Scientia Iranica

Supplementary Materials

An Integrated Quay Crane Assignment and Scheduling Problem with Several Contractors in Container Terminals

Mojgan Safaeian, Farhad Etebari*, Behnam Vahdani

Department of Industrial Engineering, Faculty of Industrial and Mechanical Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran

* Corresponding author: F. Etebari (featebari@gmail.com)

Table S.1

Parameters of random instances in small size.

No.	Problem Information												
	M	J_m	Q	I_q	μ_q	D_m	R_m	R'_m	C	C'	I_m	C''_{qm}	ω_{jm}
1	3	(4 3 4)	5	(3 2 3 2 3)	(15 14 13 15 16)	(5 7 6)	(5 6 6)	(4 3 5)	7	4	(12 14 11)	11 11 5 7 5 4 8 7 11 7 6 9 5 9 4	22 35 18 20 30 25 17 15 25 14 23 30
2	3	(3 3 3)	4	(3 2 3 3)	(11 12 12 13)	(3 3 4)	(8 8 5)	(3 4 3)	5	3	(12 8 15)	3 7 5 7 3 4 7 5 11 8 6 10	32 5 28 17 31 15 22 25 45
3	4	(2 3 2 3)	5	(2 2 4 3 4)	(10 11 11 14 9)	(2 3 4 3)	(5 6 6 5)	(3 3 4 3)	6	4	(17 20 10 15)	4 9 7 7 9 5 6 6 5 6 8 11 6 4 9 9 5 9 4 8	12 25 18 22 20 30 25 17 17 15 25 35
4	2	(4 5)	3	(4 3 4)	(15 14 12)	(3 3)	(6 5)	(4 3)	5	3	(20 10)	1 9 4 3 7 4	12 21 20 25 17 15 18 22 25 22
5	3	(4 3 3)	5	(3 2 2 3 3)	(12 16 17 15 15)	(2 2 4)	(6 5 6)	(4 3 4)	5	4	(21 12 15)	7 9 6 5 7 8 11 9 11 8 5 9 9 7 10	16 13 15 22 28 26 16 15 21 25 9 27
6	3	(2 3 3)	5	(2 3 4 3 4)	(12 11 13 11 9)	(2 4 3)	(5 5 6)	(4 3 4)	6	1	(16 16 12)	7 9 8 7 7 8 7 9 6 8 5 9 9 7 6	30 33 22 12 28 16 24 11 31

Table S.1

Continued

No.	Problem Information											
	M	J_m	Q	I_q	μ_q	D_m	R_m	R'_m	C	C'	I_m	C''_{qm}	ω_{jm}
7	3	(3 3 3)	3	(2 4 3)	(11 8 9)	(3 3 2)	(5 5 6)	(2 3 3)	4	3	(12 13 11)	7 9 8 7 7 8 7 9 7	36 43 35 42 38 46 46 45 31
8	3	(4 4 4)	3	(3 3 4)	(8 10 9)	(3 2 3)	(5 5 6)	(4 3 3)	6	2	(20 10 30)	7 9 8 7 9 11 9 11 10	32 28 46 26 49 39 45 35 31 23 31 41
9	3	(3 3 3)	4	(3 3 4 4)	(11 16 14 12)	(3 3 2)	(5 5 6)	(4 3 4)	5	1	(16 11 23)	7 9 8 7 7 8 7 9 11 8 5 9	32 28 16 16 25 11 15 15 27
10	3	(4 4 3)	4	(4 3 2 4)	(11 12 13 12)	(3 3 3)	(5 5 5)	(4 3 4)	6	2	(16 13 15)	7 9 8 7 7 8 7 9 11 9 11 10	20 23 25 32 28 36 16 25 11 25 15 27
11	3	(4 4 3)	4	(3 5 2 5)	(14 16 15 14)	(3 4 2)	(5 6 6)	(2 3 3)	6	3	(15 16 11)	7 5 8 7 7 7 8 5 8 9 6 10	9 5 35 32 8 16 16 35 9 25 15 21
12	4	(3 5 4 2)	5	(5 3 4 5 4)	(12 14 11 10 11)	(4 3 3 2)	(6 6 7 5)	(3 3 4 2)	7	3	(19 16 14 17)	8 6 7 5 7 9 4 6 7 8 5 6 3 6 4 8 6 5 8 4	23 17 9 11 12 20 19 18 8 24 22 10 17 30 28 16 15 19 22 12
13	3	(4 5 4)	6	(4 5 3 4 4 5)	(10 11 12 10 12 12)	(2 3 4)	(3 5 4)	(2 3 4)	4	4	(15 14 11)	5 9 8 6 7 7 7 9 12 8 8 11 6 7 10 9 8 9	24 8 15 12 14 24 9 21 11 17 15 17 18 19 22

Table S.1

Continued

No.	Problem Information												
	M	J_m	Q	I_q	μ_q	D_m	R_m	R'_m	C	C'	I_m	C''_{qm}	ω_{jm}
14	6	(4 5 3 5 3 4)	6	(4 4 5 3 5 4)	(11 14 12 13 13 12)	(4 5 4 4 3 2)	(6 6 5 6 4 5)	(3 2 2 3 3 2)	7	3	(10 21 23 14 12 17)	5 9 9 8 6 7 6 6 9 5 6 4 8 9 8 7 8 5 7 8 6 5 7 4 6 8 5 7 4 7 5 7 6 5 6 6	20 33 35 36 25 14 32 18 16 18 34 32 16 25 8 32 18 23 15 11 27 28 17 21 9 24 14 11 21 16
15	4	(4 5 5 3)	6	(5 5 4 5 3 4)	(12 11 10 11 10 11)	(3 3 2 4)	(6 7 5 6)	(3 4 3 3)	3	4	(11 9 14 10)	9 9 5 8 7 6 4 6 7 6 7 5 6 7 5 6 8 6 7 5 6 4 5 7	20 23 24 27 18 16 28 26 26 21 26 29 25 24 24 28 19 26 25 27
16	6	(5 3 4 5 5 4)	6	(5 4 5 3 3 5)	(10 12 11 13 13 11)	(4 4 5 3 4 5)	(7 8 6 7 6 6)	(4 4 3 4 3 3)	6	4	(12 16 15 10 9 13)	8 5 6 7 4 7 5 6 7 6 4 6 9 7 8 9 8 7 9 9 8 7 8 9 5 9 8 6 7 8 8 4 6 5 7 6	33 23 18 32 16 29 23 37 16 24 32 18 19 16 32 17 27 31 22 28 36 19 10 21 20 16 23 19 11 22
17	4	(3 3 5 2)	5	(4 4 5 3 4)	(15 13 14 12 14)	(3 3 4 3)	(7 8 6 8)	(4 4 3 4)	8	5	(11 16 14 18)	9 5 7 6 7 4 6 5 8 3 6 4 7 4 9 5 5 6 4 8	12 24 14 22 24 12 9 23 26 20 25 26 15 19 20 10 19 27 21 16
18	2	(4 5)	4	(5 3 4 4)	(10 9 11 9)	(5 4)	(6 5)	(3 3)	3	5	(14 10)	7 5 6 6 8 7 8 7	22 19 11 29 35 42 24 31 36 13
19	4	(4 3 4 2)	4	(4 5 4 5)	(10 9 10 8)	(3 5 4 2)	(8 8 7 5)	(4 5 4 3)	5	5	(19 11 13 15)	9 12 9 8 8 7 9 11 7 9 9 7 6 5 9 8	20 33 39 33 32 28 36 42 26 25 31 23 35 35 17 11

Table S.1

Continued

No.	Problem Information												
	M	J_m	Q	I_q	μ_q	D_m	R_m	R'_m	C	C'	I_m	C''_{qm}	ω_{jm}
20	4	(4 4 3 4)	4	(3 3 2 4)	(9 9 10 9)	(3 4 3 2)	(3 3 5 4)	(2 2 3 2)	7	5	(12 17 23 16)	8 11 8 11 5 9 8 9 8 9 10 5 6 5 7 9	25 33 35 24 36 28 36 37 29 38 36 38 30 35 37 31
21	2	(3 5)	3	(5 3 4)	(10 11 12)	(2 2)	(7 6)	(3 3)	3	4	(14 12)	8 9 9 11 9 7	24 33 29 22 32 28 21 25 25 19
22	4	(4 4 5 3)	6	(4 3 4 5 4 5)	(14 13 12 13 12 13)	(2 3 4 4)	(5 5 6 5)	(3 2 3 3)	2	3	(15 12 10 13)	8 7 7 6 9 5 6 5 8 6 7 5 7 8 5 6 6 5 7 8 5 7 6 4	20 33 34 27 38 16 28 36 26 21 26 29 25 29 24 28 19 26 28 27
23	5	(4 5 4 5 3)	6	(4 5 3 4 5 4)	(12 13 12 13 13 11)	(4 3 3 2 3)	(5 6 6 6 4)	(4 3 3 3 2)	4	6	(13 11 12 13 11)	11 8 9 10 11 9 7 8 9 9 8 8 7 6 8 7 8 6 8 5 7 6 9 8 7 9 5 7 6 8	20 13 34 23 30 22 28 11 27 16 12 15 27 26 32 15 13 32 29 19 15 26 11 16 24
24	5	(3 5 2 3 4)	6	(4 5 5 4 4 5)	(12 14 15 16 14 14)	(4 3 3 2 3)	(6 7 6 6 7)	(3 4 3 3 4)	3	8	(13 11 12 13 11)	9 6 7 5 8 6 4 7 5 6 6 7 4 6 7 4 8 6 7 4 5 7 4 7 5 5 6 4 7 7	11 10 27 31 22 21 22 21 14 13 26 10 12 11 19 28 29 14 19 27 16 21 9 20 12
25	5	(3 4 3 3 4)	6	(4 5 4 4 5 4)	(15 17 16 15 16 15)	(2 3 3 4 3)	(8 6 7 7 8)	(4 3 4 4 4)	7	11	(21 17 16 16 19)	8 6 7 5 8 9 6 8 5 7 6 4 5 7 7 6 6 8 7 6 7 6 5 5 9 4 8 6 7 6	21 17 19 24 22 14 18 15 22 28 11 16 19 26 12 17 20 28 12 18

Table S.1

Continued

No.	Problem Information											
	M	J_m	Q	I_q	μ_q	D_m	R_m	R'_m	C	C'	I_m	C''_{qm}	ω_{jm}
26	2	(4 5)	4	(5 4 3 4)	(8 11 13 9)	(4 3)	(7 6)	(4 4)	2	4	(13 12)	6 8 5 4 7 5 6 4	33 15 12 36 25 21 15 27 15 26
27	3	(4 3 4)	5	(2 4 4 3 4)	(14 17 13 15 15)	(2 3 3)	(6 5 6)	(4 3 5)	2	2	(12 14 13)	11 9 8 9 6 8 6 8 11 9 8 5 6 6 7	10 33 15 32 22 6 16 15 31 21 5 17
28	3	(3 3 3)	4	(3 5 4 3)	18 16 17 15	(3 2 3)	(8 7 6)	(3 3 2)	3	2	(7 18 9)	13 6 8 9 5 4 8 6 9 7 8 7	17 7 18 35 34 15 15 21 41
29	4	(3 3 3 2)	6	(4 3 5 4 4 5)	(10 9 7 11 8 9)	(2 3 3 4)	(6 6 7 5)	(3 4 4 3)	7	1	(12 12 14 11)	7 9 7 6 11 5 6 5 6 9 11 7 7 7 8 6 9 8 8 5 10 8 9 6	40 33 30 22 32 18 16 34 36 25 31 24
30	3	(3 3 3)	5	(3 5 3 2 5)	15 15 16 14 15	(3 3 3)	(4 8 5)	(2 4 3)	8	4	(13 16 13)	5 8 5 7 5 11 8 7 9 5 8 7 7 6 7	22 35 18 30 10 35 17 15 5

Table S.2

The first part of parameters of random instances in large size.

No.	Problem Information						
	M	J_m	Q	I_q	μ_q	D_m	R_m
1	4	(5 4 5 5)	7	(4 5 4 4 5 3 4)	(43 65 37 54 30 44 51)	(8 11 7 9)	(190 230 205 310)
2	5	(4 4 5 5 4)	7	(5 3 5 5 4 4 5)	(47 35 54 45 60 49 39)	(17 14 20 15 12)	(55 52 49 47 60)
3	6	(4 5 5 4 5 5)	7	(4 4 5 4 5 4 4)	(55 43 47 39 48 55 49)	(11 15 17 12 18 14)	(179 237 369 360 290 340)
4	7	(5 5 4 4 5 5 5)	7	(5 4 5 3 4 5 5)	(46 53 42 39 46 44 56)	(16 11 17 15 10 18 15)	(157 284 257 163 158 284 356)
5	3	(5 4 3)	7	(3 5 4 5 3 3 4)	(56 73 45 27 35 52 39)	(16 14 15)	(286 352 175)
6	3	(4 3 4)	5	(3 3 3 2 3)	(47 36 53 40 29)	(12 16 17)	(248 165 249)
7	4	(3 2 3 3)	5	(4 4 2 3 4)	(46 53 44 58 39)	(16 18 12 15)	(275 196 186 230)
8	4	(5 3 5 5)	6	(5 5 4 3 4 3)	(45 64 73 40 55 64)	(16 18 13 11)	(239 264 258 248)
9	5	(3 5 4 5 5)	6	(4 4 5 4 5 3)	(44 57 63 48 39 69	(16 13 15 17 12)	(164 286 256 198 223)
10	6	(3 4 4 5 4 5)	6	(4 5 5 4 3 4)	(56 47 63 45 37 51)	(14 16 14 17 15 12)	(376 254 256 176 265 256)

Table S.3

The second part of parameters of random instances in large size.

No.	Problem Information					
	R'_m	C	C'	I_m	C''_{qm}	ω_{jm}
1	(80 125 120 170)	15	90	(45 66 49 70)	45 38 65 56 47 29 76 45 65 48 54 38 45 54 27 54 54 55 46 48 67 54 56 68 55 48 65 39	188 360 295 340 350 275 390 280 405 370 400 190 355 540 370 450 440 380 530 290
2	(28 25 24 30 35)	12	35	(46 38 53 55 46)	38 43 55 67 69 46 64 55 63 49 47 55 64 57 50 64 57 64 38 49 44 63 58 48 50 56 74 56 49 59 65 78 56 64 49	270 485 380 430 345 386 295 485 453 395 370 564 485 290 468 196 348 548 374 279 439 463 473 480 310
3	(80 120 160 180 130 170)	16	49	(37 62 54 57 37 63)	49 53 69 53 53 39 48 63 49 72 36 48 48 63 54 73 48 36 58 63 47 56 38 64 47 63 38 72 47 55 38 74 56 75 48 64 58 47 64 58 36 85	389 478 386 148 379 296 467 535 289 376 438 539 427 377 455 297 486 290 347 538 463 286 464 386 537 475 386 576 465 576
4	(90 140 170 85 75 125 190)	19	54	(84 63 57 62 85 66 73)	78 46 73 48 67 38 64 74 56 93 57 64 54 38 46 56 73 64 55 87 48 84 57 65 52 58 67 25 58 63 63 84 74 58 92 74 56 75 62 46 82 49 46 57 28 64 52 57 63	367 537 647 257 386 486 463 536 573 453 296 463 465 365 587 565 276 379 586 386 358 456 456 365 475 265 387 465 573 298 465 480 276 586 496

Continued

No.	Problem Information					
	R'_m	C	C'	I_m	C''_{qm}	ω_{jm}
5	(145 175 85)	22	42	(46 58 73)	53 64 57 74 56 36 46 73 45 49 55 38 47 63 48 48 63 58 66 48 53	374 583 496 465 397 476 487 286 186 386 497 276 475 309 197 386 466 276 199 286 539
6	(145 85 150)	20	35	(35 63 44)	46 57 53 53 47 41 55 61 48 32 47 52 63 46 51	375 485 298 638 584 538 573 273 387 297 427 364
7	(139 110 104 125)	35	45	(48 64 58 66)	47 36 53 29 47 58 73 46 55 39 74 68 44 63 48 57 55 48 64 39	387 539 599 334 476 599 370 453 298 196 630 520
8	(130 145 150 125)	45	40	(48 65 49 29)	46 74 58 66 46 74 65 48 77 56 38 54 55 64 58 36 64 75 46 53 55 47 39 64	487 563 287 573 537 276 375 453 186 352 532 275 264 536 186 573 354 450 455 376
9	(86 142 125 105 110)	22	30	(57 38 72 47 58)	43 74 57 64 55 47 63 58 69 83 59 73 68 73 57 58 73 52 68 98 47 84 92 40 37 57 38 75 93 63	463 475 286 374 463 645 354 563 465 466 487 367 367 647 386 732 386 486 574 646 476 365 365 677 455
10	(180 120 130 140 130 225)	25	45	(39 84 56 74 36 46)	47 63 47 58 84 55 46 73 68 57 63 50 54 57 63 49 73 87 58 74 63 59 68 72 58 63 59 67 54 83 65 73 56 45 59 46	365 465 254 587 465 376 176 367 467 376 267 638 476 537 645 653 578 387 567 376 678 387 268 198 367 532 467 527 398 467

Table S.4

Computational results of random instances in small and large sizes

	B&B						TLBO						
No:	T'_m	E_m	F_m	Assignment	OFV	CPU Time (s)	T'_m	E_m	F_m	Assignment	OFV	CPU Time (s)	Gap (%)
1	(3,3,3)	(2,4,3)	(0,0,0)	q1:m1 ; q3:m2 q5:m3	2140	22	(3,3,3)	(2,4,3)	(0,0,0)	q1:m1 ; q3:m2 q5:m3	2150	6	0.4
2	(3,3,4)	(0,0,0)	(0,0,0)	q1:m1 ; q3:m2 q4:m3	1406	36	(3,3,4)	(0,0,0)	(0,0,0)	q1:m1 ; q3:m2 q4:m3	1430	7	1.7
3	(3,3,2,4)	(0,0,2,0)	(1,0,0,1)	q1:m1 ; q3:m2 q4:m3 ; q5:m4	1228	94	(3,3,2,4)	(0,0,2,0)	(1,0,0,1)	q1:m1 ; q3:m2 q4:m3 ; q5:m4	1228	8	0
4	(2,3)	(1,0)	(0,0)	q1:m1 ; q3:m2	1049	19	(2,3)	(1,0)	(0,0)	q1:m1 ; q3:m2	1057	5	0.7
5	(3,2,2)	(0,0,2)	(1,0,0)	q1:m1 ; q4:m2 q5:m3	1032	23	(3,2,2)	(0,0,2)	(1,0,0)	q1:m1 ; q4:m2 q5:m3	1032	6	0
6	(3,3,4)	(0,1,0)	(1,0,1)	q3:m1 ; q4:m2 q5:m3	999	445	(3,3,3)	(0,1,0)	(1,0,0)	q1:m1 ; q2:m2 q3:m3	1009	6	1
7	(7,6,6)	(0,0,0)	(4,3,4)	q1:m1 ; q2:m2 q3:m3	2011	494	(7,6,6)	(0,0,0)	(4,3,4)	q1:m1 ; q2:m2 q3:m3	2083	10	3.5
8	(6,6,6)	(0,0,0)	(3,4,3)	q1:m1 ; q2:m2 q3:m3	5343	27	(6,6,6)	(0,0,0)	(3,4,3)	q1:m1 ; q2:m2 q3:m3	5959	10	11
9	(2,3,3)	(1,0,0)	(0,0,1)	q2:m1 ; q3:m2 q4:m3	492	14	(2,3,3)	(1,0,0)	(0,0,1)	q2:m1 ; q3:m2 q4:m3	492	6	0
10	(3,4,4)	(0,0,0)	(0,1,1)	q1:m1 ; q2:m2 q4:m3	1918	344	(3,4,4)	(0,0,0)	(0,1,1)	q1:m1 ; q2:m2 q4:m3	1918	7	0
11	(2,3,3)	(1,1,0)	(0,0,1)	q2:m1 ; q3:m2 q4:m3	2030	11	(3,3,3)	(0,1,0)	(0,0,1)	q1:m1 ; q2:m2 q4:m3	2166	6	6

Table S.4

Continued

	B&B						TLBO						
No:	T'_m	E_m	F_m	Assignment	OFV	CPU Time (s)	T'_m	E_m	F_m	Assignment	OFV	CPU Time (s)	Gap (%)
12	(2,3,3,2)	(2,0,0,0)	(0,0,0,0)	q2:m1 ; q3:m2 q4:m3 ; q5:m4	2703	72	(2,3,3,2)	(2,0,0,0)	(0,0,0,0)	q2:m1 ; q3:m2 q4:m3 ; q5:m4	2746	10	1.5
13	(3,2,2)	(0,1,2)	(1,0,0)	q1:m1 ; q2:m2 q6:m3	1048	799	(3,2,2)	(0,1,2)	(1,0,0)	q1:m1 ; q2:m2 q6:m3	1061	8	1.2
14	(3,3,4,4,3,4)	(1,2,0,0,0,0)	(0,0,0,0,0,2)	q1:m1 ; q2:m2 q3:m3 ; q4:m4 q5:m5 ; q6:m6	6379	45	(3,3,3,4,3,3)	(1,2,1,0,0,0)	(0,0,0,0,0,1)	q1:m1 ; q2:m2 q3:m3 ; q4:m4 q5:m5 ; q6:m6	6963	14	9.1
15	(3,3,3,3)	(0,0,0,1)	(0,0,1,0)	q1:m1 ; q2:m2 q4:m3 ; q5:m4	1391	41	(3,3,3,3)	(0,0,0,1)	(0,0,1,0)	q1:m1 ; q2:m2 q4:m3 ; q5:m4	1392	10	0
16	(4,4,4,4,4,3)	(0,0,1,0,0,2)	(0,0,0,1,0,0)	q1:m1 ; q2:m2 q3:m3 ; q4:m4 q5:m5 ; q6:m6	6133	34	(4,4,4,4,4,3)	(0,0,1,0,0,2)	(0,0,0,1,0,0)	q1:m1 ; q2:m2 q3:m3 ; q4:m4 q5:m5 ; q6:m6	6969	15	13.6
17	(2,2,2,2)	(1,1,2,1)	(0,0,0,0)	q1:m1 ; q2:m2 q3:m3 ; q4:m4	1211	960	(2,2,2,2)	(1,1,2,1)	(0,0,0,0)	q1:m1 ; q2:m2 q3:m3 ; q4:m4	1211	7	0
18	(4,4)	(1,0)	(0,0)	q1:m1 ; q3:m2	2005	111	(4,4)	(1,0)	(0,0)	q1:m1 ; q3:m2	2010	7	0.2
19	(4,5,5,6)	(0,0,0,0)	(1,0,1,4)	q1:m1 ; q2:m2 q3:m3 ; q4:m4	2814	199	(4,5,5,6)	(0,0,0,0)	(1,0,1,4)	q1:m1 ; q2:m2 q3:m3 ; q4:m4	2862	14	1.7
20	(5,6,6,5)	(0,0,0,0)	(2,2,3,3)	q1:m1 ; q2:m2 q3:m3 ; q4:m4	6096	832	(6,6,6,5)	(0,0,0,0)	(3,2,3,3)	q1:m1 ; q2:m2 q3:m3 ; q4:m4	6726	11	10.3
21	(3,4)	(0,0)	(1,2)	q2:m1 ; q3:m2	1143	900	(3,4)	(0,0)	(1,2)	q2:m1 ; q3:m2	1153	7	0.8
22	(3,3,3,3)	(0,0,1,1)	(1,0,0,0)	q1:m1 ; q3:m2 q4:m3 ; q6:m4	1195	48	(3,3,3,3)	(0,0,1,1)	(1,0,0,0)	q1:m1 ; q3:m2 q4:m3 ; q6:m4	1196	9	0

Table S.4

Continued

	B&B						TLBO						
No:	T'_m	E_m	F_m	Assignment	OFV	CPU Time (s)	T'_m	E_m	F_m	Assignment	OFV	CPU Time (s)	Gap (%)
23	(2,3,3,3,3)	(2,0,0,0,0)	(0,0,0,1,0)	q1:m1 ; q2:m2 q4:m3 ; q5:m4 q6:m5	2219	23	(2,3,3,3,3)	(2,0,0,0,0)	(0,0,0,1,0)	q1:m1 ; q2:m2 q4:m3 ; q5:m4 q6:m5	2239	10	23
24	(2,2,2,3,2)	(2,1,1,0,1)	(0,0,0,1,0)	q2:m1 ; q3:m2 q4:m3 ; q5:m4 q6:m5	1145	164	(2,2,2,3,2)	(2,1,1,0,1)	(0,0,0,1,0)	q2:m1 ; q3:m2 q4:m3 ; q5:m4 q6:m5	1169	11	24
25	(2,2,2,2,2)	(0,1,1,2,1)	(0,0,0,0,0)	q1:m1 ; q2:m2 q3:m3 ; q5:m4 q6:m5	1623	4	(2,2,2,2,2)	(0,1,1,2,1)	(0,0,0,0,0)	q1:m1 ; q2:m2 q3:m3 ; q5:m4 q6:m5	1623	7	25
26	(3,4)	(1,0)	(0,1)	q2:m1 ; q3:m2	1156	237	(3,4)	(1,0)	(0,1)	q2:m1 ; q3:m2	1195	7	26
27	(2,3,3)	(0,0,0)	(0,0,0)	q2:m1 ; q4:m2 q5:m3	641	84	(2,3,3)	(0,0,0)	(0,0,0)	q2:m1 ; q4:m2 q5:m3	641	6	27
28	(2,3,3)	(1,0,0)	(0,1,0)	q1:m1 ; q2:m2 q3:m3	584	21	(2,3,3)	(1,0,0)	(0,1,0)	q1:m1 ; q2:m2 q3:m3	584	6	28
29	(4,4,3,4)	(0,0,0,0)	(2,1,0,0)	q1:m1 ; q2:m2 q4:m3 ; q6:m4	1704	30	(4,4,3,4)	(0,0,0,0)	(2,1,0,0)	q1:m1 ; q2:m2 q4:m3 ; q6:m4	1704	9	29
30	(3,3,3)	(0,0,0)	(0,0,0)	q1:m1 ; q3:m2 q5:m3	1597	24	(3,3,3)	(0,0,0)	(0,0,0)	q1:m1 ; q3:m2 q5:m3	1597	6	30
31	-	-	-	-	-	more than one hour	(13 9 12 11)	(0 2 0 0)	(5 0 5 2)	q1:m1 ; q2:m2 q4:m3 ; q7:m4	600942	34	31
32	-	-	-	-	-	more than one hour	(10 12 14 10 12)	(7 2 6 5 0)	(0 0 0 0 0)	q1:m1 ; q3:m2 q4:m3 ; q5:m4 q6:m5	372812	42	32

Table S.4

Continued

	B&B						TLBO						
No:	T'_m	E_m	F_m	Assignment	OFV	CPU Time (s)	T'_m	E_m	F_m	Assignment	OFV	CPU Time (s)	Gap (%)
33	-	-	-	-	-	more than one hour	(11 15 14 10 12 15)	(0 0 3 2 6 0)	(0 0 0 0 0 1)	q1:m1 ; q3:m2 q4:m3 ; q5:m4 q6:m5 ; q7:m6	927570	47	-
34	-	-	-	-	-	more than one hour	(16 15 16 17 15 15 12)	(0 0 1 0 0 3 3)	(0 4 0 2 5 0 0)	q1:m1 ; q2:m2 q3:m3 ; q4:m4 q5:m5 ; q6:m6 q7:m7	1957922	65	-
35	-	-	-	-	-	more than one hour	(7 14 10)	(9 0 5)	(0 0 0)	q2:m1 ; q3:m2 q6:m3	303408	27	-
36	-	-	-	-	-	more than one hour	(16 18 13)	(0 0 4)	(4 2 0)	q1:m1 ; q2:m2 q3:m3	495681	26	-
37	-	-	-	-	-	more than one hour	(12 12 11 14)	(4 6 1 1)	(0 0 0 0)	q1:m1 ; q2:m2 q4:m3 ; q5:m4	278545	29	-
38	-	-	-	-	-	more than one hour	(9 8 11 13)	(7 10 2 0)	(0 0 0 2)	q2:m1 ; q3:m2 q5:m3 ; q6:m4	1814196	31	-
39	-	-	-	-	-	more than one hour	(15 13 12 15 13)	(1 0 3 2 0)	(0 0 0 0 1)	q1:m1 ; q2:m2 q3:m3 ; q4:m4 q6:m5	1396838	37	-
40	-	-	-	-	-	more than one hour	(11 13 13 18 16 14)	(3 3 1 0 0 0)	(0 0 0 1 1 2)	q1:m1 ; q2:m2 q3:m3 ; q4:m4 q5:m5 ; q6:m6	1987959	51	-