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Data Article

A benchmark dataset for multi-objective flexible job shop cell scheduling

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ABSTRACT

This data article presents a description of a benchmark dataset for the multi-objective flexible job shop scheduling problem in a cellular manufacturing environment. This problem considers intercellular moves, exceptional parts, sequence-dependent family setup and intercellular transportation times, and recirculation requiring minimization of makespan and total tardiness simultaneously. It is called a flexible job shop cell scheduling problem with sequence-dependent family setup times and intercellular transportation times (FJCS-SDFSTs-ITTs) problem. The dataset has been developed to evaluate the multi-objective evolutionary algorithms of the FJCS-SDFSTs-ITTs problems that are presented in 'Evolutionary algorithms for multi-objective flexible job shop cell scheduling'. The dataset contains forty- three benchmark instances from 'small' to 'large', including a large real-world problem instance. Researchers can use the dataset to evaluate the future algorithms for the FJCS-SDFSTs- ITTs problems and compare the performance with the existing algorithms.

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Specifications Table

Subject	Management Science and Operations Research.
Specific subject area	Multi-objective flexible job shop cell scheduling.
Data format	Raw.
Type of data	Tables, Instances folder (.zip) containing csv files.
Data collection	The parameters for data collection are: the number of machines in the flexible job shop environment, the number of jobs to be scheduled, the number of operations for each job, the number of cell and machine groups assigned to each cell, the number of part family and part (job) groups assigned to part family, operations routing, the processing times and due dates of each job, transportation times between cells, and setup times between part families.
Data source location	Institution: Kütahya Dumlupınar University City/Town/Region: Kütahya Country: Turkey
Data accessibility	Public repository: Repository name: Mendeley Data Data identification number (DOI): 10.17632/rtzby7pv7m.1 Direct URL to data: https://data.mendeley.com/datasets/rtzby7pv7m/1
Related research article	D. Deliktaş, E. Özcan, O. Ustun, O. Torkul, Evolutionary algorithms for multi-objective flexible job shop cell scheduling, Applied Soft Computing (2021) 107890 [1]. https://doi.org/10.1016/j.asoc.2021.107890.

1. Value of the Data

- The dataset provides 43 different flexible job shop cell scheduling problems with sequence-dependent family setup times and intercellular transportation times (FJCS-SDFSTs-ITTs) benchmark problem instances with various characteristics as well as solutions to those instances for the use of researchers planning to conduct further research.
- This data set is the only one containing data for a highly complex job shop scheduling problem, i.e., the FJCS-SDFSTs-ITTs. Moreover, it is helpful for testing algorithms in a real-world scenario because one of the instances is based on a real industrial problem occurring at a large locomotive and wagon production factory in Turkey.
- The provided solutions to the benchmark problem instances would serve as a basis for the performance comparison of new search/optimization algorithms.
- The benchmark problem instances and their solutions will benefit the researchers from different communities interested in scheduling, multi-objective optimization and/or search/(meta)heuristic algorithm design. In addition, researchers can use these data to solve other types of flexible job shop cell scheduling problems, such as job shop cell scheduling problems and a combination of cell formation and cell scheduling problems.

2. Data Description

The dataset consists of the instance archive files. The problem instances in this folder are divided into three sub-folders (small, medium, and large) based on the number of jobs, machines, cells, and part families in the problem. In the file “Instances.zip”, the 43 files named Ins#1.csv, Ins#2.csv, ..., and Ins#43.csv can be found in Table 1. Each file contains a csv workspace with the following information:

- n is the total number of jobs.
- m is the total number of machines.
- L is the total number of part families.
- C is the total number of cells.

Table 1
Description of the files in the folder "Instances.zip".

Files named	Size
Ins.#1.csv, Ins.#2.csv,..., Ins.#12.csv	Small
Ins.#13.csv, Ins.#14.csv,..., Ins.#21.csv	Medium
Ins.#22.csv, Ins.#23.csv,..., Ins.#43.csv	Large

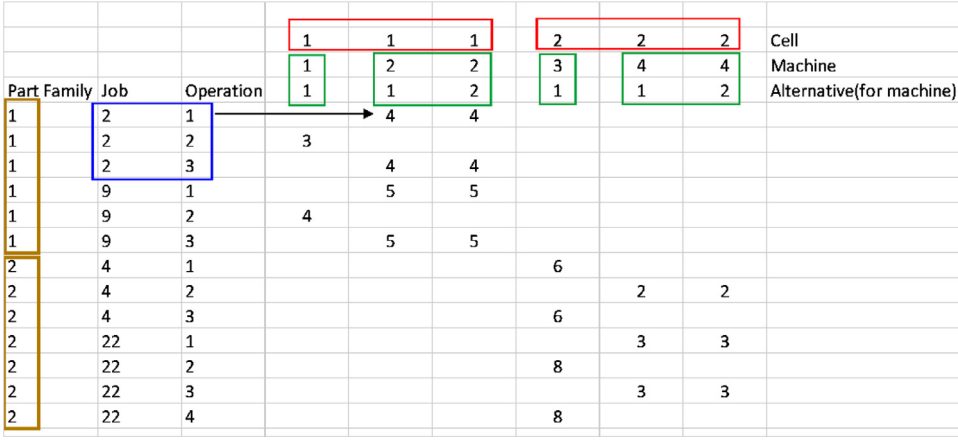

Fig. 1. Snippet from the dataset to provide an impression regarding the processing times of jobs and the cell structure of instance#1 in the Ins#1.csv file.

- opi is the total number of operations for job i.
- N_Cmax represents the nadir point of the makespan objective.
- N_TT represents the nadir point of the total tardiness objective.
- I_Cmax represents the ideal point of the makespan objective.
- I_TT represents the ideal point of the total tardiness objective.
- MaxFES represents the maximum number of fitness evaluations.

For illustration purposes of data in csv files, let's use the FJCS-SDFSTs-ITTs problem instance#1 in Ins#1.csv as an example for further explanation of our dataset. As presented in Tables 3–7 and Fig. 1, there are four parts, including jobs 2, 9, 4, and 22, and 4 machines, including machines 1, 2, 3, and 4 in instance#1. The parts are grouped into two part families, each containing two items. The yellow rectangle in Fig. 1 indicates part families and their jobs. Accordingly, Part Family 1 has jobs 2 and 9 (P_2 and P_9). In contrast, Part Family 2 includes jobs 4 and 22 (P_4 and P_{22}) (see the yellow rectangular in Fig. 1). In addition, the machines are also grouped into two cells (see the red rectangle in Fig. 1), both containing two machines. Cell 1 has machines 1 and 2 (M_1 and M_2), while Cell 2 contains machines 3 and 4 (M_3 and M_4). As seen in the green rectangle in Fig. 1, M_1 in Cell 1 has only one machine, which means that this machine does not have an alternative machine. M_2 in Cell 1 has two machines, meaning two identical parallel machines exist. Similarly, there is one machine for M_3 in Cell 2, while M_4 in Cell 2 has two identical parallel machines. As seen in Fig. 1 in the blue rectangle, the P_2 has three operations in total. For example, Fig. 1 indicates that the first operation of P_2 with the due date of 77 (see Fig. 2) belongs to the first part family, requiring a processing time of 4. Similarly, the processing times of the other operations of each part can be seen in this figure. Fig. 2 indicates the machine setup times between part families, the required transportation times for the movement of operations between cells, and the due date of each part. For example, if an operation of a part goes from the first cell to the second cell, that would require 3 units of time. Likewise, should a part P_2 operation be allocated to a machine immediately after it completes

Table 2
The characteristics of the benchmark problem instances as provided in [1] and the intervals for generating the reference points R f1 and R f2 used in the fitness functions CSM and TSM for each instance [1].

Size	Refs.	Inst.#	n/L/m/C/t_{op}	$I_{R\ f1}$	$I_{R\ f2}$	Size	Ref.	Inst.#	n/L/m/C/t_{op}	$I_{R\ f1}$	$I_{R\ f2}$
Small	[2]	1	4/2/6/2/13	[28;33]	[33;34]	Large	[3]	22	20/4/26/4/81	[30;53]	[95;170]
		2	5/2/6/2/14	[28;33]	[33;50]			23	20/5/26/5/81	[34;52]	[102;203]
	[4]	3	4/2/7/2/13	[16;27]	[11;11]		[4]	24	22/4/27/4/71	[62;77]	[172;398]
		4	8/2/7/2/27	[31;71]	[23;54]		[5]	25	21/4/26/4/86	[63;93]	[200;440]
	[6]	5	4/2/6/2/13	[27;50]	[11;24]			26	24/4/22/4/96	[51;71]	[260;494]
		6	6/2/6/2/21	[28;67]	[34;56]		[7]	27	25/5/33/5/90	[67;77]	[178;466]
		7	6/2/8/2/18	[26;49]	[33;39]			28	25/5/35/5/96	[48;68]	[159;375]
		8	7/3/7/2/25	[37;81]	[21;56]			29	26/5/38/5/87	[57;66]	[146;352]
		9	7/2/9/3/24	[29;63]	[25;38]			30	27/5/30/5/97	[67;81]	[208;502]
		10	7/3/8/3/24	[29;62]	[36;56]			31	27/5/30/5/132	[91;105]	[347;831]
		11	8/4/11/4/25	[29;74]	[38;63]			32	27/5/40/5/101	[42;59]	[173;337]
		12	9/3/9/3/30	[34;71]	[74;135]			33	27/5/40/5/101	[48;65]	[158;375]
Medium	[6]	13	10/4/11/4/33	[34;73]	[60;108]			34	27/5/29/5/104	[33;48]	[130;219]
		14	10/4/13/4/31	[31;67]	[60;91]		[5]	35	30/5/26/5/111	[48;74]	[261;519]
	[5]	15	11/3/11/3/37	[35;55]	[75;134]		[4]	36	30/5/30/5/105	[47;75]	[152;384]
	[7]	16	10/2/8/2/33	[47;55]	[85;153]			37	35/5/30/5/126	[34;68]	[149;330]
		17	12/2/8/2/38	[52;61]	[117;233]		[8]	38	30/4/25/4/113	[51;75]	[248;551]
		18	12/4/12/4/38	[35;48]	[75;125]		[5]	39	35/5/27/5/132	[51;71]	[215;500]
	[4]	19	12/3/9/3/38	[42;58]	[141;239]		[4]	40	40/6/25/6/138	[59;94]	[239;638]
	[6]	20	14/4/13/4/45	[35;77]	[84;192]			41	45/6/28/6/157	[59;92]	[313;758]
		21	15/4/16/4/48	[31;86]	[63;129]			42	50/6/30/6/175	[59;93]	[340;820]
							Case study	43	58/4/41/4/269	[1671;2181]	[1449;16595]

For each problem instance, the following information is provided: Job index, i = 1, 2,..., n; Machine index, q = 1, 2,..., m; L: The total number of part families; C: The total number of cells; op_i: The total number of operations of job i; top: The total number of all operations ($\sum_{\forall i} op_i$). Rf_1 and Rf_2 are arbitrarily fixed reference points/values from a certain interval for makespan and total tardiness in CSM and TSM.

Part Family	Part Family	Setup Time
1	1	0
1	2	3
2	1	4
2	2	0
Cell	Cell	Transportation Time
1	1	0
1	2	3
2	1	4
2	2	0
Job	Due Date	
2	77	
9	50	
4	3	
22	11	

Fig. 2. Snippet from the dataset to provide an impression regarding setup times between part families, transportation times between cells, and the due dates of instance#1 in the Ins#1.csv file.

processing an operation for a part from the second part family, the machine will necessitate a setup time of 4 units.

This data article utilised 1000 reference points, including random weights generated within the interval of [0,1]. These values for the instance#1 in the Ins#1.csv file can be seen in Fig. 3.

3. Experimental Design, Materials and Methods

Forty-three problem example sets have been considered and converted into FJCS-SDFSTs-ITT problem examples from various relevant problem domains published in the scientific literature [2–8]. The last instance represents a real-world scenario derived from a locomotive and wagon manufacturing facility. We briefly outline the adaptation process for creating the new FJCS-SDFSTs-ITTs benchmark. Table 2 presents details on the attributes of each benchmark problem instance, encompassing a spectrum of sizes from small to large. The cellular data for each problem instance is employed as documented in the respective papers, as outlined in Table 2. While certain instances already encompass cell formation, routes, processing, transportation, and setup times, we randomly generated the lacking pertinent information for the others. As an illustration, in cases where it is absent, the processing times for each operation are randomly selected as discrete values from a uniform distribution ranging between [1, 10]. Meanwhile, setup and transportation times are extracted from the interval [1,8]. The discrete due date for each task is also randomly generated within the range of [1,110]. Our real-world case study is the most extensive, comprising 58 parts, 41 machines, and four cells and part families. The benchmark solutions for all the problem instances are presented in the original paper [1]. The data utilised in this research are created in four main tables: (i) Machine groups assigned to each cell (Table 3), (ii) Part groups assigned to each part family (Table 4), (iii) Family setup times for each part family and transportation times for each cell (Tables 5), and (iv) Processing times, routing and due dates belonging to each job processed each machine (Table 6). The data used in the real-world case study are given in Table 7 [9].

Table 3
Machine groups assigned to each cell.

Inst.#	Machines in cells					
	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
1	M_1, $M_2(2)^*$	M_3, $M_4(2)$	–	–	–	–
2	M_1, $M_2(2)$	M_3, $M_4(2)$	–	–	–	–
3	M_1, $M_2(2)$	$M_3(2)$, M_4, M_6	–	–	–	–
4	M_1, $M_2(2)$	$M_3(2)$, M_4, M_6	–	–	–	–
5	M_1, $M_2(2)$	$M_3(2)$, M_4	–	–	–	–
6	M_1, $M_2(2)$	$M_3(2)$, M_4	–	–	–	–
7	M_1, $M_2(2)$, M_5	M_3, $M_4(2)$, M_6	–	–	–	–
8	$M_1(2)$, $M_2(2)$	M_3, $M_4(2)$	–	–	–	–
9	$M_1(2)$, $M_2(2)$	M_3, M_4	$M_7(2)$, M_8	–	–	–
10	M_1, $M_2(2)$	$M_3(2)$, M_4	M_7, M_8	–	–	–
11	M_1, $M_2(2)$	M_3, $M_4(2)$	$M_7(2)$, M_8	M_9, M_{10}	–	–
12	M_1, $M_2(2)$, M_5	M_3, $M_4(2)$	M_7, M_8	–	–	–
13	M_1, $M_2(2)$	M_3, $M_4(2)$	$M_7(2)$, M_8	M_9, M_{10}	–	–
14	M_1, $M_2(2)$, M_5	M_3, $M_4(2)$, M_6	$M_7(2)$, M_8	M_9, M_{10}	–	–
15	M_1, $M_2(2)$, M_5	M_3, $M_4(2)$, M_6	$M_7(2)$, M_8	–	–	–
16	M_1, $M_2(2)$, M_5	M_3, $M_4(2)$, M_6	–	–	–	–
17	$M_1(2)$, M_2, M_5	M_3, $M_4(2)$, M_6	–	–	–	–
18	M_1, $M_2(2)$, M_5	M_3, $M_4(2)$, M_6	M_7, M_8	M_9, M_{10}	–	–
19	M_1, $M_2(2)$, M_5	M_3, $M_4(2)$	M_7, M_8	–	–	–
20	M_1, $M_2(2)$, M_5	M_3, $M_4(2)$, M_6	$M_7(2)$, M_8	M_9, M_{10}	–	–
21	M_1, $M_2(2)$, M_5	M_3, $M_4(2)$, M_6	$M_7(2)$, M_8	$M_9(2)$, M_{10}, M_{11}, M_{12}	–	–
22	$M_1(3)$, M_2, M_5, M_{19}, M_{29}	M_3, M_4, M_6, $M_{20}(3)$, M_{30}, M_{31}, M_{32}	M_7, M_8, $M_{13}(3)$, M_{14}, M_{33}	M_9, M_{10}, M_{11}	–	–
23	$M_1(3)$, M_2, M_5, M_{19}, M_{29}	M_3, M_4, $M_{20}(4)$, M_{30}	M_7, M_8, M_{13}, M_{14}, M_{33}	M_6, M_{31}, M_{32}	M_{18}, M_{19}, M_{20}	–
24	M_1, $M_2(6)$, M_5	M_3, $M_4(6)$, M_6	M_7, M_8	M_9, M_{10}, $M_{11}(6)$, M_{12}	–	–
25	$M_1(5)$, M_2, M_5	M_3, $M_4(5)$, M_6	M_7, $M_8(5)$, M_{13}, M_{14}	M_9, M_{10}, M_{11}, M_{12}	–	–
26	M_1, $M_2(3)$, M_5, M_{19}	$M_3(3)$, M_4, M_6, M_{20}	M_7, $M_8(3)$, M_{13}, M_{14}	M_9, M_{10}, M_{11}, M_{12}	–	–
27	M_1, $M_2(4)$, M_5	M_3, $M_4(4)$, M_6	M_7, $M_8(4)$, M_{13}, M_{14}	$M_9(4)$, M_{10}, M_{11}, M_{12}	M_{15}, $M_{16}(4)$, M_{17}, M_{18}	–
28	M_1, $M_2(4)$, M_5, M_{19}	M_3, M_4, $M_6(4)$, M_{20}	M_7, $M_8(4)$, M_{13}, M_{14}	M_9, M_{10}, $M_{11}(4)$, M_{12}	M_{15}, M_{16}, $M_{17}(4)$, M_{18}	–
29	M_1, $M_2(7)$	M_3, $M_4(7)$	M_7, $M_8(7)$, M_{14}	M_9, $M_{10}(7)$, M_{11}	M_{15}, M_{16}, M_{17}, M_{18}	–
30	$M_1(3)$, $M_2(3)$, M_5	M_3, $M_4(3)$, M_6	M_7, $M_8(3)$, M_{13}, M_{14}	M_9, $M_{10}(3)$, M_{11}, M_{12}	M_{15}, $M_{16}(3)$, M_{17}, M_{18}	–
31	$M_1(3)$, $M_2(3)$, M_5	M_3, $M_4(3)$, M_6	M_7, $M_8(3)$, M_{13}, M_{14}	M_9, $M_{10}(3)$, M_{11}, M_{12}	M_{15}, $M_{16}(3)$, M_{17}, M_{18}	–
32	$M_1(3)$, M_2, M_5, $M_{19}(3)$	M_3, $M_4(3)$, $M_6(3)$, M_{20}	M_7, $M_8(3)$, M_{13}, $M_{14}(3)$	$M_9(3)$, M_{10}, $M_{11}(3)$, M_{12}	M_{15}, $M_{16}(3)$, $M_{17}(3)$, M_{18}	–
33	$M_1(2)$, M_2, M_5, M_{19}	M_3, M_4, $M_6(5)$, M_{20}	M_7, $M_8(6)$, M_{13}, $M_{14}(7)$	M_9, M_{10}, $M_{11}(4)$, M_{12}	M_{15}, M_{16}, $M_{17}(2)$, M_{18}	–
34	M_1, M_2, M_5, M_{19}	M_3, M_4, M_6, M_{20}	M_7, $M_8(2)$, M_{13}, M_{14}	$M_9(2)$, M_{10}, $M_{11}(3)$, $M_{12}(3)$, M_{21}	M_{15}, $M_{16}(2)$, M_{17}, M_{18}, M_{22}	–
35	M_1, M_2, $M_5(2)$, M_{19}	M_3, M_4, $M_6(2)$, M_{20}	M_7, M_8, M_{13}, $M_{14}(3)$	$M_9(3)$, M_{10}, M_{11}, M_{12}	M_{15}, M_{16}, M_{17}, M_{18}	–
36	$M_1(2)$, $M_2(3)$	M_3, $M_4(2)$	M_7, M_8, M_{13}, $M_{14}(4)$	$M_9(2)$, $M_{10}(4)$, $M_{11}(3)$, M_{12}	M_{15}, $M_{16}(2)$, M_{17}, M_{18}	–
37	$M_1(2)$, $M_2(2)$, M_5	$M_3(3)$, $M_4(3)$, M_6	M_7, $M_8(2)$, M_{13}, $M_{14}(2)$	$M_9(2)$, $M_{10}(3)$, $M_{11}(2)$, M_{12}	M_{15}, M_{16}, M_{17}, M_{18}	–

(*continued on next page*)

Table 3 (*continued*)

Inst.#	Machines in cells					
	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
38	M_1, M_2, M_5, M_{19}	$M_3(2)$, M_4, M_6, M_{20}	M_7, $M_8(2)$, M_{13}, M_{14}	$M_9(2)$, $M_{10}(3)$, $M_{11}(2)$, $M_{12}(2)$, M_{21}	–	–
39	M_1, M_2, M_5, M_{19}	M_3, M_4, $M_6(2)$, M_{20}	M_7, $M_8(3)$, M_{13}, M_{14}	M_9, M_{10}, $M_{11}(2)$, M_{12}, M_{21}	M_{15}, $M_{16}(2)$, M_{17}, M_{18}, M_{22}	–
40	$M_1(2)$, $M_2(2)$	M_3, $M_4(2)$	M_7, M_8, M_{14}	$M_9(2)$, $M_{10}(2)$, M_{11}	M_{15}, M_{16}, M_{17}, M_{18}	M_{23}, M_{24}, M_{25}, M_{26}, M_{27}, M_{28}
41	$M_1(2)$, $M_2(2)$	M_3, $M_4(2)$	M_7, $M_8(2)$, M_{13}, M_{14}	$M_9(2)$, $M_{10}(2)$, M_{11}, M_{12}	M_{15}, M_{16}, M_{17}, M_{18}	M_{23}, M_{24}, M_{25}, M_{26}, M_{27}, M_{28}
42	$M_1(2)$, $M_2(3)$, M_5, M_{19}	M_3, $M_4(2)$	M_7, M_8, M_{13}, M_{14}	$M_9(2)$, $M_{10}(2)$, M_{11}, M_{12}	M_{15}, M_{16}, M_{17}, M_{18}	M_{23}, M_{24}, M_{25}, M_{26}, M_{27}, M_{28}

∗ Value in parentheses shows that there are two identical parallel machines for machine 2 if the problem is in the flexible environment. There is no available identical machine in the job shop environment.

No	Reference_point1	Reference_point2
1	29	33
2	30	34
3	31	33
4	30	34
5	28	34
6	28	33
7	29	34
8	32	34
9	29	34
10	32	34
11	33	33
12	28	33
13	32	33
...	...	...
995	31	33
996	32	34
997	32	33
998	31	33
999	30	34
1000	33	34

Fig. 3. Snippet from the dataset to provide an initial impression regarding the reference point value of each objective of instance#1 in the Ins#1.csv file.

Table 4
Part groups assigned to each part family.

Inst.#	Parts in part families						
	Part family 1	Part family 2	Part family 3	Part family 4	Part family 5	Part family 6	Part family 7
1	P2, P9	P4, P22	–	–	–	–	–
2	P2, P9	P4, P22, P23	–	–	–	–	–
3	P2, P9	P4, P11	–	–	–	–	–
4	P1, P2, P5, P9	P4, P11, P12, P22	–	–	–	–	–
5	P1, P2	P3, P4	–	–	–	–	–
6	P1, P2, P5	P3, P4, P6	–	–	–	–	–
7	P7, P8, P9	P10, P11, P12	–	–	–	–	–
8	P1, P2, P5	P3, P4	–	–	–	–	P13, P14
9	P1, P2, P5, P9	–	P15, P16, P17	–	–	–	–
10	P1, P2, P5	P3, P4	P15, P16	–	–	–	–
11	P1, P2	P3, P4	P15, P16	P18, P19	–	–	–
12	P1, P7, P8	P3, P4, P6	P15, P16, P17	–	–	–	–
13	P1, P2, P5	P3, P4, P6	P15, P16	P18, P19	–	–	–
14	P1, P7, P8	P10, P11, P12	P15, P16	P18, P19	–	–	–
15	P2, P5, P7, P8	P10, P11, P12, P22	P15, P16, P17	–	–	–	–
16	P2, P5, P7, P8, P9	P4, P10, P11, P12, P22	–	–	–	–	–
17	P2, P5, P7, P8, P9	P4, P6, P10, P11, P12, P22, P23	–	–	–	–	–
18	P2, P7, P8	P10, P11, P12, P22	P15, P16, P17	P18, P24	–	–	–
19	P2, P5, P7, P8	P4, P6, P10, P22, P23	P15, P16, P17	–	–	–	–
20	P1, P5, P7, P9	P3, P6, P10, P11, P12	P15, P16, P17	P18, P19	–	–	–
21	P1, P2, P5, P7	P3, P6, P11, P12	P15, P16, P17	P18, P19, P20, P21	–	–	–
22	P74, P75, P76, P77, P78, P79	P80, P81, P82, P83, P84, P85, P86	P87, P88, P89, P90	P91, P92, P93	–	–	–
23	P74, P75, P76, P77, P78, P79	P80, P81, P84, P86	P87, P88, P89, P90	P82, P83, P85	P91, P92, P93	–	–
24	P1, P2, P5, P7, P8, P9	P3, P4, P6, P10, P11, P12, P22, P23	P15, P16, P17	P20, P21, P49, P90, P92	–	–	–
25	P1, P2, P5, P7, P8	P3, P4, P11, P22, P31	P25, P26, P27, P28, P29, P30	P20, P21, P49, P32, P33	–	–	–
26	P2, P8, P38, P39, P40, P44	P10, P11, P22, P31, P41, P42, P43	P25, P26, P27, P28, P29, P30	P19, P20, P21, P32, P33	–	–	–
27	P1, P2, P5, P7, P8	P3, P4, P6, P10, P11, P22	P25, P26, P28, P29, P30	P19, P20, P21, P32, P33	P34, P35, P36, P37	–	–

(*continued on next page*)

Table 4 (*continued*)

Inst.#	Parts in part families						
	Part family 1	Part family 2	Part family 3	Part family 4	Part family 5	Part family 6	Part family 7
28	P8, P38, P39, P40, P44	P12, P31, P41, P42, P43	P25, P26, P28, P29, P30	P19, P20, P21, P32, P33	P34, P35, P36, P37, P45	–	–
29	P1, P2, P5, P9	P3, P4, P6, P10, P22, P23	P15, P16, P17, P30, P47, P48	P18, P19, P24, P33, P46	P34, P35, P36, P37, P45	–	–
30	P1, P2, P5, P7, P8	P3, P4, P6, P10, P11, P22	P25, P26, P28, P29, P30, P47, P48	P19, P20, P21, P32, P33	P34, P35, P36, P37	–	–
31	P1, P2, P5, P7, P8	P3, P4, P6, P10, P11, P22	P25, P26, P28, P29, P30, P47, P48	P19, P20, P21, P32, P33	P34, P35, P36, P37	–	–
32	P8, P38, P39, P40, P44	P12, P31, P41, P42, P43	P25, P26, P28, P29, P30, P47, P48	P19, P20, P21, P32, P33	P34, P35, P36, P37, P45	–	–
33	P8, P38, P39, P40, P44	P12, P31, P41, P42, P43	P25, P26, P28, P29, P30, P47, P48	P19, P20, P21, P32, P33	P34, P35, P36, P37, P45	–	–
34	P8, P38, P39, P40	P31, P41, P42, P43	P25, P26, P29, P30	P20, P21, P32, P33, P49, P50, P51, P52	P34, P35, P36, P37, P53, P54, P55	–	–
35	P7, P8, P38, P39, P40, P44	P12, P31, P41, P42, P43	P25, P26, P28, P29, P30, P47, P48	P19, P20, P21, P32, P33, P46, P49	P34, P35, P36, P37, P45	–	–
36	P1, P2, P9, P69, P70, P71	P3, P4, P6, P10, P23	P25, P26, P28, P29, P30, P47, P48	P19, P20, P21, P32, P33, P46, P49	P34, P35, P36, P37, P45	–	–
37	P1, P2, P5, P7, P8, P9	P3, P4, P6, P10, P11, P12, P22, P58, P59	P25, P26, P28, P29, P30, P47, P48	P19, P20, P21, P32, P33, P49, P56, P57	P34, P35, P36, P37, P45	–	–
38	P2, P8, P38, P39, P40, P44	P10, P11, P22, P31, P41, P42, P43	P25, P26, P27, P28, P29, P30	P19, P20, P21, P32, P33, P49, P50, P51, P52, P56, P57	–	–	–
39	P5, P7, P8, P38, P39, P40, P44	P31, P41, P42, P43, P58, P59	P25, P26, P27, P28, P29, P30, P48	P20, P21, P32, P33, P49, P50, P51, P52	P34, P35, P36, P37, P53, P54, P55	–	–
40	P1, P2, P5, P9, P69, P70, P71, P72	P3, P4, P6, P10, P22, P23, P73	P15, P16, P17, P30, P47, P48	P18, P19, P24, P33, P46, P67, P68	P34, P35, P36, P37, P45	P60, P61, P62, P63, P64, P65, P66	–
41	P1, P2, P5, P9, P69, P70, P71, P72	P3, P4, P6, P10, P22, P23, P73	P15, P16, P17, P27, P28, P29, P30, P_{47}, P_{48}	P18, P20, P21, P24, P32, P33, P49, P67, P68	P34, P35, P36, P37, P45	P60, P61, P62, P63, P64, P65, P66	–
42	P1, P2, P5, P7, P8, P9, P38, P40, P44, P69, P70, P71, P72	P3, P4, P6, P10, P22, P23, P73	P15, P16, P17, P27, P28, P29, P30, P_{47}, P_{48}	P18, P20, P21, P24, P32, P33, P49, P67, P68	P34, P35, P36, P37, P45	P60, P61, P62, P63, P64, P65, P66	–

Table 5
Family setup times for each part family and transportation times for each cell.

Transportation times ($t_{cc'}$)							Setup times ($s_{ll'}$)							
c\c'	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6		Part family1	Part family2	Part family3	Part family4	Part family5	Part family6	Part family7
Cell 1	–	3	5	4	8	5	Part family1	–	3	7	4	5	6	5
Cell 2	4	–	8	5	4	4	Part family2	4	–	4	2	8	4	8
Cell 3	6	5	–	3	3	7	Part family3	6	5	–	5	4	5	4
Cell 4	5	4	3	–	2	6	Part family4	7	5	2	–	3	3	3
Cell 5	7	5	7	2	–	5	Part family5	5	3	5	3	–	5	6
Cell 6	6	4	6	8	5	–	Part family6	6	8	7	5	8	–	8
							Part family7	6	5	6	6	8	3	–

$T_{cc'}$: Transportation time from cell c to cell c', $s_{ll'}$: Setup time for part family l' if processed immediately after part family l.

Table 6
Processing times, routing and due dates belonging to each job processed each machine.

Machines	Parts										
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}
M_1	4	3	–	–	6	1	6	3	4	–	–
M_2	5	4	7	–	2	–	–	9	5	7	–
M_3	6	–	2	6	–	5	–	–	–	9	5
M_4	–	–	4	2	3	7	5	–	–	3	–
M_5	–	–	–	–	–	–	5	4	–	–	–
M_6	–	–	–	–	–	–	–	–	–	–	3
Route (Except Ins#31)	1-2-3-2[a]	2-1-2[a]	4-2-3[a]	3-4-3	4-2-1-4[a]	1-4-3-1	4-1-5[a]	1-2-5	2-1-2	3-2-4	6-3-6-3[b]
Route for Ins#31*	1-2-3-2-3-1	2-1-2-1-2	4-2-3-2-4	3-4-3-4-3	4-2-1-4-1-4	1-4-3-1-4-1	4-1-5-4-1	1-2-5-1-2	–	3-2-4-2-4	6-3-6-3-6-3
Due dates	98	77	75	3	48	2	5	110	50	8	53
Machines	Parts										
	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}	P_{20}	P_{21}	P_{22}
M_1	–	4	5	–	–	–	–	–	–	–	–
M_2	–	3	1	–	2	–	–	–	–	–	–
M_3	–	2	4	–	–	–	–	–	–	–	8
M_4	4	3	1	1	–	1	–	–	–	–	3
M_6	5	–	–	–	–	–	–	–	–	–	–
M_7	–	–	–	4	5	1	–	6	–	–	–
M_8	–	–	–	2	3	2	–	–	–	–	–
M_9	–	–	–	–	–	–	4	3	–	4	–
M_{10}	–	–	–	–	–	–	6	2	8	–	–
M_{11}	–	–	–	–	–	–	–	–	5	5	–
M_{12}	–	–	–	–	–	–	–	–	7	3	–
Route (Except Ins#31)	4-6-4	2-3-4-1	4-3-1-2	8-7-4	7-2-8-2	4-7-8	10-9	9-7-10[c]	11-10-12[c,d]	12-9-11[c]	4-3-4-3
Route for Ins#31*	–	–	–	–	–	–	–	9-7-10	11-10-12-10	12-9-11-9	4-3-4-3
Due dates	21	82	23	103	4	13	67	15	28	43	11

(*continued on next page*)

Table 6 (*continued*)

Machines	Parts										
	P_{23}	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}	P_{29}	P_{30}	P_{31}	P_{32}	P_{33}
M_3	–	–	–	–	–	–	–	–	5	–	–
M_4	7	–	–	–	–	–	–	–	9	–	–
M_6	–	–	–	–	–	–	–	–	6	–	–
M_7	–	–	–	2	8	–	5	5	–	–	–
M_8	–	–	4	5	–	2	6	3	4	–	–
M_9	–	7	–	–	–	–	–	–	–	5	6
M_{10}	–	4	–	–	–	–	–	–	–	7	5
M_{11}	–	–	–	–	–	–	–	–	–	2	3
M_{12}	–	–	–	–	–	–	–	–	–	6	–
M_{13}	–	–	6	7	5	9	7	–	–	–	–
M_{14}	–	–	9	4	3	3	4	6	–	–	–
Route (Except Ins#31)	4	9-10-9	13-8-14-8	14-8-13-7	7-14-13	8-14-13-14[a]	8-13-14-7	14-8-7-8	8-4-3-6[a]	10-12-9-11	11-9-10-9
Route for Ins#31*	–	–	13-8-14-8-14-8	14-8-13-7	–	8-14-13-14-8-14	8-13-14-7	14-8-7-8-14	–	10-12-9-11-10	11-9-10-9-10
Due dates	5e	89	29	22	14	3	8	18	7	62	15

Machines	Parts										
	P_{34}	P_{35}	P_{36}	P_{37}	P_{38}	P_{39}	P_{40}	P_{41}	P_{42}	P_{43}	P_{44}
M_1	–	–	–	–	–	4	5	–	–	–	5
M_2	–	–	–	–	2	5	2	–	–	–	–
M_3	–	–	–	–	–	–	–	–	4	8	–
M_4	–	–	–	–	–	–	–	1	8	–	–
M_5	–	–	–	–	4	–	–	–	–	–	3
M_6	–	–	–	–	–	–	–	8	3	4	–
M_{13}	–	–	–	–	–	–	–	–	–	–	4
M_{15}	6	–	4	5	–	–	–	–	–	–	–
M_{16}	2	5	6	1	–	–	–	–	–	–	–
M_{17}	1	3	2	3	–	–	–	–	–	–	–
M_{18}	3	7	–	6	–	–	–	–	–	–	–
M_{19}	–	–	–	–	3	5	7	–	–	–	1
M_{20}	–	–	–	–	–	2	–	7	7	2	–
Route (Except Ins#31)	16-15-18-17	17-16-18[d]	16-17-16-15	15-17-16-18	19-5-2-5	20-19-1-2[c]	2-19-1-19	6-4-6-20	3-20-4-6	20-3-6-3	5-13-19-1
Route for Ins#31*	16-15-18-17-16	17-16-18-16	16-17-16-15-16	15-17-16-18-16-17	–	–	–	–	–	–	–
Due dates	52	17	42	61	47	2	106	5	25	6	74

(*continued on next page*)

Table 6 (*continued*)

Machines	Parts										
	P_{45}	P_{46}	P_{47}	P_{48}	P_{49}	P_{50}	P_{51}	P_{52}	P_{53}	P_{54}	P_{55}
M_7	–	–	–	4	–	–	–	–	–	–	–
M_8	–	–	8	1	–	–	–	–	–	–	–
M_9	–	–	–	–	8	–	–	7	–	–	–
M_{10}	–	7	3	–	1	2	5	–	–	–	–
M_{11}	4	2	–	–	3	4	–	8	–	–	–
M_{12}	–	–	–	–	2	3	6	3	–	–	–
M_{14}	–	–	7	3	–	–	–	–	–	–	–
M_{15}	2	–	–	–	–	–	–	–	–	3	4
M_{16}	–	3	–	–	–	–	–	–	7	2	–
M_{17}	6	–	–	–	–	–	–	–	5	–	8
M_{18}	8	–	–	–	–	–	–	–	–	2	–
M_{21}	–	–	–	–	–	1	9	4	–	–	–
M_{22}	–	–	–	–	–	–	–	–	4	8	3
Route (Except Ins#31)	15-11-18-17	16-10-11	10-8-14-10	8-7-14	10-9-12-11	21-10-12-11	12-21-10-21	12-9-21-11	17-22-16-22	22-16-18-15	15-22-17-15
Route for Ins#31*	–	–	10-8-14-10	8-7-14	–	–	–	–	–	–	–
Due dates	29	46	30	21	9	29	41	16	91	35	43

Machines	Parts										
	P_{56}	P_{57}	P_{58}	P_{59}	P_{60}	P_{61}	P_{62}	P_{63}	P_{64}	P_{65}	P_{66}
M_3	–	–	2	2	–	–	–	–	–	–	–
M_4	–	–	8	7	–	–	–	–	–	–	–
M_6	–	–	3	9	–	–	–	–	–	–	–
M_{10}	7	5	–	–	–	–	–	–	–	–	–
M_{11}	2	1	–	–	–	–	–	–	–	–	–
M_{12}	–	3	–	–	–	–	–	–	–	–	–
M_{13}	1	–	–	–	–	–	–	–	–	–	–
M_{19}	5	–	–	–	–	–	–	–	–	–	–
M_{23}	–	–	–	–	–	4	–	1	3	–	7
M_{24}	–	–	–	–	5	8	–	9	7	7	–
M_{25}	–	–	–	–	4	–	4	6	–	2	9
M_{26}	–	–	–	–	8	7	5	–	–	4	4
M_{27}	–	–	–	–	6	–	1	3	5	–	8
M_{28}	–	–	–	–	–	9	3	–	8	–	–
Route	13-11-9-10	11-10-12-10	4-6-3-6	6-4-3	25-27-24-26	23-26-28-24	26-28-25-27	27-24-23-25	24-27-28-23	25-26-24	26-23-25-27
Due dates	84	34	74	65	12	57	71	102	8	13	27

(*continued on next page*)

Table 6 (*continued*)

Machines	Parts										
	P_{67}	P_{68}	P_{69}	P_{70}	P_{71}	P_{72}	P_{73}	P_{74}	P_{75}	P_{76}	P_{77}
M_1	–	–	3	4	8	9	–	2	4	5	3
M_2	–	–	5	7	1	8	–	3	2	1	–
M_3	–	–	–	–	–	–	2	–	–	–	4
M_4	–	–	–	–	–	–	5	–	–	–	–
M_5	–	–	–	–	–	–	–	–	–	–	2
M_6	–	–	–	–	–	–	–	–	–	3	–
M_8	–	–	–	–	3	–	–	–	–	–	–
M_9	5	7	–	–	–	2	–	–	–	–	1
M_{10}	4	8	–	–	–	–	–	–	–	–	–
M_{11}	3	1	–	–	–	–	–	5	–	–	–
M_{19}	–	–	–	–	–	–	–	1	5	4	–
M_{20}	–	–	–	–	–	–	–	–	3	–	–
M_{29}	–	–	–	–	–	–	–	4	1	2	–
Route											
Due dates											

Machines	Parts										
	P_{78}	P_{79}	P_{80}	P_{81}	P_{82}	P_{83}	P_{84}	P_{85}	P_{86}	P_{87}	P_{88}
M_1	2	3	–	–	–	–	–	–	–	–	–
M_2	1	–	–	–	–	–	–	–	–	–	4
M_3	–	–	3	3	–	–	–	–	2	–	–
M_4	–	–	2	1	–	–	3	–	1	–	–
M_5	–	2	–	4	–	–	–	–	–	–	–
M_6	–	–	–	–	5	1	–	–	4	–	–
M_7	–	–	–	–	–	–	–	–	–	1	5
M_8	–	–	–	–	–	–	–	–	–	3	–
M_{13}	–	–	–	–	–	–	–	–	–	4	3
M_{14}	–	–	–	–	–	–	–	1	–	–	2
M_{19}	3	4	–	–	–	–	–	–	–	–	–
M_{20}	–	–	1	2	1	–	1	–	3	–	–
M_{29}	–	1	–	–	–	–	–	–	–	–	–
M_{30}	–	–	–	–	2	–	2	2	–	–	–
M_{31}	–	–	–	–	3	2	–	3	–	–	–
M_{32}	–	–	–	–	4	3	–	4	–	–	–
M_{33}	–	–	–	–	–	–	–	–	–	2	1
Route	19-1-2-1	5-1-29-19	4-3-20	20-5-4-3	20-6-32-31-30	31-6-32-6	4-30-20	14-30-32-31	6-3-4-20	8-13-7-33	14-2-33-13-7
Due dates	74	28	21	25	58	77	12	5	89	14	17

(*continued on next page*)

Table 6 (*continued*)

Machines	Parts				
	P_{89}	P_{90}	P_{91}	P_{92}	P_{93}
M_5	–	–	–	–	4
M_8	1	3	–	–	–
M_9	–	–	1	3	1
M_{10}	–	4	3	1	2
M_{11}	–	–	2	2	3
M_{13}	2	2	–	–	–7y
9					
M_{32}	4	–	–	–	–
M_{33}	3	1	–	–	–
Route	13-32-8-33	33-10-13-8	10-9-11	9-10-11	10-5-9-11
Due dates	13	19	9	78	2

∗ Route belonging to each part (job) of the Ins#31 is completely different from that of the other instances. Therefore, the route of the Ins#31 is given in a separate row instead of being shown with a superscript for a different route. P: Part; M: Machine

[a] : Routes used in Ins#25: Route 1 – 2 – 3 – 2 – 1 – 3 for P1, Route 2 – 1 – 2 – 1 for P2, Route 4 – 2 – 3 – 2 – 4 for P3, Route 4 – 2 – 1 – 4 – 1 for P5, Route 4 – 1 – 5 – 4 – 1 for P7, Route 8 – 14 – 13 – 14 – 8 for P28, and Route 8 – 4 – 3 – 6 – 8 – 4 for P31.

[b] : Route 6 3 6 is used in Inst#4, #7, #20, #21, and #25.

[c] : Routes used in Ins#26: Route 9 7 10 7 10 for P19, Route 11 10 12 10 11 for P20, Route 12 9 11 12 11 for P21, and Route 20 19 1 2 20 for P39.

[d] : Routes used in Ins#28: Route 11 10 12 11 for P20 and Route 17 16 18 17 for P35.

[e] : Due-date for Ins#2 is used as 8.

Table 7
Part-machine matrix, processing times, routing, family setup times for each part family, and transportation times for each cell of the real-world case study (Ins#43).

		Cell 1					Cell 2		Cell 3			Cell 4			
		M6(4)	M9	M10	M11(2)	M12	M5(2)	M7(7)	M2(7)	M1(6)	M3(2)	M4(4)	M8(4)	Routing	Due Dates
Part family 1	P_{38}	–	1.30	2.28	–	–	0.15	–	–	–	–	1.13	3.10/ 6.15*	5-**8**-10-**8**-9-4	1434.5
	P_4	–	3.00	–	–	–	1.15	9.38	–	5.25	–	3.00	–	5-7-1-9-4	1182.3
	P_5	–	1.50	–	–	–	1.31	5.06	–	–	–	–	–	5-7-9	1283.2
	P_6	–	1.50	–	–	–	1.31	5.06	–	–	–	–	–	5-7-9	243.1
	P_7	–	0.56	–	–	–	0.19	3.38	–	–	–	–	–	5-7-9	326.1
	P_9	–	2.25	–	–	–	1.15	4.15	–	4.50	–	4.50	–	5-7-1-9-4	586.0
	P_{12}	–	–	–	–	–	0.09	–	–	–	–	–	4.15	5-8	15.0
	P_{17}	–	–	–	–	–	3.38	–	–	–	–	–	30.00	5-8	794.9
	P_{19}	–	–	–	–	–	3.00	–	–	–	–	–	7.13	5-8	962.6
	P_{20}	–	–	–	–	–	0.38	–	–	–	–	–	13.50	5-8	894.0
	P_{21}	–	–	–	–	–	0.28	11.25	–	–	–	–	–	5-7	340.4
	P_{22}	–	–	–	–	–	0.23	9.35	–	7.15	–	3.00	–	5-7-1-4	559.1
	P_{28}	–	–	–	–	–	0.47	9.38	23.28	–	–	–	–	5-7-2	1171.6
Part family 2	P_{31}	–	–	–	–	–	1.34	18.56	18.21	–	–	0.56	–	5-4-7-2	1137.2
	P_{32}	–	–	1.04	–	–	0.21	–	–	–	–	–	–	5-10	586.0
	P_{33}	–	–	–	–	–	1.34	18.56	18.21	–	–	0.56	–	5-4-7-2	570.8
	P_{34}	–	–	3.00	–	–	0.56	–	–	–	–	–	–	5-10	1511.5
	P_{37}	–	–	–	–	–	0.38	–	–	–	–	–	7.15	5-8	903.5
	P_{40}	–	–	–	–	–	1.15	–	–	–	–	–	34.15	5-8	1336.8

(*continued on next page*)

Table 7 (*continued*)

		Cell 1					Cell 2		Cell 3			Cell 4			
		M6(4)	M9	M10	M11(2)	M12	M5(2)	M7(7)	M2(7)	M1(6)	M3(2)	M4(4)	M8(4)	Routing	Due Dates
	P_{42}	–	–	1.50	–	–	0.38	–	–	–	–	3.38	–	5-10-4	254.7
	P_{44}	–	–	–	–	–	1.15	71.28/ 7.15	11.25/ 8.28	7.50/ 14.06	–	3.00/ 12.56/ 2.28/1.15/ 4.15	–	5-**7**-**4**-**1**-**4**-**2**-**1**-**4**-**7**-**4**-**2**-**4**	1573.9
	P_{50}	–	1.50	–	–	–	0.50	9.00	–	–	–	1.50	–	5-7-4-9	194.5
	P_{53}	–	–	–	–	–	36.00	–	–	–	–	–	54.00	5-8	1620.0
	P_{54}	–	–	–	–	–	24.00	–	–	–	–	–	54.00	5-8	749.9
	P_{55}	–	–	–	–	–	9.00	–	–	–	–	–	–	5	1552.9
	P_{57}	–	–	–	–	–	36.00	–	–	–	–	–	129.00	5-8	1180.1
	P_{10}	8.44	–	–	–	–	0.09	–	1.50	–	–	2.06	2.06	5-8-2-6-4	828.6
	P_{23}	–	–	–	–	–	–	–	7.50	–	–	–	46.15/ 6.00	**8**-2-**8**	1555.1
	P_{24}	–	–	1.34	–	–	–	–	–	–	–	–	–	10	568.4
	P_{25}	–	–	–	–	–	0.38	–	2.39	–	–	3/1.13	16.31/ 3.38/ 7.50	5-**8**-**4**-**8**-2-**8**-**4**	1225.7
Part family 3	P_{26}	180.00	–	–	–	–	–	157.15	79.50	–	77.28	15/20 1.38	–	7-**4**-6-3-**4**-2	1565.0
	P_{35}	–	–	–	–	–	–	–	0.56	–	–	–	3.21	8-2	936.3
	P_{36}	–	–	–	–	–	1.15	–	23.44	–	–	–	32.06/ 3.38	5-**8**-2-**8**	1190.5
	P_{43}	–	2.28	–	–	–	0.38	–	4.50	6.03	–	–	7.50	5-8-1-9-2	736.4
	P_{49}	–	–	–	–	–	3.00	–	9.00	–	–	6.00	9.00	5-8-2-4	162.5

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Table 7 (*continued*)

		Cell 1					Cell 2		Cell 3			Cell 4			
		M6(4)	M9	M10	M11(2)	M12	M5(2)	M7(7)	M2(7)	M1(6)	M3(2)	M4(4)	M8(4)	Routing	Due Dates
	P_1	–	–	–	–	–	–	–	9.00 /4.13	5.28 /26.25	34.15 /27.00	4.50/ 3.38	–	**1-2-1-2-3-4-3-4**	836.8
	P_2	–	–	–	–	–	1.15	–	–	–	3.38	–	32.09	5-8-3	1073.1
	P_3	–	–	–	–	–	–	–	–	72.38	10.13	9.00	–	4-3-1	210.9
	P8	–	–	–	–	–	0.14	–	–	2.37	–	0.28/ 3.23	0.14/ 4.38/ 2.48	5-**8**-1-**4-8-4-8**	1172.0
	P_{11}	–	–	–	–	–	0.18	–	–	3.45	–	2.04	10.18	5-8-1-4	1473.7
	P_{13}	–	–	–	–	–	–	–	–	–	–	2.02/ 2.48	11.18 /8.37	**8-4-8-4**	225.6
	P_{14}	–	–	–	–	–	0.19	–	–	2.09	–	0.19/ 2.53	0.19/ 3.38/ 2.09	5-**8**-1-**4-8-4-8**	24.3
	P_{15}	–	1.13	–	–	–	0.19	–	–	3.38	–	2.09	7.15	5-8-1-9-4	262.9
	P_{16}	–	1.15	–	–	–	1.15	–	–	4.50	–	2.28	9.00	5-8-1-4-9	152.4
	P_{18}	–	–	–	–	10.13	–	–	54.21	37.50	5.06	–	56.25	12-8-3-2-1	864.2
	P_{27}	–	–	–	–	–	–	–	–	–	6.38/ 7.15	–	17.28	**3**-8-**3**	1374.9
Part family 4	P_{29}	–	–	–	–	–	–	–	37.50	25.15/ 28.13	30.00/ 60.00	6.38/ 6.38/ 10.13/ 12.00	22.50/ 10.15	**4-1-8-3-8-1-4-3-4**-2-**4**	1620.2
	P_{30}	–	–	–	–	–	–	–	37.51	25.15 /28.14	30.00/ 60.01	6.38/ 6.38/ 10.13/ 12.01	22.50/ 10.16	**4-1-8-3-8-1-4-3-4**-2-**4**	254.7
	P_{39}	–	1.24	–	–	–	1.24	–	–	5.09	–	1.24	17.53	5-8-1-9-4	1195.1

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Table 7 (*continued*)

	Cell 1					Cell 2		Cell 3			Cell 4			
	M6(4)	M9	M10	M11(2)	M12	M5(2)	M7(7)	M2(7)	M1(6)	M3(2)	M4(4)	M8(4)	Routing	Due Dates
P_{41}	–	–	–	–	–	2.25	–	–	–	–	3.38/ 2.25	17.28	5-**4**-8-**4**	1665.4
P_{45}	–	1.13	–	–	–	0.19	–	–	4.15	–	2.28	8.28/ 3.38	5-**8**-1-9-**8**-4	1616.0
P_{46}	–	–	–	60.00	–	6.00/30.00	–	216.00	144.00/ 18.00	18.00	78.00/ 12.00/ 6.00	12.00/ 216.00	**5**-**8**-**5**-**8**-**1**-**4**-11-**1**-3-**4**-2-**4**	1615.2
P_{47}	–	–	–	–	–	6.00/30.00	–	216.00	600.00/ 9.00	18.00/ 54.00	6.00/ 72.00	12.00/ 216.00/ 120.00/ 180.00/ 30.00	**5**-**8**-**5**-**8**-**1**-**8**-**3**-**4**-**8**-2-**8**-**3**-**4**-**1**	1306.9
P_{48}	–	–	–	–	–	–	–	15.00	9.00	12.00/ 3.00	6.00	6.00/ 60.00	**8**-**3**-**8**-**3**-2-1-4	326.4
P_{51}	–	–	–	–	–	30.00	–	–	–	240.00	–	24.00 /84.00	5-**8**-3-**8**	1440.6
P_{52}	–	–	–	–	–	18.00	–	–	–	4.50	3.00	–	5-3-4	924.6
P_{56}	–	–	–	–	–	108.00	–	258.00	–	120.00	30.00	252.00/ 54.00/ 54.00	5-**8**-3-4-**8**-2-**8**	552.2
P_{58}	–	–	–	–	–	108.00	162.00	516.00	60.00 /60.00	54.00	48.00/ 186.00/ 30.00	180.00	5-7-3-**4**-**1**-**4**-8-1-2-**4**	1578.5

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Table 7 (*continued*)

c\c'	Cell 1	Cell 2	Cell 3	Cell 4	l\l'	Part family1	Part family2	Part family3	Part family4
Cell 1	–	12.14	18.19	21.25	Part family1	–	35.45	65.25	49.50
Cell 2	25.50	–	10.20	21.30	Part family2	75.35	–	45.45	25.47
Cell 3	9.53	16.45	–	25.26	Part family3	65.33	58.45	–	35.25
Cell 4	24.31	15.15	19.25	–	Part family4	79.26	55.33	25.45	–

* This job is the reentrant part that visits machine 8 twice requiring different processing times as 3.10 and 6.15 minutes. Bold entries in routing highlight the machine indices for the reentrant parts. All times are in minutes for this real-world case study.

Limitations

Not applicable.

Ethics Statement

The authors have read and follow the ⟨13:italic ⟩ethical requirements⟨/13:italic⟩ for publication in Data in Brief and confirm that the current work does not involve human subjects, animal experiments, or any data collected from social media platforms.

Data Availability

A benchmark dataset for multi-objective flexible job shop cell scheduling (Original data) (Mendeley Data).

CRediT Author Statement

Derya Deliktaş: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Project administration, Visualization; **Ender Özcan:** Writing – review & editing, Formal analysis, Resources, Supervision; **Ozden Ustun:** Methodology, Formal analysis, Writing – review & editing; **Orhan Torkul:** Conceptualization.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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