Data Article

Experimental dataset for optimising the freight rail operations

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A B S T R A C T

The freight rail systems have an essential role to play in transporting the commodities between the delivery and collection points at different locations such as farms, factories and mills. The freight transport system uses a daily schedule of train runs to meet the needs of both the harvesters and the mills (An Integrated Approach to Optimise Cane Rail Operations (M. Masoud, E. Kozan, G. Kent, Liu, Shi Qiang, 2016b) [1]). Producing an efficient daily schedule to optimise the rail operations requires integration of the main elements of harvesting, transporting and milling in the value chain of the Australian agriculture industry. The data utilised in this research involve four main tables: sidings, harvesters, sectional rail network and trains. The utilised data were collected from Australian sugar mills as a real application. Operations Research techniques such as metaheuristic and constraint programming are used to produce the optimised solutions in an analytical way.

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**Specifications Table**

| Subject area                      | Operations Research                      |
|-----------------------------------|------------------------------------------|
| More specific subject area        | Rail Systems Optimisation                 |
| Type of data                      | Table, graph, figure                     |
| How data was acquired             | From mills and farm locations             |
| Data format                       | Filtered, analysed                        |
| Experimental factors              | Data had been customised to remove any mismatching with real life application such as siding capacity, daily allotment, |
| Experimental features             | A near optimal scheduler for trains was produced using a real sector of Australian rail network. |
| Data source location              | Queensland University of Technology, Brisbane, Australia |
| Data accessibility                | Data is within this article               |

**Value of Data**

- The main aim of the presented data is to develop mathematical models of the freight rail systems and help in producing effective solutions in a reasonable CPU time.
- In this research, minimising the makespan is proposed as a main criterion to optimise the freight rail systems using the introduced data. The results in this research can be used to compare the performance of the proposed mathematical methods in optimising complex systems such as rail systems in many prospective studies.
- The data of the produced schedules of the train runs can be used for many different types of the freight systems such as the sugarcane or coal rail systems [5]. The data describe the daily trips of each train to deliver the empty bins at different locations called sidings and collect the full bins from these sidings for delivery to the mills or the factories.

1. **Data**

   Based on the feedback from our industry partners, the data utilised in this research are created in four main tables: Sidings (Table 1), Trains (Table 2), Harvesters (Table 3) and Rail Network (Table 4). In addition, three figures are presented to show the main steps of the proposed solutions: Kalamia’s mill with the main original map (Fig. 1), the main steps to produce the final solution (Fig. 2), and the daily trips of each train in the system (Fig. 3).

2. **Experimental design, materials and methods**

   A case study was examined to validate the constraint programming models and metaheuristic techniques. Fig. 1 shows a sector of the transport system of Townsville’s mill in Queensland, Australia. Many train runs are generated where each run start at one mill and finishes at the same mill after visiting many different siding locations. The number of trains was selected to implement different runs requiring a fewer number of trains. Kalamia’s mill has 58 sidings located in 9 segments but not all of them work on the same day. Approximately 14 trains can be used to construct
| Segment name | Siding index | Siding name | Capacity empty | Capacity full | Time from mill | Shunt time |
|--------------|--------------|-------------|----------------|---------------|----------------|------------|
| BRANDON/     | 1            | H E A       | 242            | 242           | 6              | 15         |
| GAINS福德    | 2            | KAL PLAINS  | 320            | 328           | 16             | 15         |
|              | 3            | BRANDON 1   | 272            | 272           | 18             | 15         |
|              | 4            | BRANDON 3   | 200            | 196           | 20             | 35         |
|              | 5            | BRANDON 4   | 328            | 328           | 0              | 15         |
|              | 6            | GAINS福德 2 | 288            | 272           | 22             | 15         |
|              | 7            | GAINS福德 4 | 320            | 320           | 26             | 20         |
| CHIVERTON/   | 8            | CHIVERTON 2 | 232            | 280           | 12             | 10         |
| TOWN         | 9            | CHIV TERMINUS | 208         | 208           | 17             | 15         |
|              | 10           | LILLESMERE  | 264            | 264           | 8              | 10         |
|              | 11           | TOWN 3      | 440            | 440           | 12             | 20         |
|              | 12           | TOWN TERMINUS | 264         | 240           | 15             | 30         |
| MLINE/CENTRAL| 13           | MAIN LINE 1A| 256            | 264           | 5              | 10         |
|              | 14           | MAIN LINE 1 | 112            | 136           | 6              | 10         |
|              | 15           | MAIN LINE 3 | 296            | 296           | 10             | 15         |
|              | 16           | MAIN LINE 4 A| 200        | 200           | 14             | 20         |
|              | 17           | MAIN LINE 4B| 192            | 192           | 14             | 20         |
|              | 18           | CENTRAL 1A  | 136            | 136           | 17             | 10         |
|              | 19           | CENTRAL 1   | 280            | 320           | 18             | 10         |
|              | 20           | CENTRAL 2   | 264            | 280           | 21             | 10         |
|              | 21           | CENTRAL 3   | 288            | 328           | 22             | 10         |
| JARVISFIELD  | 22           | JARVISFIELD 2A | 208        | 264           | 15             | 10         |
|              | 23           | JARVISFIELD 2B | 208        | 264           | 15             | 10         |
|              | 24           | JARVISFIELD 3 | 240            | 344           | 21             | 10         |
|              | 25           | JARVISFIELD 6 | 216            | 264           | 24             | 10         |
|              | 26           | J/FIELD TERM A | 304            | 304           | 32             | 15         |
|              | 27           | J/FIELD TERM B | 184            | 216           | 32             | 15         |
|              | 28           | JARVISFIELD 8A | 224            | 248           | 26             | 15         |
|              | 29           | JARVISFIELD 8B | 248            | 248           | 26             | 15         |
|              | 30           | JARVISFIELD 8C | 208            | 208           | 26             | 15         |
| NORHAM/IVANHOE| 31           | IVANHOE 2   | 376            | 376           | 16             | 10         |
|              | 32           | IVANHOE 3   | 257            | 273           | 16             | 10         |
|              | 33           | IVAN TERMINUS | 240            | 240           | 21             | 15         |
|              | 34           | NORHAM 3    | 504            | 504           | 19             | 10         |
|              | 35           | NORHAM 4    | 240            | 256           | 25             | 10         |
|              | 36           | NORHAM DEPOT | 240            | 240           | 27             | 10         |
| RITA ISLAND  | 37           | RITA ISLAND 4 | 248            | 312           | 30             | 10         |
|              | 38           | RITA ISLAND 6 | 232            | 272           | 35             | 10         |
|              | 39           | RITA ISLAND 7 | 248            | 248           | 36             | 10         |
|              | 40           | RITA ISLAND 9 | 104            | 144           | 42             | 10         |
|              | 41           | RITA ISLAND 10 | 200           | 224           | 46             | 10         |
|              | 42           | RITA ISLAND 12 | 200           | 224           | 50             | 10         |
|              | 43           | RITA ISLAND 15 | 184            | 184           | 55             | 10         |
|              | 44           | RITA ISLAND 16 | 248            | 256           | 58             | 10         |
|              | 45           | RITA ISLAND 17A | 136            | 136           | 58             | 40         |
|              | 46           | RITA ISLAND 17B | 160            | 160           | 40             | 40         |
| MCDESM/E/AIRDAL  | 47           | MCDESM 1    | 192            | 216           | 32             | 15         |
|              | 48           | 2 MCDESM    | 206            | 206           | 35             | 10         |
|              | 49           | MCDESM 3A   | 344            | 352           | 45             | 15         |
|              | 50           | MCDESM 3B   | 344            | 352           | 45             | 15         |
|              | 51           | MCDESM 4    | 248            | 208           | 50             | 10         |
|              | 52           | MCDESM 5    | 208            | 240           | 55             | 10         |
|              | 53           | AIRDALE 1   | 256            | 224           | 60             | 10         |
|              | 54           | LAUNS       | 264            | 270           | 65             | 20         |
|              | 55           | AIRDALE 2   | 232            | 256           | 65             | 10         |
|              | 56           | AIRDALE 3   | 176            | 216           | 67             | 10         |
|              | 57           | AIRDALE 4   | 240            | 296           | 68             | 10         |
|              | 58           | AIRDALE 5   | 200            | 248           | 60             | 10         |
|              | 59           | AIRDALE 6   | 248            | 280           | 62             | 10         |
|              | 60           | AIRDALE 7   | 224            | 250           | 70             | 10         |
the train trips that deliver empty bins to sidings at farms and collect full bins from farms top sidings.

The data table of sectional rail network was constructed to describe the rail section length between different sidings.

Constraint programming (CP) is one of solution techniques to find a near optimal scheduler for the sugarcane rail systems. The proposed mathematical model considers the siding and train capacity constraints, daily allotment constraints of each harvester, train passing constraints where each train cannot occupy more than one rail section at a time or two trains can occupy one section at a time. Constraint programming that deals with problems defined within the finite set of possible values of each variable is the main technology used for solving mathematical formulation problems.

**Table 1 (continued)**

| Segment name | Siding index | Siding name   | Capacity empty | Capacity full | Time from mill | Shunt time |
|--------------|--------------|---------------|----------------|---------------|---------------|------------|
| LOOPS        | 61           | SHEPPARDS RD  | 328            | 360           | 80            | 10         |
|              | 62           | BROWNS 1      | 224            | 264           | 80            | 10         |
|              | 63           | BEACH LOOP    | 422            | 422           | 5             | 10         |
|              | 64           | AIRD LOOP     | 332            | 332           | 10            | 10         |
|              | 65           | MADDENS       | 558            | 558           | 13            | 10         |
|              | 66           | MCDESME 2     | 223            | 223           | 40            | 10         |
|              | 67           | BALLOON LOOP  | 429            | 429           | 5             | 10         |
|              | 68           | BROWNS 1      | 224            | 264           | 80            | 10         |
|              | 69           | BROWNS 2      | 832            | 832           | 84            | 15         |
|              | 70           | BROWNS 3      | 248            | 272           | 112           | 20         |
|              | 71           | BROWNS 4      | 200            | 232           | 115           | 10         |
|              | 72           | BROWNS 5      | 320            | 328           | 95            | 20         |
|              | 73           | BROWNS 6      | 352            | 352           | 120           | 10         |
|              | 74           | BROWNS 7      | 848            | 848           | 100           | 15         |
|              | 75           | BROWNS 8      | 320            | 384           | 128           | 15         |
|              | 76           | MONA PARK 2   | 160            | 160           | 0             | 10         |
|              | 77           | MONA PARK 3   | 240            | 240           | 0             | 10         |
|              | 78           | MONA PARK 4   | 240            | 240           | 0             | 10         |

**Table 2**

Kalamia mill’s trains.

| Train order | Train name  | Load empty | Load full | Speed empty | Speed full | Speed light | Average speed |
|-------------|-------------|------------|-----------|-------------|------------|-------------|---------------|
| 1           | NORHAM      | 120        | 120       | 22          | 22         | 22          | 22            |
| 2           | SELKIRK     | 120        | 120       | 22          | 22         | 22          | 22            |
| 3           | BURDEKIN    | 120        | 120       | 22          | 22         | 22          | 22            |
| 4           | STRATHALBYN | 120        | 120       | 22          | 22         | 22          | 22            |
| 5           | DELTA       | 120        | 100       | 20          | 18         | 20          | 20            |
| 6           | AIRDILLIAN  | 100        | 80        | 20          | 18         | 20          | 20            |
| 7           | CHIVERTON   | 100        | 72        | 20          | 18         | 20          | 20            |
| 8           | KALAMIA     | 110        | 82        | 14          | 12         | 14          | 13.3          |
| 9           | BOJACK      | 120        | 120       | 30          | 30         | 32          | 30.6          |
| 10          | CARSTAIRS   | 110        | 90        | 28          | 22         | 30          | 26.6          |
| 11          | NORTHCOATE  | 110        | 90        | 28          | 28         | 28          | 28            |
| 12          | JARVISFIELD | 120        | 120       | 34          | 34         | 34          | 34            |
| 13          | RITA ISLAND | 120        | 120       | 34          | 34         | 34          | 34            |
| 14          | KILRIE      | 120        | 120       | 34          | 34         | 34          | 34            |
Table 3
Kalamia mill's harvesters.

| Group No | Harvester name      | Enabled | Start time | Nom allot | Harvest rate |
|----------|---------------------|---------|------------|-----------|--------------|
| 137      | BUNDY               | FALSE   | 5:00 AM    | 705       | 75           |
| 140      | HAUGHTON/ SUGAR     | FALSE   | 6:00 AM    | 1140      | 75           |
| 206      | DOWSON              | TRUE    | 4:30 AM    | 986       | 90           |
| 208      | DAVCO               | FALSE   | 6:00 AM    | 0         | 140          |
| 212      | ROCKS HARV          | FALSE   | 6:00 AM    | 1381      | 1            |
| 216      | KELLY               | FALSE   | 6:00 AM    | 0         | 0.1          |
| 225      | CHAPMAN             | FALSE   | 6:00 AM    | 514       | 1            |
| 226      | DENNIS              | FALSE   | 6:00 AM    | 471       | 1            |
| 227      | MCLEAN              | FALSE   | 6:00 AM    | 651       | 1            |
| 229      | GIDDY               | FALSE   | 6:00 AM    | 801       | 1            |
| 231      | VIERO               | FALSE   | 6:00 AM    | 781       | 1            |
| 233      | BUGEJA              | FALSE   | 6:00 AM    | 760       | 62           |
| 234      | NEWMAN              | FALSE   | 6:00 AM    | 628       | 1            |
| 238      | INVICTA 1           | FALSE   | 6:00 AM    | 600       | 0.1          |
| 241      | H.C.L.              | FALSE   | 6:00 AM    | 1         | 75           |
| 242      | DRAIN               | FALSE   | 6:00 AM    | 664       | 1            |
| 245      | SEXTON              | FALSE   | 6:00 AM    | 692       | 1            |
| 246      | MILLER              | FALSE   | 6:00 AM    | 508       | 1            |
| 247      | SPENCE              | FALSE   | 6:00 AM    | 844       | 65           |
| 301      | MUGUIRA             | TRUE    | 4:30 AM    | 707       | 70           |
| 301      | GALEA P             | FALSE   | 4:00 AM    | 1         | 70           |
| 302      | T.F.D.              | TRUE    | 7:00 AM    | 0         | 30           |
| 303      | LAIDLOW             | TRUE    | 3:30 AM    | 571       | 76           |
| 306      | BONNANO.M.          | TRUE    | 3:00 AM    | 645       | 75           |
| 310      | TUFFIN. G.          | TRUE    | 5:00 AM    | 494       | 70           |
| 311      | BURKE.B.            | FALSE   | 6:00 AM    | 0         | 1            |
| 313      | SATORL.M.           | TRUE    | 4:30 AM    | 550       | 65           |
| 320      | NIELSEN.J.          | TRUE    | 3:30 AM    | 593       | 76           |
| 321      | SOUTHERN.J.         | TRUE    | 3:30 AM    | 742       | 76           |
| 322      | MCDONNELL           | TRUE    | 6:00 AM    | 486       | 70           |
| 324      | ARBOIT              | TRUE    | 8:00 AM    | 243       | 26           |
| 330      | BAPTS.S.            | TRUE    | 6:30 AM    | 610       | 76           |
| 331      | JONES               | TRUE    | 7:00 AM    | 0         | 60           |
| 332      | JONES. RYAN         | TRUE    | 6:30 AM    | 730       | 70           |
| 333      | COASTAL             | TRUE    | 6:30 AM    | 697       | 90           |
| 341      | OLSEN.M.            | TRUE    | 6:30 AM    | 581       | 75           |
| 342      | BONNANO BROS        | TRUE    | 5:00 AM    | 612       | 70           |
| 352      | MITCHELL.J.         | FALSE   | 5:00 AM    | 445       | 80           |
| 353      | BROMBAL             | TRUE    | 2:30 AM    | 733       | 80           |
| 361      | KELLY.J.            | TRUE    | 4:30 AM    | 986       | 90           |
| 363      | CARDILLO            | TRUE    | 7:00 AM    | 69        | 26           |
| 364      | SHERLOCK            | TRUE    | 5:00 AM    | 404       | 70           |
| 373      | SCUDERI.M.          | TRUE    | 3:30 AM    | 931       | 85           |
| 380      | MINUZZO. C          | TRUE    | 4:30 AM    | 619       | 80           |
| 381      | MALAPONTE           | TRUE    | 5:00 AM    | 607       | 78           |
| 383      | PIRKONE             | TRUE    | 6:00 AM    | 437       | 20           |
| 391      | QUAGLIATA.C.        | TRUE    | 4:00 AM    | 809       | 90           |
| 393      | BETTERIDGE S        | TRUE    | 4:30 AM    | 625       | 70           |
| 394      | DROVANDI            | FALSE   | 7:00 AM    | 0         | 75           |
| 395      | AHERN               | TRUE    | 5:00 AM    | 563       | 75           |
| 398      | IVORY 2             | TRUE    | 6:00 AM    | 0         | 60           |
| 399      | INKERMAN 1          | FALSE   | 12:00 AM   | 0         | 0            |
| 400      | SISL                | FALSE   | 12:00 AM   | 600       | 1            |
| 401      | INVOLATA            | FALSE   | 12:00 AM   | 420       | 1            |
through the search trees. Fig. 2 shows an example of four feasible solutions to clarify the stages of obtaining these solutions using the search tree for the DFS algorithm, where each solution is shown by three subgraphs that start with discovering the nodes of the search tree to find the solution. The search tree uses coloured nodes to express the node types. For example, the red nodes are the failures, the solutions are green, the blue nodes are the explored choice points, white are the nodes

Table 4
Kalamia’s sectional rail network.

| From Siding       | To another Siding | Dist  | From Siding       | To another Siding | Dist  |
|-------------------|-------------------|-------|-------------------|-------------------|-------|
| SHEPHERDS_JUNCT   | BROWNS_1_         | 0.98  | JN-38             | BRANDON_3         | 0.94  |
| BROWNS_1          | BROWNS_2          | 1.06  | BRANDON_3         | BRANDON_4         | 1.6   |
| BROWNS_2          | BROWNS_3          | 1.16  | JN-39             | KAL_PAINS         | 0.98  |
| BROWNS_3          | BROWNS_4          | 1.23  | JN-38             | KAL_PAINS         | 1.82  |
| BROWNS_4          | BROWNS_5          | 2.54  | JN-40             | JN-39             | 1.59  |
| BROWNS_5          | BROWNS_6          | 0.24  | JN-35             | KAL_PAINS         | 0.48  |
| BROWNS_6          | BROWNS_7          | 2.77  | JN-39             | H_E_A             | 0.32  |
| BROWNS_7          | BROWNS_8          | 2.71  | JN-41             | GAINSFORD_2       | 0.27  |
| SHEPHERDS_JUNCT   | SHEPPARDS_RD      | 3.23  | JN-41             | GAINSFORD_4       | 2.03  |
| MONA_PARK_2       | JN-15             | 0.74  | JN-39             | JN-41             | 4.22  |
| JN-15             | MONA_PARK_4       | 0.78  | JN-35             | CHIVERTON_2       | 1.68  |
| JN-15             | MONA_PARK_3       | 0.36  | CHIVERTON_2       | CHIV_TERMINUS     | 2.4   |
| BROWNS_8          | MONA_PARK_2       | 9.33  | MAIN_LINE_4_A     | MAIN_LINE_4B      | 0.01  |
| LAUNS_POINTS      | LAUNS             | 1.48  | LAUNS_POINTS      | AIRDALE_2         | 0.07  |
| JN-21             | RITA_ISLAND_17B   | 0.17  | AIRDALE_2         | AIRDALE_3         | 0.33  |
| JN-21             | RITA_ISLAND_17A   | 0.22  | AIRDALE_3         | AIRDALE_4         | 1.21  |
| JN-22             | RITA_ISLAND_15    | 0.31  | AIRDALE_4         | AIRDALE_5         | 1.48  |
| JN-23             | RITA_ISLAND_7     | 0.22  | AIRDALE_5         | AIRDALE_6         | 2.57  |
| IVANHOE_POINTS    | IVANHOE_2         | 1.2   | AIRDALE_6         | AIRDALE_7         | 3.81  |
| IVANHOE_2         | IVANHOE_3         | 1.24  | AIRDALE_7         | SHEPHERDS_JUNCT   | 2.89  |
| JN-27             | JARVISFIELD_9A    | 1.46  | MCDESME_4         | MCDESME_5         | 1.41  |
| CREEK_POINTS      | JARVISFIELD_2A    | 0.76  | MCDESME_5         | AIRDALE_1         | 2.97  |
| JARVISFIELD_2A    | JARVISFIELD_2B    | 0.14  | AIRDALE_1         | LAUNS_POINTS      | 1.1   |
| JARVISFIELD_2B    | JARVISFIELD_3     | 1.75  | RITA_ISLAND_PTS   | MCDESME_1         | 1.3   |
| JARVISFIELD_3     | JARVISFIELD_6     | 1.39  | MCDESME_1         | MCDESME_3A        | 2.92  |
| JARVISFIELD_6     | JN-27             | 0.73  | MCDESME_3A        | MCDESME_3B        | 0     |
| JN-29             | JARVISFIELD_8B    | 0.39  | MCDESME_3B        | MCDESME_4         | 0.95  |
| JN-27             | J/FIELD_TERM_B    | 1.5   | JN-22             | RITA_ISLAND_16    | 0.71  |
| CENTRAL_PTS_J8    | CENTRAL_1A        | 0.33  | RITA_ISLAND_16    | JN-21             | 2.61  |
| CENTRAL_1A        | CENTRAL_1         | 1.4   | JN-23             | RITA_ISLAND_9     | 1.57  |
| CENTRAL_1         | CENTRAL_2         | 1.06  | RITA_ISLAND_9     | RITA_ISLAND_10    | 1.13  |
| JN-33             | MAIN_LINE_4_A     | 0.32  | RITA_ISLAND_12    | RITA_ISLAND_12    | 2.49  |
| JN-33             | CENTRAL_PTS_J8    | 0.13  | RITA_ISLAND_PTS   | RITA_ISLAND_6     | 1.43  |
| TOWN_PTS_J2       | MAIN_LINE_1A      | 1.11  | RITA_ISLAND_6     | JN-23             | 1.73  |
| MAIN_LINE_1A      | MAIN_LINE_1       | 0.44  | IVANHOE_POINTS    | NORHAM_3          | 0.19  |
| MAIN_LINE_1       | MAIN_LINE_3       | 2.19  | NORHAM_3          | NORHAM_4          | 1.22  |
| MAIN_LINE_3       | JN-33             | 1.07  | NORHAM_4          | NORHAM_DEPOT      | 1.94  |
| Mill              | TOWN_PTS_J2       | 0.71  | NORHAM_DEPOT      | RITA_ISLAND_4     | 0.68  |
| Mill              | JN-35             | 0     | RITA_ISLAND_4     | RITA_ISLAND_PTS   | 0.67  |
| JN-37             | TOWN_3            | 1.53  | CREEK_POINTS      | IVANHOE_POINTS    | 1.9   |
| TOWN_PTS_J2       | JN-37             | 0.66  | CENTRAL_PTS_J8    | CREEK_POINTS      | 2     |
| JN-37             | LILLESMORE        | 0.36  | J/FIELD_TERM_B    | J/FIELD_TERM_A    | 0.43  |
| JN-38             | BRANDON_1         | 0.19  | JN-29             | JARVISFIELD_8C    | 0.37  |
| JARVISFIELD_8A    | JN-29             | 0.15  | IVANHOE_3         | IVAN_TERMINUS     | 0.99  |
created internally and still unexplored, and the black nodes are pruned points that appear in the CP Optimiser [4].

Metaheuristic techniques such as Simulated Annealing and Tabu Search are integrated with CP to improve the CP’s solutions [1–4]. The use of the Gantt chart has been proven as a useful tool to validate the solutions’ applicability and to evaluate the algorithms’ performance through the ACTSS Schedule Checker for Kalamia Mill. As shown in Fig. 3, the different numbers of trains are indicated by using different colours to satisfy the specific allotment for each siding during a day. The rail sections have been constructed on the vertical axis while the time of each trip had been shown on the horizontal axis. The red numbers on the graph show the number of delivered empty bins and green numbers show the number of collected full bins at each siding.
Fig. 2. Search tree of the stages for discovering four feasible solutions using DFS. a. Started discovering the first solution. b. Sector of search tree of first solution. c. First solution is discovered. d. Started discovering the second solution. e. Sector of search tree of second solution. f. Second feasible solution is discovered. g. Started discovering the third solution. h. Sector of search tree of third solution. i. Third feasible solution is discovered. j. Started discovering the fourth solution. k. Sector of search tree of fourth solution. l. Fourth feasible solution is discovered.
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Transparency document. Supporting information

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Fig. 3. A Gantt chart showing delivered and collected bins and shunting times.