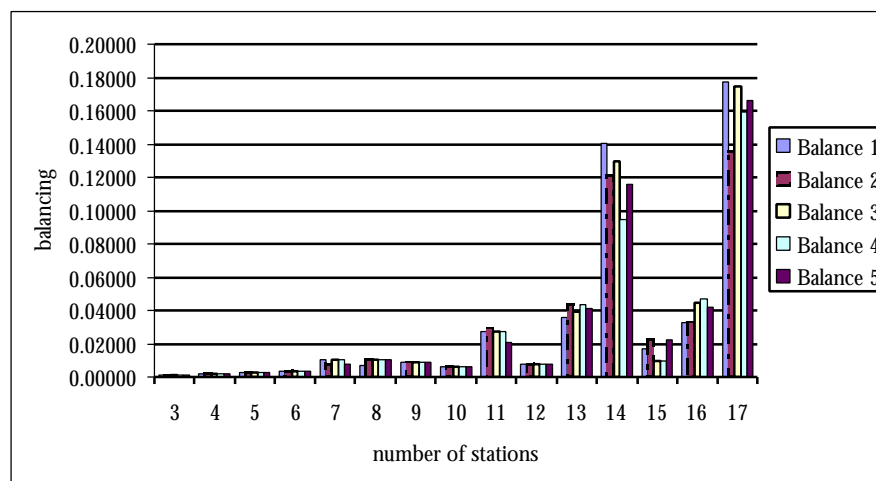


Figure A4.6. Evolution of the balancing with the number of stations (WEE-MAG).