Supplementary material to the article "Energy-aware flexible job shop scheduling problem with nonlinear routes and position-based learning effect"

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Abstract

This document contains supplemental material related to (the numerical experiments section of) the article "Energy-aware flexible job shop scheduling problem with nonlinear routes and position-based learning effect"

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Main instance characteristics								MILP formulation			
Instance	$\|\mathcal{F}\|$	$\|\mathcal{O}\|$	n	$\|\widehat{A}\|$	$\sum_{i\in\mathcal{O}}\mathcal{F}_i$	ω_1	ω_2	#binary variables	#continuous variables	#constraints	#additional constraints
DAFJS01	5	26	4	26	82	0.54	0.54	1,435	213	23,513	77
DAFJS02	5	25	4	23	79	0.45	0.54	1,347	205	21,743	74
DAFJS03	10	55	4	52	279	0.32	0.45	8,118	660	225,311	269
DAFJS04	10	43	4	40	220	0.25	0.46	5,170	518	116,301	210
DAFJS05	5	39	6	34	104	0.35	0.42	2,341	283	50,762	99
DAFJS06	5	44	6	41	136	0.38	0.52	3,855	357	103,952	131
DAFJS07	10	85	6	82	431	0.30	0.45	19,116	1,024	819,871	421
DAFJS08	10	85	6	82	403	0.31	0.42	16,750	968	672,789	393
DAFJS09	5	45	8	42	135	0.40	0.50	3,885	357	108,362	130
DAFJS10	5	58	8	52	168	0.40	0.47	5,927	449	202,593	163
DAFJS11	10	113	8	108	534	0.40	0.41	29,172	1,286	1,549,453	524
DAFJS12	10	117	8	114	603	0.49	0.46	37,106	1,432	2,226,223	593
DAFJS13	5	62	10	55	193	0.41	0.53	7,699	507	296,584	188
DAFJS14	5	69	10	62	206	0.37	0.50	8,779	547	363,000	201
DAFJS15	10	120	10	117	595	0.32	0.44	36,396	1,422	2,187,347	585
DAFJS16	10	120	10	114	602	0.33	0.45	36,936	1,436	2,206,146	592
DAFJS17	5	82	12	77	246	0.43	0.50	12,485	653	618,328	241
DAFJS18	5	74	12	64	231	0.41	0.53	11,011	607	510,639	226
DAFJS19	7	70	8	66	283	0.34	0.51	11,783	701	473,399	276
DAFJS20	7	92	10	87	361	0.36	0.49	19,063	901	977,888	354
DAFJS21	7	107	12	102	425	0.38	0.50	26,271	1,059	1,579,980	418
DAFJS22	7	116	12	109	450	0.39	0.48	29,739	1,127	1,934,612	443
DAFJS23	9	76	8	71	367	0.31	0.48	15,461	879	630,804	358
DAFJS24	9	92	8	87	463	0.31	0.50	24,347	1,103	1,241,284	454
DAFJS25	9	123	10	119	619	0.31	0.50	43,363	1,477	2,970,603	610
DAFJS26	9	119	10	116	606	0.34	0.51	41,623	1,443	2,797,904	597
DAFJS27	9	127	12	118	625	0.27	0.49	44,077	1,497	3,032,252	616
DAFJS28	10	91	8	89	457	0.32	0.45	21,512	1,088	983,116	447
DAFJS29	10	95	8	94	468	0.34	0.44	22,908	1,118	1,111,763	458
DAFJS30	10	98	10	94	509	0.20	0.47	26,558	1,206	1,346,638	499
YFJS01	7	40	4	36	104	0.10	0.27	1,921	283	38,811	97
YFJS02	7	40	4	36	104	0.17	0.27	1,665	283	25,023	97
YFJS03	7	24	6	18	63	0.28	0.27	667	169	6,865	56
YFJS04	7	28	7	21	71	0.19	0.26	877	193	10,608	64
YFJS05	7	32	8	24	81	0.33	0.26	1,077	221	13,819	74
YFJS06	7	36	9	27	95	0.19	0.27	1,453	257	21,690	88
YFJS07	7	36	9	27	93	0.26	0.26	1,365	253	19,054	86
YFJS08	12	36	9	27	100	0.26	0.16	976	262	9,355	88
YFJS09	12	36	9	27	219	0.22	0.46	4,286	500	79,545	207
YFJS10	12	40	10	30	113	0.17	0.17	1,270	296	14,138	101
YFJS11	10	50	10	40	134	0.22	0.19	1,984	360	28,048	124
YFJS12	10	50	10	40	133	0.12	0.18	2,038	358	30,750	123
YFJS13	10	50	10	40	137	0.15	0.19	2,022	366	27,862	127
YFJS14	26	221	13	208	641	0.24	0.08	17,218	1,700	457,475	615
YFJS15	26	221	13	208	648	0.23	0.08	17,242	1,714	445,083	622
YFJS16	26	221	13	208	633	0.13	0.07	16,644	1,684	427,509	607
YFJS17	26	289	17	272	1,328	0.15	0.14	69,804	3,210	3,579,141	1,302
YFJS18	26	289	17	272	1,362	0.15	0.15	73,690	3,278	3,908,347	1,336
YFJS19	26	289	17	272	1,347	0.20	0.15	71,848	3,248	3,744,631	1,321
YFJS20	26	289	17	272	1,343	0.12	0.15	71,688	3,240	3,749,631	1,317

Table S1: Main features of the fifty large-sized instances based on the instances introduced in [2].

instance	$\alpha = 0.1$								$\alpha = 0.2$								$\alpha = 0.3$							
	GCH	LS-SRRN			LS-SRDRR				GCH	LS-SRRN			LS-SRDRR				GCH	LS-SRRN			LS-SRDRR			
	E	E	#it	Time	E	#it	Time		E	E	#it	Time	E	#it	Time		E	E	#it	Time	E	#it	Time	
DAFJS01	397,432	383,793	5	2.17	392,796	5	18.74		398,638	371,886	7	3.71	359,759	3	10.70		356,380	349,377	4	3.49	393,572	5	18.10	
DAFJS02	1,203,971	1,064,101	4	1.37	966,138	5	15.79		1,035,854	937,025	4	1.56	876,111	5	16.44		874,471	846,444	3	1.41	805,725	5	15.56	
DAFJS03	365,430	344,053	16	54.98	344,821	4	128.29		327,785	318,509	10	32.26	296,658	5	152.53		275,186	267,972	7	22.14	252,515	8	215.98	
DAFJS04	803,260	779,026	7	12.55	792,815	5	97.32		735,494	702,661	10	15.10	714,959	5	88.42		651,370	612,873	10	16.21	630,842	4	72.94	
DAFJS05	1,386,590	1,268,850	6	7.62	1,179,549	6	56.19		1,213,945	1,151,442	6	7.67	1,097,221	7	70.09		1,236,488	1,107,365	14	18.08	976,457	3	27.64	
DAFJS06	555,611	512,661	13	26.22	492,635	11	189.91		483,258	456,254	11	20.38	427,890	9	161.16		429,921	406,049	11	21.39	382,463	9	150.78	
DAFJS07	1,611,384	1,552,999	12	212.52	1,464,349	6	1,251.79		1,363,719	1,309,053	11	204.59	1,288,461	3	607.79		1,204,314	1,180,411	10	166.33	1,173,502	7	1,426.77	
DAFJS08	1,380,014	1,368,969	4	67.63	1,333,611	4	654.38		1,213,519	1,194,971	6	99.02	1,175,145	7	1,142.64		1,115,885	1,003,186	7	122.31	1,027,393	6	935.00	
DAFJS09	325,458	299,821	8	17.34	286,684	6	108.81		272,547	255,056	12	26.26	260,017	6	103.54		244,271	223,807	13	30.89	224,604	5	76.10	
DAFJS10	1,235,465	1,217,861	8	35.18	1,088,842	6	260.28		1,073,290	1,015,558	7	32.88	939,593	3	130.33		919,372	832,809	10	43.70	816,425	3	123.99	
DAFJS11	785,697	747,507	28	1,413.14	722,981	8	2,763.86		671,442	655,387	16	779.77	632,568	5	1,583.95		549,446	526,898	23	1,208.31	532,155	5	1,481.80	
DAFJS12	696,337	654,466	29	1,930.36	676,797	7	3,295.41		593,763	558,494	37	2,168.84	569,298	9	4,471.48		519,513	560,080	22	1,270.14	481,380	4	1,605.22	
DAFJS13	1,223,548	1,164,869	17	96.48	1,063,071	6	432.17		942,095	941,744	3	17.21	882,218	3	214.11		849,755	887,877	15	81.38	736,882	8	561.24	
DAFJS14	2,476,217	1,968,025	41	333.10	1,894,786	9	820.61		1,726,736	1,673,281	10	79.82	1,595,193	8	631.02		1,456,081	1,450,893	2	15.71	1,384,930	3	239.23	
DAFJS15	911,487	859,382	37	2,836.70	865,018	8	5,471.78		821,065	791,885	12	887.60	752,404	6	3,927.06		715,828	709,074	9	633.22	656,472	6	3,778.56	
DAFJS16	1,269,829	1,235,294	30	2,157.43	1,155,584	9	5,446.81		1,061,257	1,059,262	18	1,294.21	994,434	7	4,299.40		944,230	915,859	25	1,759.92	861,295	5	2,969.11	
DAFJS17	2,493,908	2,228,211	32	581.50	2,155,718	6	870.65		1,984,723	1,844,712	45	794.30	1,709,666	6	921.31		1,709,050	1,521,599	22	369.98	1,499,707	6	886.16	
DAFJS18	492,447	487,569	4	33.78	479,957	3	309.62		429,900	407,899	15	140.40	413,878	4	408.92		401,595	380,241	20	156.42	333,133	5	450.71	
DAFJS19	1,072,253	1,008,335	21	191.24	894,109	11	1,083.95		894,979	875,976	7	69.19	763,122	10	1,063.64		819,081	735,380	15	140.22	672,185	9	963.81	
DAFJS20	1,122,226	1,092,723	16	429.75	1,072,368	3	705.87		955,649	925,768	15	362.96	902,677	8	1,927.82		824,664	802,428	13	306.26	747,159	6	1,348.19	
DAFJS21	2,094,408	1,956,237	28	1,192.94	1,957,655	6	3,195.98		1,791,022	1,627,070	28	1,104.99	1,627,958	7	3,258.44		1,448,826	1,383,916	25	1,118.98	1,353,516	9	4,642.57	
DAFJS22	2,485,324	2,258,335	29	1,807.62	2,079,089	10	4,730.06		1,942,002	1,879,967	19	1,363.58	1,668,341	14	7,177.40		1,639,602	1,513,676	30	1,970.28	1,370,548	14	6,750.53	
DAFJS23	1,696,176	1,589,324	6	64.41	1,573,492	10	1,500.62		1,547,862	1,512,131	11	115.50	1,391,497	7	1,011.85		1,351,747	1,338,914	7	72.90	1,243,227	10	1,491.34	
DAFJS24	1,123,117	1,100,800	13	318.12	1,040,271	12	3,882.32		940,336	917,406	13	369.84	917,349	6	1,923.95		875,751	795,339	25	637.37	788,146	14	4,523.05	
DAFJS25	2,262,120	2,115,205	46	4,098.66	2,065,445	11	8,837.59		1,855,996	1,814,677	18	1,592.35	1,744,235	9	7,487.01		1,616,688	1,582,165	19	1,578.64	1,470,542	7	5,694.27	
DAFJS26	1,432,486	1,282,261	26	2,034.05	1,208,831	9	7,686.39		1,170,736	1,095,582	43	3,374.56	1,057,302	9	7,322.88		976,533	953,113	18	1,376.92	868,048	8	6,742.81	
DAFJS27	1,586,658	1,529,245	35	3,193.43	1,500,899	6	5,385.85		1,371,388	1,290,375	47	4,699.45	1,254,681	6	5,405.24		1,120,365	1,099,272	16	1,590.83	1,055,871	9	8,209.90	
DAFJS28	588,774	542,353	36	773.42	533,745	10	2,110.45		494,771	471,017	13	277.67	475,361	6	1,184.66		445,346	401,816	36	683.91	398,881	4	697.77	
DAFJS29	1,411,822	1,360,945	24	760.34	1,311,522	12	3,580.47		1,313,178	1,224,251	43	1,207.04	1,124,340	8	2,417.35		1,076,627	1,053,283	19	531.41	991,768	12	3,326.25	
DAFJS30	780,383	749,377	26	884.54	692,321	9	3,281.49		652,662	620,476	16	593.40	662,094	7	2,229.02		555,644	549,019	8	260.09	525,847	4	1,197.65	
mean	1,245,668.07	1,157,385.23	20.23	849.92	1,109,329.97	7.43	2,272.45		1,043,387.63	996,649.17	17.10	723.87	950,481.00	6.60	2,045.01		906,801.00	86,4704.50	15.27	540.29	818,844.27	6.77	2,027.10	
wins	6				24				6				24					3			27			

instance	$\alpha = 0.1$								$\alpha = 0.2$								$\alpha = 0.3$							
	GCH	LS-SRRN			LS-SRDRR				GCH	LS-SRRN			LS-SRDRR				GCH	LS-SRRN			LS-SRDRR			
	E	E	#it	Time	E	#it	Time		E	E	#it	Time	E	#it	Time		E	E	#it	Time	E	#it	Time	
YFJS01	1,560,216	1,284,482	5	6.04	1,111,821	3	18.29		1,361,692	1,135,383	5	5.79	1,098,438	4	25.24		1,104,656	979,901	9	10.71	897,111	5	29.30	
YFJS02	1,140,805	1,133,741	3	3.40	1,112,419	2	12.13		1,019,493	1,001,933	6	6.66	987,913	3	18.28		957,084	938,676	4	4.39	885,889	4	24.36	
YFJS03	1,133,119	1,122,981	2	0.38	1,003,404	5	7.34		1,047,620	1,032,519	2	0.37	959,606	4	5.91		970,344	952,258	3	0.55	918,317	3	4.49	
YFJS04	437,536	437,289	2	0.60	420,816	4	9.60		403,556	391,467	4	1.10	367,502	6	13.50		351,615	349,968	2	0.68	348,857	3	7.47	
YFJS05	925,920	854,852	5	2.18	791,005	10	39.62		848,077	762,244	4	1.78	724,520	6	23.78		774,197	706,392	3	1.39	686,744	3	11.03	
YFJS06	1,156,728	1,152,913	4	2.46	1,100,074	3	16.98		1,023,993	1,023,340	2	1.46	968,017	5	28.27		935,236	928,212	3	2.31	872,054	5	28.94	
YFJS07	1,397,657	1,397,657	1	0.57	1,265,726	5	27.73		1,226,090	1,222,411	3	1.72	1,126,641	6	32.58		1,096,750	1,096,407	3	1.64	950,338	8	43.04	
YFJS08	1,249,850	1,226,079	5	2.34	940,160	10	38.00		1,131,702	1,106,227	5	2.23	890,416	12	43.78		1,030,987	1,002,130	5	2.22	848,017	10	38.86	
YFJS09	891,186	880,402	5	4.81	889,023	3	32.04		903,245	874,111	6	6.08	825,914	5	55.02		849,479	823,550	4	3.93	771,506	3	32.05	
YFJS10	1,411,209	1,278,934	7	4.18	1,165,041	6	25.34		1,265,472	1,157,113	6	3.55	1,097,274	5	22.34		1,230,221	1,106,638	9	5.24	986,091	6	28.50	
YFJS11	554,450	499,130	7	9.11	516,356	4	42.20		536,253	460,251	13	17.63	471,277	5	55.89		477,867	442,356	9	14.57	428,957	10	101.82	
YFJS12	1,241,270	1,195,844	7	9.26	1,142,723	6	70.06		1,111,432	1,059,723	8	9.81	1,011,849	8	92.97		992,323	939,260	9	10.96	913,337	6	68.76	
YFJS13	873,871	867,345	5	6.88	765,360	6	74.00		787,318	778,664	6	8.26	719,441	4	47.43		754,546	699,962	5	6.66	646,440	2	24.70	
YFJS14	4,654,733	4,575,776	26	4,330.70	4,397,827	9	5,476.11		4,112,389	3,975,398	27	4,319.42	3,803,990	7	4,248.65		3,467,408	3,370,736	30	4,821.58	3,360,901	9	5,491.13	
YFJS15	1,948,356	1,841,990	50	7,667.29	1,875,811	7	3,960.73		1,725,485	1,643,153	41	6,304.91	1,642,323	5	2,774.57		1,575,631	1,462,253	49	7,771.12	1,439,899	8	4,216.55	
YFJS16	3,220,506	3,134,839	28	4,207.15	3,170,239	8	4,914.26		2,807,943	2,740,962	16	2,305.08	2,759,477	8	4,672.57		2,461,779	2,411,754	14	2,154.89	2,431,613	9	5,416.30	
YFJS17	2,102,104	2,031,740	41	28,524.12	2,037,974	10	32,077.11		1,852,045	1,789,294	49	33,687.92	1,760,050	6	18,727.47		1,587,279	1,538,912	41	27,854.07	1,515,259	14	42,835.20	
YFJS18	2,183,918	2,102,589	53	39,303.48	2,014,165	8	25,270.44		1,894,416	1,792,009	72	52,910.32	1,710,773	7	22,019.89		1,661,522	1,566,967	89	62,307.97	1,516,866	13	38,976.02	
YFJS19	2,408,849	2,363,277	45	32,017.22	2,311,512	10	35,461.70		2,042,160	1,991,382	39	28,400.76	1,950,995	7	24,094.54		1,798,144	1,761,497	26	18,536.62	1,679,950	7	23,577.62	
YFJS20	1,949,578	1,694,688	106	58,816.01	1,725,522	8	19,105.95		1,633,872	1,463,295	98	57,613.75	1,518,531	8	18,825.41		1,533,296	1,377,550	91	41,810.59	1,391,907	11	19,920.50	
mean	1,622,068.05	1,553,797.40	20.35	8,745.91	1,487,848.90	6.35	6,333.98		1,436,712.65	1,370,043.95	20.60	9,280.43	1,315,247.10	6.05	4,791.40		1,280,518.20	1,222,768.95	20.40	8,266.10	1,174,502.65	6.95	7,083.83	
wins	6				14				3				17					2			18			

Table S2: Results of applying the constructive heuristic GCH and the local searches LS-SRRN and LS-SRDRR to the 50 large-sized instances based on the instances introduced in [2], with learning rates $\alpha \in \{0.1, 0.2, 0.3\}$.

instance	GRASP-LS-SRRN			GRASP-LS-SRDRR			GVNS			SA-LS-SRRN			SA-LS-SRDRR		
	avg	min	time	avg	min	time	avg	min	time	avg	min	time	avg	min	time
DAFJS01	357356.50	356091	211.42	350573.00	349728	301.59	381513.00	381513	0.02	397357.50	397155	0.04	362326.00	354327	118.01
DAFJS02	916256.90	915414	190.05	916319.00	915414	218.56	1026164.00	1026164	0.02	1193648.20	1134684	0.00	953101.70	923065	107.83
DAFJS03	318801.30	312650	289.04	323646.10	321045	310.51	334107.80	321686	0.27	363834.10	349471	0.68	325033.30	320384	206.37
DAFJS04	765735.10	763939	369.69	774118.50	769269	355.84	762860.00	762860	0.07	799107.10	778431	0.76	778117.20	773721	293.71
DAFJS05	1162967.40	1149932	323.57	1126972.30	1118453	339.46	1217236.60	1184816	0.06	1342682.10	1260111	45.17	1177941.70	1151954	147.62
DAFJS06	472621.40	468807	282.85	468598.50	463565	345.99	481710.10	480338	1.05	547690.10	511121	3.42	473711.10	465630	158.38
DAFJS07	1484367.60	1455664	270.44	1488820.20	1485906	26.85	1417326.90	1413045	5.41	1603412.30	1562320	13.47	1516437.40	1457989	70.77
DAFJS08	1317916.40	1309998	269.44	1332728.00	1330592	71.43	1302967.10	1300682	1.39	1371156.60	1343353	123.09	1339289.30	1327183	116.07
DAFJS09	281369.70	279638	198.93	280802.90	279249	387.20	288691.20	284310	0.38	319312.80	294189	54.52	285591.40	283592	176.03
DAFJS10	1040623.40	1022374	486.55	1042489.70	1033965	313.48	1078861.70	1038592	18.22	1274637.40	1173562	92.23	1073370.80	1046206	163.58
DAFJS11	700081.30	693628	188.27	722528.70	709406	205.57	689780.50	689345	11.11	785681.20	785539	0.00	718438.20	712108	285.45
DAFJS12	647501.40	640264	204.21	668300.20	658870	293.43	657428.70	642203	43.68	694186.20	674829	1.76	660095.10	656057	360.40
DAFJS13	1025950.00	1015701	238.72	1021675.80	1013933	327.95	1017534.90	1004936	92.92	1199273.80	1100465	118.05	1030242.90	1022407	318.10
DAFJS14	1893849.20	1870370	283.79	1873280.90	1836208	263.03	1847660.00	1847660	1.17	2369502.20	1939823	69.76	1879771.20	1861840	183.49
DAFJS15	869923.20	855517	86.02	859632.00	859632	7.44	856025.00	855450	5.98	911296.20	909579	0.00	887919.70	875085	129.85
DAFJS16	1177343.60	1171374	297.69	1197545.00	1197545	6.74	1152936.60	1130400	24.89	1269634.70	1267886	0.00	1201019.70	1182324	118.32
DAFJS17	2073750.80	2055160	324.78	2049084.30	2031870	197.25	1999228.90	1980371	50.85	2453633.60	2265687	70.92	2076221.00	2039127	284.76
DAFJS18	464375.60	461164	189.26	467778.30	465925	281.77	465612.20	461406	1.00	492447.00	492447	0.00	471611.30	467375	241.30
DAFJS19	858383.30	842210	376.13	863940.50	858036	315.43	897395.20	862054	1.25	1072253.00	1072253	0.00	863780.00	853154	168.39
DAFJS20	1014813.10	996885	348.45	1022472.00	1000793	302.61	1025928.30	1005295	117.02	1111572.30	1038808	17.32	1039719.10	1020587	336.23
DAFJS21	1899440.90	1866121	274.31	1935536.80	1900495	274.84	1809654.00	1803135	55.99	2087514.50	2025500	2.21	1962344.00	1921149	193.98
DAFJS22	2002338.00	1973165	339.31	2037690.70	2014758	151.08	1920216.70	1862004	80.48	2485155.30	2483637	0.00	2022344.50	1995710	155.67
DAFJS23	1585246.70	1569910	153.32	1585593.00	1585593	0.98	1578709.00	1561330	0.94	1675108.10	1613138	43.50	1627908.40	1593430	114.87
DAFJS24	1048411.60	1035937	236.68	1080005.90	1069954	157.96	1009699.00	1009699	6.05	1117204.00	1078560	10.91	1052238.60	1039002	188.18
DAFJS25	2078253.40	2053082	412.58	2073363.00	2073363	13.95	2089110.20	1977467	14.36	2262120.00	2262120	0.00	2112815.60	2093577	160.22
DAFJS26	1219716.00	1206258	391.78	1202509.00	1202509	10.37	1173758.40	1126449	45.58	1429473.50	1402361	0.00	1227718.70	1202350	244.86
DAFJS27	1490170.20	1477591	270.15	1526941.40	1511994	125.95	1477514.10	1419795	15.25	1586282.20	1582900	0.00	1531891.40	1520608	144.19
DAFJS28	525346.20	520893	201.52	537522.00	537522	1.72	509252.00	509252	120.87	588382.90	585455	0.00	540170.10	534465	222.62
DAFJS29	1304977.00	1290580	312.18	1326047.10	1307432	369.25	1281313.80	1259044	13.84	1408035.80	1374122	19.18	1314490.60	1287514	160.23
DAFJS30	688454.90	685122	232.17	705170.20	697990	177.28	676938.10	672631	7.34	780393.00	780393	0.00	709095.40	703771	143.31
avg	1089544.74	1077181.30	275.11	1095389.50	1087000.47	205.18	1080904.47	1062464.40	24.58	1233066.26	1184646.63	22.90	1107158.51	1089523.03	190.43
wins	7			6			18			0			0		

instance	GRASP-LS-SRRN			GRASP-LS-SRDRR			GVNS			SA-LS-SRRN			SA-LS-SRDRR		
	avg	min	time	avg	min	time	avg	min	time	avg	min	time	avg	min	time
YFJS01	1041508.10	1035567	318.24	1016998.80	1014612	321.37	1098212.20	1055398	0.11	1383349.80	1300875	16.22	1112614.80	1053209	128.39
YFJS02	1086636.60	1082569	298.80	1083111.50	1082569	239.67	1092061.00	1092061	0.03	1138468.50	1135720	0.06	1109927.80	1099830	205.73
YFJS03	999984.90	999678	134.64	999678.00	999678	5.45	1020233.40	1017180	0.01	1130292.00	1122981	0.00	1011802.80	1003086	200.08
YFJS04	383110.00	379209	182.62	379092.30	378958	169.25	393271.00	393271	0.02	437536.00	437536	0.00	382646.70	379027	244.10
YFJS05	784912.20	779315	289.52	776375.90	770023	299.91	791300.70	785985	0.04	899993.90	854852	8.07	796903.10	784740	135.45
YFJS06	995751.40	988712	234.88	987989.60	980063	384.38	1045952.00	1045952	1.69	1156380.30	1154641	0.01	1028833.30	1006172	180.26
YFJS07	1145285.90	1139305	426.06	1126980.40	1120276	328.61	1175181.00	1175181	0.08	1397057.00	1397057	0.00	1187241.60	1164471	129.30
YFJS08	920471.60	920031	376.74	919295.00	919295	28.68	962835.00	962835	0.04	1249850.00	1249850	0.00	943134.60	923077	104.56
YFJS09	865324.40	853126	245.75	864314.10	862119	189.32	868605.00	868605	0.14	891095.30	890279	0.00	886910.20	878702	53.21
YFJS10	1144828.80	1140994	276.52	1131234.40	1124462	261.87	1160764.10	1145258	0.11	1409216.60	1405380	0.00	1209242.00	1176854	89.98
YFJS11	496104.20	493766	378.49	492785.30	490760	300.31	505969.00	505969	0.08	554450.00	554450	0.00	509487.90	501394	77.88
YFJS12	1058578.10	1044937	257.85	1047285.80	1034347	280.09	1119676.00	1119676	0.09	1224842.30	1179225	0.40	1116966.10	1066383	111.35
YFJS13	724714.40	720730	348.40	719173.20	715871	257.66	733181.00	733181	0.18	873716.80	872329	0.00	774271.40	756241	206.69
YFJS14	4365818.60	4264682	372.58	4479605.00	4427284	287.26	4275240.30	4260379	77.06	4649599.50	4618488	11.09	4573861.90	4513513	29.01
YFJS15	1806478.60	1768464	344.73	1848174.20	1839610	243.71	1859602.40	1851356	66.42	1948356.00	1948356	0.00	1909779.20	1890970	247.05
YFJS16	3099530.00	3099530	10.94	3169867.00	3169867	4.62	3093383.70	3089376	10.11	3220506.00	3220506	0.00	3216875.20	3194316	5.12
YFJS17	2039134.90	2004861	389.38	2082212.00	2082212	12.33	2008191.00	1956176	114.20	2102104.00	2102104	0.00	2099986.70	2089785	18.71
YFJS18	2016752.30	1980878	547.17	1976093.00	1976093	38.23	1944262.00	1843451	224.77	2183918.00	2183918	0.00	2021533.30	1976602	196.36
YFJS19	2342981.10	2290121	283.85	2353969.00	2353969	42.04	2231913.40	2231667	186.81	2408205.10	2402410	8.00	2390524.10	2359003	82.42
YFJS20	1583769.10	1562730	483.71	1690843.30	1676775	318.41	1560360.40	1548237	249.13	1949532.50	1949123	0.00	1753310.30	1724831	220.42
avg	1445083.76	1427460.25	310.04	1457253.89	1450942.15	200.66	1447009.73	1434069.70	46.56	1610423.48	1599004.00	2.19	1501692.65	1477110.30	133.30
wins	4			11			6			0			0		

Table S3: Results of applying the metaheuristics GRASP-LS-SRRN, GRASP-LS-SRDRR, GVNS, SA-LS-SRRN, and SA-LS-SRDRR to the 50 large-sized instances based on the instances introduced in [2], with learning rate $\alpha = 0.1$.

instance	GRASP-LS-SRRN			GRASP-LS-SRDRR			GVNS			SA-LS-SRRN			SA-LS-SRDRR		
	avg	min	time	avg	min	time	avg	min	time	avg	min	time	avg	min	time
DAFJS01	326744.30	321581	164.35	323760.80	322655	228.48	344495.00	344495	0.03	395096.50	387680	24.70	330746.20	323971	221.56
DAFJS02	854294.40	854226	254.84	854917.20	854226	226.81	884615.00	884615	0.03	998559.70	948833	0.00	873381.90	866748	157.60
DAFJS03	283235.30	280219	337.90	285430.90	282356	268.41	297151.00	297151	0.25	326481.30	314748	15.58	288417.50	284565	255.95
DAFJS04	676612.00	675305	266.51	686069.20	682187	336.48	673371.00	673034	0.10	732831.80	724755	0.05	691681.30	686302	180.60
DAFJS05	1027245.40	1001927	351.43	1000201.00	985023	371.90	1087874.90	1051766	0.04	1194894.80	1147537	4.76	1042564.60	1015499	139.12
DAFJS06	418238.20	412663	404.36	413520.80	409434	211.41	431876.00	431876	0.11	476781.20	451739	35.44	417237.40	410388	247.21
DAFJS07	1313128.50	1282775	214.52	1334302.10	1314395	34.50	1238599.00	1238599	3.65	1358350.90	1310038	0.37	1346999.80	1334789	84.62
DAFJS08	1156466.70	1149401	412.25	1171153.30	1165585	58.59	1161290.00	1161290	1.44	1213519.00	1213519	0.00	1186180.80	1167533	202.56
DAFJS09	248753.70	248078	331.21	248737.20	246931	257.98	251943.50	251409	3.75	272371.40	270791	0.00	253325.00	251697	260.73
DAFJS10	888413.40	878454	255.80	892470.00	875313	381.00	928251.30	892697	0.88	1058759.10	990034	12.54	919627.50	900375	127.24
DAFJS11	600534.80	591252	396.07	617703.50	608837	256.60	596542.60	596225	166.49	671442.00	671442	0.00	609882.30	606240	179.18
DAFJS12	547187.90	544438	348.60	567988.80	560494	107.45	545316.50	545228	7.47	595763.00	595763	0.00	560542.90	549582	165.35
DAFJS13	868319.50	861432	190.45	868429.00	859410	146.18	876727.00	876727	37.17	942095.00	942095	0.00	874209.00	863097	210.88
DAFJS14	1593036.10	1582708	286.79	1595646.40	1582672	213.43	1580002.10	1577084	0.59	1709987.80	1625721	87.40	1601614.10	1576721	191.93
DAFJS15	748278.00	742111	261.23	762651.00	762651	12.09	742426.00	726665	11.27	817446.20	784877	41.92	766554.60	751406	164.55
DAFJS16	1007616.30	991870	165.49	1013704.00	1013704	9.48	988626.10	975163	13.23	1078968.00	1061933	33.64	1029078.60	1015060	100.51
DAFJS17	1709995.40	1691507	231.66	1705440.40	1681063	325.02	1675212.90	1672217	341.45	1984723.00	1984723	0.00	1737554.50	1721227	234.17
DAFJS18	391223.00	387881	341.15	393624.50	391725	309.77	389779.30	384568	1.03	426672.90	404188	2.24	397703.40	395175	228.51
DAFJS19	750787.00	738799	251.23	757282.70	745240	414.45	751436.30	750844	1.55	894979.00	894979	0.00	761267.00	750410	259.51
DAFJS20	860534.60	852285	329.51	874353.50	867859	279.99	835637.70	828173	14.01	955649.00	955649	0.00	883928.30	872599	240.46
DAFJS21	1596698.00	1585909	291.44	1618857.60	1609131	41.47	1545123.40	1538564	7.36	1763955.60	1650427	69.17	1632789.20	1586689	90.23
DAFJS22	1639132.50	1617087	304.87	1697466.60	1681856	358.54	1614673.00	1565476	39.92	1941087.60	1933086	0.00	1667318.50	1639618	194.93
DAFJS23	1401674.50	1378545	273.89	1418638.00	1385464	280.43	1355501.00	1355501	2.32	1542012.30	1507795	22.03	1433459.90	1385713	123.99
DAFJS24	910241.60	909284	50.31	923912.00	923912	2.45	892025.00	891204	3.30	933988.00	899249	64.72	919501.70	907812	225.07
DAFJS25	1761569.10	1726490	249.98	1765763.00	1765763	10.29	1669245.00	1669245	12.77	1847658.10	1772617	28.47	1802029.70	1765919	201.83
DAFJS26	1037468.70	1028980	356.01	1034377.00	1034377	6.74	987707.10	985798	13.03	1161323.80	1077998	51.57	1048721.60	1029830	250.07
DAFJS27	1249992.20	1234049	291.39	1289180.90	1279313	43.35	1228340.60	1228229	46.74	1371388.00	1371388	0.00	1289148.80	1276047	125.16
DAFJS28	453098.70	449639	265.04	466255.90	460311	323.50	451818.80	447590	58.88	493544.10	484741	0.00	467607.30	465253	249.10
DAFJS29	1136490.40	1121644	311.79	1162192.50	1136681	298.05	1103131.00	1103131	6.01	1313178.00	1313178	0.00	1159748.70	1143785	121.20
DAFJS30	601648.70	596701	118.68	618385.10	607913	260.68	612090.40	589720	3.48	652662.00	652662	0.00	619796.30	611638	234.67
avg	935288.63	924574.67	276.96	945413.83	936549.37	202.52	924694.28	917809.47	26.61	1037538.97	1011472.83	16.49	953753.95	938522.93	188.95
wins		7			6			17			0			1	

instance	GRASP-LS-SRRN			GRASP-LS-SRDRR			GVNS			SA-LS-SRRN			SA-LS-SRDRR		
	avg	min	time	avg	min	time	avg	min	time	avg	min	time	avg	min	time
YFJS01	931842.60	920641	175.91	920911.30	916390	214.48	946395.50	937930	0.09	1193842.60	1107344	1.76	998975.60	946432	172.06
YFJS02	972642.20	971294	352.39	964714.00	963708	185.12	973057.00	973057	0.05	1015503.90	1011269	9.93	988246.90	976048	166.57
YFJS03	916183.00	916183	53.68	916183.00	916183	3.02	956532.80	951763	0.01	1042231.30	1032519	0.00	939327.90	930844	102.95
YFJS04	352761.20	352610	31.27	351975.70	351120	208.18	365935.00	365935	0.01	403556.00	403556	0.00	357282.20	355994	128.42
YFJS05	716443.30	715089	251.27	714482.70	711613	242.04	717565.70	716793	0.02	840021.50	776795	0.00	732144.10	726673	115.88
YFJS06	919544.80	912536	325.58	909249.40	903518	243.60	955129.00	955129	0.03	1019771.50	1010139	0.48	948762.10	923018	91.98
YFJS07	1051093.70	1046924	375.94	1028013.50	1023225	286.48	1099970.00	1099970	0.04	1225849.50	1224369	1.19	1077020.80	1032959	38.30
YFJS08	871510.80	867730	304.69	866811.00	866811	109.29	874305.00	874305	0.04	1130872.30	1123405	0.00	891741.60	870783	152.17
YFJS09	820669.80	817340	377.51	814790.60	804587	289.10	836818.70	831452	0.07	902714.60	900593	0.00	877192.70	842461	115.11
YFJS10	1066003.40	1058652	279.73	1052353.60	1049319	374.40	1160812.00	1160812	0.01	1265283.70	1264648	0.00	1115621.30	1082764	86.67
YFJS11	453481.80	451783	362.45	450386.90	449544	167.27	459065.30	457613	0.07	533408.60	507809	0.09	467697.90	462342	112.30
YFJS12	960290.80	948247	376.64	955442.60	948269	250.91	1024383.00	1024383	0.11	1095148.40	1073063	8.43	1008869.20	988867	94.93
YFJS13	665870.70	659996	264.91	661262.60	656300	240.34	710383.30	693736	2.52	786516.10	779890	0.01	706770.20	689258	50.16
YFJS14	3802489.10	3762242	380.77	3887508.60	3858958	270.90	3800029.70	3696869	20.28	4104560.40	4034103	6.53	3995783.10	3907508	27.86
YFJS15	1581320.60	1572551	265.72	1625172.30	1614231	306.55	1556372.00	1556372	38.55	1719502.30	1665658	25.35	1687704.90	1642914	150.49
YFJS16	2752018.20	2702565	40.39	2782060.00	2782060	11.66	2751015.00	2751015	18.54	2807943.00	2807943	0.00	2805867.90	2797427	37.90
YFJS17	1732423.00	1705111	231.93	1798398.00	1798398	36.09	1672768.00	1672768	171.56	1852045.00	1852045	0.00	1814783.60	1784829	50.78
YFJS18	1723728.90	1701929	519.14	1805654.60	1790646	340.65	1636590.20	1635159	205.86	1894416.00	1894416	0.00	1793253.30	1760080	233.06
YFJS19	2000490.20	1968497	82.56	1967121.00	1967121	39.51	1906795.00	1906795	95.19	2040871.10	2029271	42.06	2031249.40	2007805	13.98
YFJS20	1381649.50	1337624	472.91	1477222.70	1462351	423.61	1379946.40	1376635	291.86	1633872.00	1633872	0.00	1538929.90	1515181	213.94
avg	1283622.88	1269477.20	276.27	1297485.71	1291717.60	212.16	1289193.43	1281924.55	42.25	1425396.49	1406635.35	4.79	1338861.23	1312209.35	107.78
wins		4			12			4			0			0	

Table S4: Results of applying the metaheuristics GRASP-LS-SRRN, GRASP-LS-SRDRR, GVNS, SA-LS-SRRN, and SA-LS-SRDRR to the 50 large-sized instances based on the instances introduced in [2], with learning rate $\alpha = 0.2$.

instance	GRASP-LS-SRRN		GRASP-LS-SRDRR			GVNS			SA-LS-SRRN			SA-LS-SRDRR		
	avg	min	time	avg	min	time	avg	min	time	avg	min	time	avg	min	time
DAFJS01	301770.20	300226	354.63	298861.80	298166	405.62	302442.00	302442	0.04	349464.40	334671	18.18	305532.10	301795	82.81
DAFJS02	791119.70	790009	173.35	785638.00	785255	282.53	848023.00	848023	0.01	869517.90	846444	0.00	810197.30	803057	267.73
DAFJS03	246838.10	242748	247.37	249788.00	247254	285.15	250024.00	250024	0.31	274083.80	264164	1.68	254197.80	250740	153.05
DAFJS04	598343.50	596308	239.34	606519.80	600931	269.62	607357.20	591938	0.09	650901.00	648716	0.01	613626.90	607903	116.75
DAFJS05	910763.50	903549	356.58	896325.40	884199	277.78	944824.30	923040	0.12	1165119.10	1106628	64.06	926345.40	916589	244.75
DAFJS06	366738.90	361993	282.42	366587.60	362859	278.41	378696.60	373905	0.20	419873.60	398849	16.48	373215.20	365884	174.07
DAFJS07	1170979.80	1145251	196.78	1179371.60	1172411	7.32	1167725.00	1167725	2.84	1204249.10	1203665	0.00	1193857.00	1171191	74.90
DAFJS08	1021910.20	1008773	265.93	1045361.50	1036970	313.12	1017545.40	1002267	1.00	1115241.20	1109447	0.00	1050771.40	1032513	115.85
DAFJS09	216696.60	216202	331.89	217884.90	215990	377.47	221318.60	221239	3.34	232865.50	223483	127.23	220566.90	218525	209.03
DAFJS10	764097.40	755553	391.23	768703.90	763202	360.85	817412.00	817412	0.16	914089.30	866545	0.62	791675.70	778362	151.55
DAFJS11	513658.30	508263	347.78	515674.00	515674	4.76	501103.90	500750	169.41	549446.00	549446	0.00	515006.90	507239	195.67
DAFJS12	459427.30	456208	418.11	468928.00	468928	10.87	451298.70	448080	200.26	514952.80	473911	16.02	465681.90	462919	153.11
DAFJS13	738750.90	731973	263.37	738093.00	733093	0.80	741704.00	741704	0.42	836670.80	750447	88.27	750024.60	743742	39.31
DAFJS14	1364178.40	1356675	392.86	1367248.20	1355482	275.20	1354338.00	1354338	0.34	1456081.00	1456081	0.00	1367838.70	1346328	150.59
DAFJS15	648976.50	642296	368.88	673346.30	661540	98.87	635879.20	633116	43.85	713609.70	693645	45.41	664104.00	658498	223.47
DAFJS16	863943.70	851458	343.29	888276.20	882816	138.75	834037.70	832294	9.71	944230.00	944230	0.00	889494.80	878970	123.36
DAFJS17	1416736.10	1402926	308.53	1430417.40	1409777	266.34	1412778.70	1399142	66.67	1709042.70	1708977	0.00	1450005.50	1417256	103.39
DAFJS18	328030.60	324916	351.50	330722.90	326884	240.74	341110.00	341110	1.10	390010.10	364904	80.23	341348.50	334741	224.23
DAFJS19	661350.60	653452	307.42	667361.60	658320	309.48	643783.00	643783	1.40	819081.00	819081	0.00	671586.40	659952	157.41
DAFJS20	736815.60	729864	290.06	741438.00	741438	2.15	746892.00	732822	2.77	819808.50	777477	6.48	755820.90	744116	298.22
DAFJS21	1347854.90	1331279	236.58	1340593.70	1339484	9.23	1307306.40	1297726	6.27	1438265.30	1353589	27.49	1384718.90	1354405	239.81
DAFJS22	1368721.60	1351612	302.64	1413492.10	1405048	191.43	1318134.10	1299489	12.25	1627211.70	1533901	10.83	1407852.50	1367893	143.45
DAFJS23	1252537.80	1237151	224.14	1252794.50	1200528	319.79	1221252.00	1221252	1.08	1350484.80	1339125	3.66	1287818.60	1252662	93.65
DAFJS24	802608.70	798804	335.70	814503.00	814503	5.28	787787.20	777520	3.97	875751.00	875751	0.00	809057.10	795098	45.09
DAFJS25	1513013.00	1494410	238.76	1501466.00	1501466	17.55	1438074.60	1424121	99.42	1616688.00	1616688	0.00	1545826.50	1508770	90.58
DAFJS26	889189.20	880468	315.77	908218.60	907342	45.88	851686.30	851321	16.55	967576.00	922026	32.96	898363.00	888327	228.00
DAFJS27	1060105.20	1042305	341.23	1070108.00	1070108	6.84	1040129.50	1025875	53.54	1120365.00	1120365	0.00	1097680.70	1077691	206.78
DAFJS28	387223.80	383366	325.30	387701.00	387701	2.70	384560.10	384508	80.25	441728.60	409382	59.93	394025.40	389110	183.90
DAFJS29	1002782.20	990368	260.52	1012975.30	1001842	51.71	988649.00	985749	3.10	1076412.60	1074483	0.00	1022915.70	1002734	171.88
DAFJS30	525346.00	521327	352.96	535935.70	528372	50.86	516564.00	516564	3.10	555644.00	555644	0.00	536415.00	528838	243.55
avg	809016.94	800324.43	305.50	815644.53	809252.77	163.57	802414.55	796975.97	26.12	900615.48	878058.83	19.98	826519.04	812194.93	163.53
wins		8			5			16			0			1	

instance	GRASP-LS-SRRN			GRASP-LS-SRDRR			GVNS			SA-LS-SRRN			SA-LS-SRDRR		
	avg	min	time	avg	min	time	avg	min	time	avg	min	time	avg	min	time
YFJS01	826505.50	823776	253.46	831394.20	828542	300.18	866443.10	866024	3.02	1040283.50	959334	1.38	900581.10	861254	126.15
YFJS02	873944.30	873416	216.90	870477.80	870221	187.73	883674.10	882643	0.03	950398.40	938676	0.07	891368.20	883709	203.29
YFJS03	862769.60	862728	206.31	862728.00	862728	9.65	897821.60	882468	0.01	966446.50	957996	0.00	886017.00	880340	150.30
YFJS04	326378.00	326378	10.28	326378.00	326378	6.69	349822.00	349822	0.01	351615.00	351615	0.00	333259.40	332173	168.43
YFJS05	649417.20	649050	236.20	649080.00	649050	206.05	670859.00	670859	0.02	764209.50	711330	0.34	667564.10	660846	78.94
YFJS06	843378.80	835453	202.91	834318.50	830331	319.51	860799.00	860799	0.05	935205.70	935135	0.00	869497.60	851140	164.38
YFJS07	946961.10	940976	367.80	940312.90	937858	353.59	957945.00	957945	0.04	1096720.40	1096454	0.00	980672.10	958126	68.81
YFJS08	820072.00	819528	245.25	819218.10	819211	177.38	879001.00	879001	0.04	1030229.10	1023408	0.00	851399.60	822674	99.06
YFJS09	778492.50	767276	305.97	769492.30	763059	311.27	768992.00	768992	0.07	848546.40	844816	0.00	834265.00	796816	38.41
YFJS10	985981.80	976164	363.56	970322.40	967469	390.19	976935.50	973152	0.07	1222847.70	1167064	1.46	1015606.50	983851	62.54
YFJS11	413860.20	411809	310.44	409849.10	408761	332.97	419622.00	419622	0.09	477867.00	477867	0.00	429963.70	417979	160.74
YFJS12	871025.70	865510	316.90	870560.20	863923	262.21	899858.00	899858	0.09	986592.50	965986	2.66	927624.20	893124	194.30
YFJS13	616214.20	612150	236.12	612992.70	603977	431.84	628330.90	621891	0.10	754546.00	754546	0.00	645509.20	627447	239.08
YFJS14	3311849.10	3244695	199.88	3371637.40	3370534	27.83	3213944.50	3201356	76.88	3441413.20	3366067	88.94	3435686.40	3391264	0.65
YFJS15	1394064.60	1387770	278.31	1433443.00	1409213	340.16	1415745.80	1414925	55.12	1575631.00	1575631	0.00	1505293.80	1491542	202.34
YFJS16	2391298.00	2391298	3.10	2432425.00	2432425	11.48	2387311.90	2386816	9.51	2461779.00	2461779	0.00	2461779.00	2461779	0.00
YFJS17	1510152.30	1471800	318.16	1554652.00	1554652	104.15	1490004.60	1489859	88.44	1587279.00	1587279	0.00	1577207.70	1547590	76.83
YFJS18	1477819.80	1437443	550.78	1520804.00	1520804	68.58	1470003.80	1468469	213.30	1661263.30	1658935	0.00	1570053.30	1549884	337.37
YFJS19	1755823.10	1736872	206.58	1747279.00	1747279	37.76	1638413.00	1638413	168.54	1798144.00	1798144	0.00	1785891.90	1771627	33.80
YFJS20	1211745.30	1199598	488.42	1280723.30	1257615	306.52	1284146.80	1235496	211.58	1533041.10	1531936	0.01	1374415.20	1352037	159.88
avg	1143387.66	1131684.50	265.87	1155404.40	1151201.50	209.29	1147983.68	1143420.50	41.35	1274202.92	1258199.90	4.74	1197182.75	1176760.10	128.27
wins		8			12			3			0			0	

Table S5: Results of applying the metaheuristics GRASP-LS-SRRN, GRASP-LS-SRDRR, GVNS, SA-LS-SRRN, and SA-LS-SRDRR to the 50 large-sized instances based on the instances introduced in [2], with learning rate $\alpha = 0.3$.

Instance	E	Effort measurement		
		#iterations	#B&B	CPU
DAFJS01	[283314.30, 385965] 26.60%	5992430	44704	3600.00
DAFJS02	[684350.06, 974925] 29.80%	9124262	41719	3600.01
DAFJS03	[244590.61, 364530] 32.90%	315367	540	3600.02
DAFJS04	[620099.24, 801999] 22.68%	453474	1085	3600.08
DAFJS05	[774248.32,1386048] 44.14%	1698052	3717	3600.01
DAFJS06	[319602.76, 554971] 42.41%	487353	1290	3600.00
DAFJS07	[961124.45,1610921] 40.34%	62778	11	3600.41
DAFJS08	[964298.61,1379296] 30.09%	89480	26	3600.77
DAFJS09	[209635.55, 324591] 35.42%	654953	1681	3600.02
DAFJS10	[575642.61,1335109] 56.88%	362148	515	3600.07
DAFJS11	[488334.59, 784540] 37.76%	69796	4	3600.64
DAFJS12	[436324.05, 695412] 37.26%	46581	7	3600.78
DAFJS13	[506756.19,1222775] 58.56%	290836	970	3600.01
DAFJS14	[825088.32,2475607] 66.67%	251115	140	3600.44
DAFJS15	[562116.30, 910621] 38.27%	44019	9	3600.63
DAFJS16	[768609.61,1269197] 39.44%	38245	4	3600.93
DAFJS17	[750881.02,2493735] 69.89%	141277	22	3600.18
DAFJS18	[295799.67, 492165] 39.90%	137029	50	3600.22
DAFJS19	[604957.70,1071785] 43.56%	137999	42	3600.30
DAFJS20	[571141.28,1121422] 49.07%	78382	37	3600.88
DAFJS21	[999123.48,2093205] 52.27%	44550	4	3600.99
DAFJS22	[1031352.01,2484982] 58.50%	19235	0	3602.17
DAFJS23	[1052692.80,1695613] 37.92%	109077	21	3600.22
DAFJS24	[652954.01,1122189] 41.81%	52126	10	3600.48
DAFJS25	[1175570.73,2260534] 48.00%	31189	1	3600.99
DAFJS26	[739220.97,1430891] 48.34%	32956	0	3603.95
DAFJS27	[818816.40,1585073] 48.34%	27718	1	3601.15
DAFJS28	[373217.07, 586826] 36.40%	58156	18	3600.54
DAFJS29	[837461.88,1410872] 40.64%	71216	14	3600.23
DAFJS30	[445035.50, 779578] 42.91%	71284	8	3600.42
YFJS01	[855110.12,1556831] 45.07%	2816931	10036	3602.07
YFJS02	[1024753.71,1110637] 7.73%	2901237	16500	3600.05
YFJS03	[960260.22,1002326] 4.20%	11594942	219854	3600.00
YFJS04	[349016.84, 383757] 9.05%	16591052	194515	3600.00
YFJS05	[682680.68, 798293] 14.48%	6826917	56450	3600.01
YFJS06	[750855.91,1094743] 31.41%	4521564	27772	3600.00
YFJS07	[984176.17,1161764] 15.29%	10802914	97215	3600.00
YFJS08	[894994.40, 936910] 4.47%	27961486	441031	3600.00
YFJS09	[662580.73, 887201] 25.32%	2582339	8724	3600.01
YFJS10	[960511.02,1172096] 18.05%	18598018	99695	3600.00
YFJS11	[458096.87, 502314] 8.80%	7587215	36102	3600.01
YFJS12	[851915.14,1106538] 23.01%	9449360	32397	3600.01
YFJS13	[599433.52, 763001] 21.44%	6449597	29272	3600.01
YFJS14	[3613880.70,4643837] 22.18%	69310	7	3600.33
YFJS15	[1487367.63,1944218] 23.50%	96038	45	3600.37
YFJS16	[2553807.92,3210592] 20.46%	85258	2	3600.25
YFJS17	[1518254.78,2095248] 27.54%	21236	0	3601.23
YFJS18	[1336069.36,2181882] 38.77%	30628	0	3601.84
YFJS19	[1500409.49,2405539] 37.63%	31328	0	3601.24
YFJS20	[1140540.32,1934417] 41.04%	28645	0	3601.18

Table S6: Result of applying CPLEX, with a 1-hour limit, to the 50 large-sized instances based on the instances introduced in [2], with learning rate $\alpha = 0.1$.

Instance	E		Effort measurement		
			#iterations	#B&B	CPU
DAFJS01	[221139.36, 351557]	37.10%	12791167	55959	3600.00
DAFJS02	[595921.83, 884216]	32.60%	15810313	81936	3600.00
DAFJS03	[190509.90, 326957]	41.73%	268875	542	3600.05
DAFJS04	[480310.47, 732403]	34.42%	1017679	1494	3600.00
DAFJS05	[588250.46,1127729]	47.84%	4946740	16376	3600.02
DAFJS06	[243717.68, 482408]	49.48%	1117917	1986	3600.00
DAFJS07	[683853.08,1363106]	49.83%	75453	10	3600.37
DAFJS08	[685298.36,1212890]	43.50%	113353	17	3600.28
DAFJS09	[160307.31, 269906]	40.61%	1277823	2483	3600.02
DAFJS10	[414804.34,1072639]	61.33%	327469	588	3600.04
DAFJS11	[346487.12, 671274]	48.38%	40688	4	3601.57
DAFJS12	[298616.25, 595425]	49.85%	18262	0	3604.44
DAFJS13	[353887.29, 941665]	62.42%	187790	211	3600.21
DAFJS14	[598180.54,1726319]	65.35%	157350	95	3600.24
DAFJS15	[390659.58, 819675]	52.34%	53144	10	3600.65
DAFJS16	[524225.29,1080644]	51.49%	38967	4	3600.57
DAFJS17	[549645.50,1984447]	72.30%	95248	17	3600.17
DAFJS18	[210313.33, 429178]	51.00%	118105	376	3600.22
DAFJS19	[433174.61, 894157]	51.55%	176546	74	3600.20
DAFJS20	[404804.80, 955193]	57.62%	74648	14	3600.37
DAFJS21	[684909.50,1789323]	61.72%	84219	8	3600.23
DAFJS22	[690906.52,1941166]	64.41%	73763	14	3600.40
DAFJS23	[745112.27,1547095]	51.84%	205500	67	3600.04
DAFJS24	[460395.91, 939479]	50.99%	76156	16	3600.28
DAFJS25	[795523.98,1855474]	57.13%	40602	1	3600.67
DAFJS26	[503300.48,1169559]	56.97%	37174	1	3601.13
DAFJS27	[561078.47,1370588]	59.06%	32741	1	3601.06
DAFJS28	[268228.65, 493245]	45.62%	58450	12	3600.45
DAFJS29	[593117.43,1312259]	54.80%	68586	11	3600.43
DAFJS30	[312508.47, 651746]	52.05%	61738	8	3600.14
YFJS01	[731493.14,1078525]	32.18%	6154387	20681	3600.00
YFJS02	[871572.84, 985698]	11.58%	11269560	59638	3600.00
YFJS03		915340	11734737	327595	1803.16
YFJS04	[314131.17, 388991]	19.24%	25415839	236720	3600.00
YFJS05	[627526.56, 723663]	13.28%	17780461	150146	3600.00
YFJS06	[709747.13, 967601]	26.65%	14235374	72866	3600.01
YFJS07	[815337.45,1085369]	24.88%	16440399	104822	3600.00
YFJS08	[801535.16, 873346]	8.22%	33275228	254277	3600.00
YFJS09	[562295.77, 862637]	34.82%	2330303	4792	3600.04
YFJS10	[867431.37,1055845]	17.84%	22610092	114002	3600.00
YFJS11	[384461.89, 462185]	16.82%	4076965	16798	3600.01
YFJS12	[710028.73,1107061]	35.86%	3170291	8792	3600.00
YFJS13	[514598.04, 716235]	28.15%	4546849	11706	3600.01
YFJS14	[2761758.64,4105898]	32.74%	50982	0	3600.05
YFJS15	[1203195.34,1718120]	29.97%	24009	0	3600.48
YFJS16	[2047388.51,2801929]	26.93%	30624	0	3600.63
YFJS17	[1101397.96,1849104]	40.44%	26324	0	3601.19
YFJS18	[956394.85,1889850]	49.39%	28580	0	3601.46
YFJS19	[1066111.35,2037505]	47.68%	28158	0	3601.55
YFJS20	[772709.10,1619887]	52.30%	29459	0	3601.08

Table S7: Result of applying CPLEX, with a 1-hour limit, to the 50 large-sized instances based on the instances introduced in [2], with learning rate $\alpha = 0.2$.

Instance	E		Effort measurement		
			#iterations	#B&B	CPU
DAFJS01	[184964.77, 343747]	46.19%	13218679	55849	3600.00
DAFJS02	[426168.47, 833805]	48.89%	15042207	47834	3600.01
DAFJS03	[144373.63, 274518]	47.41%	160582	522	3600.03
DAFJS04	[363678.47, 651093]	44.14%	536473	1030	3600.03
DAFJS05	[489000.47,1163847]	57.98%	4877200	8662	3600.00
DAFJS06	[184047.96, 429697]	57.17%	1681450	3328	3600.02
DAFJS07	[495355.55,1203685]	58.85%	96912	8	3600.37
DAFJS08	[490118.26,1115377]	56.06%	93297	15	3600.37
DAFJS09	[123498.45, 243071]	49.19%	916903	2644	3600.05
DAFJS10	[307103.06, 918988]	66.58%	287617	534	3600.06
DAFJS11	[249330.94, 548825]	54.57%	57763	6	3600.74
DAFJS12	[212983.80, 517092]	58.81%	36485	8	3601.52
DAFJS13	[255362.24, 849340]	69.93%	192715	137	3600.12
DAFJS14	[423141.82,1455826]	70.93%	233255	194	3600.17
DAFJS15	[275848.90, 715313]	61.44%	54387	7	3600.49
DAFJS16	[360953.04, 942925]	61.72%	46512	6	3601.07
DAFJS17	[374445.49,1708701]	78.09%	100524	17	3600.34
DAFJS18	[154376.77, 401530]	61.55%	106967	463	3600.29
DAFJS19	[308899.70, 818261]	62.25%	143499	71	3600.38
DAFJS20	[284740.31, 823982]	65.44%	74105	13	3600.34
DAFJS21	[470746.21,1448149]	67.49%	53976	4	3600.71
DAFJS22	[472128.73,1639315]	71.20%	45870	8	3600.99
DAFJS23	[540605.28,1351399]	60.00%	102169	19	3600.55
DAFJS24	[323920.88, 875168]	62.99%	56057	8	3600.45
DAFJS25	[532278.92,1616450]	67.07%	41527	4	3600.85
DAFJS26	[341334.14, 975574]	65.01%	47295	5	3601.34
DAFJS27	[386517.46,1119678]	65.48%	40367	4	3601.02
DAFJS28	[197665.56, 443205]	55.40%	62629	10	3600.88
DAFJS29	[416452.69,1075753]	61.29%	53457	12	3600.49
DAFJS30	[223418.91, 554958]	59.74%	59573	6	3600.35
YFJS01	[638630.00,1042669]	38.75%	3627026	20007	3600.03
YFJS02	[733034.97, 937044]	21.77%	6989486	19008	3600.00
YFJS03	[810517.24, 862240]	6.00%	24554393	281167	3600.00
YFJS04	[268775.38, 340854]	21.15%	19462434	143249	3600.00
YFJS05	[559095.98, 648858]	13.83%	14785531	103214	3600.00
YFJS06	[654171.21, 868915]	24.71%	10221123	47032	3600.01
YFJS07	[752734.63, 990469]	24.00%	10000561	55265	3600.00
YFJS08	[750272.11, 871262]	13.89%	26609818	187664	3600.01
YFJS09	[472544.10, 842391]	43.90%	1163991	3126	3600.02
YFJS10	[843892.41, 970637]	13.06%	20313513	68410	3600.01
YFJS11	[336266.65, 420053]	19.95%	8031770	24041	3600.01
YFJS12	[644502.52, 925474]	30.36%	8184485	18753	3600.00
YFJS13	[440317.45, 644327]	31.66%	6673327	15660	3600.01
YFJS14	[2133574.84,3463954]	38.41%	55132	0	3600.39
YFJS15	[973692.49,1570383]	38.00%	88409	14	3600.28
YFJS16	[1618266.73,2457112]	34.14%	72321	10	3600.17
YFJS17	[734763.53,1584996]	53.64%	28815	0	3601.87
YFJS18	[752964.51,1658190]	54.59%	31418	0	3602.03
YFJS19	[766725.29,1794759]	57.28%	34811	0	3601.10
YFJS20	[629296.14,1530027]	58.87%	34983	0	3601.26

Table S8: Result of applying CPLEX, with a 1-hour limit, to the 50 large-sized instances based on the instances introduced in [2], with learning rate $\alpha = 0.3$.

Instance	CPLEX	GVNS				GRASP-LS-SRRN			
	E	$\bar{E}$	gap (%)	E	gap (%)	$\bar{E}$	gap (%)	E	gap (%)
DAFJS01	*385965	381513.00	-1.15	381513	-1.15	357356.50	-7.41	356091	-7.74
DAFJS02	*974925	1026164.00	5.26	1026164	5.26	916256.90	-6.02	915414	-6.10
DAFJS03	*364530	334107.80	-8.35	321686	-11.75	318801.30	-12.54	312650	-14.23
DAFJS04	*801999	762860.00	-4.88	762860	-4.88	765735.10	-4.52	763939	-4.75
DAFJS05	*1386048	1217236.60	-12.18	1184816	-14.52	1162967.40	-16.09	1149932	-17.04
DAFJS06	*554971	481710.10	-13.20	480338	-13.45	472621.40	-14.84	468807	-15.53
DAFJS07	*1610921	1417326.90	-12.02	1413045	-12.28	1484367.60	-7.86	1455664	-9.64
DAFJS08	*1379296	1302967.10	-5.53	1300682	-5.70	1317916.40	-4.45	1309998	-5.02
DAFJS09	*324591	288691.20	-11.06	284310	-12.41	281369.70	-13.32	279638	-13.85
DAFJS10	*1335109	1078861.70	-19.19	1038592	-22.21	1040623.40	-22.06	1022374	-23.42
DAFJS11	*784540	689780.50	-12.08	689345	-12.13	700081.30	-10.77	693628	-11.59
DAFJS12	*695412	657428.70	-5.46	642203	-7.65	647501.40	-6.89	640264	-7.93
DAFJS13	*1222775	1017534.90	-16.78	1004936	-17.82	1025950.00	-16.10	1015701	-16.93
DAFJS14	*2475607	1847660.00	-25.37	1847660	-25.37	1893849.20	-23.50	1870370	-24.45
DAFJS15	*910621	856025.00	-6.00	855450	-6.06	869923.20	-4.47	855517	-6.05
DAFJS16	*1269197	1152936.60	-9.16	1130400	-10.94	1177343.60	-7.24	1171374	-7.71
DAFJS17	*2493735	1999228.90	-19.83	1980371	-20.59	2073750.80	-16.84	2055160	-17.59
DAFJS18	*492165	465612.20	-5.40	461406	-6.25	464375.60	-5.65	461164	-6.30
DAFJS19	*1071785	897395.20	-16.27	862054	-19.57	858383.30	-19.91	842210	-21.42
DAFJS20	*1121422	1025928.30	-8.52	1005295	-10.36	1014813.10	-9.51	996885	-11.11
DAFJS21	*2093205	1809654.00	-13.55	1803135	-13.86	1899440.90	-9.26	1866121	-10.85
DAFJS22	*2484982	1920216.70	-22.73	1862004	-25.07	2002338.00	-19.42	1973165	-20.60
DAFJS23	*1695613	1578709.00	-6.89	1561330	-7.92	1585246.70	-6.51	1569910	-7.41
DAFJS24	*1122189	1009699.00	-10.02	1009699	-10.02	1048411.60	-6.57	1035937	-7.69
DAFJS25	*2260534	2089110.20	-7.58	1977467	-12.52	2078253.40	-8.06	2053082	-9.18
DAFJS26	*1430891	1173758.40	-17.97	1126449	-21.28	1219716.00	-14.76	1206258	-15.70
DAFJS27	*1585073	1477514.10	-6.79	1419795	-10.43	1490170.20	-5.99	1477591	-6.78
DAFJS28	*586826	509252.00	-13.22	509252	-13.22	525346.20	-10.48	520893	-11.24
DAFJS29	*1410872	1281313.80	-9.18	1259044	-10.76	1304977.00	-7.51	1290580	-8.53
DAFJS30	*779578	676938.10	-13.17	672631	-13.72	688454.90	-11.69	685122	-12.12
YFJS01	*1556831	1098212.20	-29.46	1055598	-32.20	1041508.10	-33.10	1035567	-33.48
YFJS02	*1110637	1092061.00	-1.67	1092061	-1.67	1086636.60	-2.16	1082569	-2.53
YFJS03	*1002326	1020233.40	1.79	1017180	1.48	999984.90	-0.23	999678	-0.26
YFJS04	*383757	393271.00	2.48	393271	2.48	383110.00	-0.17	379209	-1.19
YFJS05	*798293	791300.70	-0.88	785985	-1.54	784912.20	-1.68	779315	-2.38
YFJS06	*1094743	1045952.00	-4.46	1045952	-4.46	995751.40	-9.04	988712	-9.69
YFJS07	*1161764	1175181.00	1.15	1175181	1.15	1145285.90	-1.42	1139305	-1.93
YFJS08	*936910	962835.00	2.77	962835	2.77	920471.60	-1.75	920031	-1.80
YFJS09	*887201	868605.00	-2.10	868605	-2.10	865324.40	-2.47	853126	-3.84
YFJS10	*1172096	1160764.10	-0.97	1145258	-2.29	1144828.80	-2.33	1140994	-2.65
YFJS11	*502314	505969.00	0.73	505969	0.73	496104.20	-1.24	493766	-1.70
YFJS12	*1106538	1119676.00	1.19	1119676	1.19	1058578.10	-4.33	1044937	-5.57
YFJS13	*763001	733181.00	-3.91	733181	-3.91	724714.40	-5.02	720730	-5.54
YFJS14	*4643837	4275240.30	-7.94	4260379	-8.26	4365818.60	-5.99	4264682	-8.16
YFJS15	*1944218	1859602.40	-4.35	1851356	-4.78	1806478.60	-7.08	1768464	-9.04
YFJS16	*3210592	3093383.70	-3.65	3089376	-3.78	3099530.00	-3.46	3099530	-3.46
YFJS17	*2095248	2008191.00	-4.15	1956176	-6.64	2039134.90	-2.68	2004861	-4.31
YFJS18	*2181882	1944262.00	-10.89	1843451	-15.51	2016752.30	-7.57	1980878	-9.21
YFJS19	*2405539	2231913.40	-7.22	2231667	-7.23	2342981.10	-2.60	2290121	-4.80
YFJS20	*1934417	1560360.40	-19.34	1548237	-19.96	1583769.10	-18.13	1562730	-19.21

Table S9: Result of applying the metaheuristics GVNS and GRASP-LS-SRRN to the 50 large-sized instances based on the instances introduced in [2], with learning rate $\alpha = 0.1$.

Instance	CPLEX	GVNS				GRASP-LS-SRRN			
	E	$\bar{E}$	gap (%)	E	gap (%)	$\bar{E}$	gap (%)	E	gap (%)
DAFJS01	*351557	344495.00	-2.01	344495	-2.01	326744.30	-7.06	321581	-8.53
DAFJS02	*884216	884615.00	0.05	884615	0.05	854294.40	-3.38	854226	-3.39
DAFJS03	*326957	297151.00	-9.12	297151	-9.12	283235.30	-13.37	280219	-14.29
DAFJS04	*732403	673371.00	-8.06	673034	-8.11	676612.00	-7.62	675305	-7.80
DAFJS05	*1127729	1087874.90	-3.53	1051766	-6.74	1027245.40	-8.91	1001927	-11.16
DAFJS06	*482408	431876.00	-10.47	431876	-10.47	418238.20	-13.30	412663	-14.46
DAFJS07	*1363106	1238599.00	-9.13	1238599	-9.13	1313128.50	-3.67	1282775	-5.89
DAFJS08	*1212890	1161290.00	-4.25	1161290	-4.25	1156466.70	-4.65	1149401	-5.23
DAFJS09	*269906	251943.50	-6.66	251409	-6.85	248753.70	-7.84	248078	-8.09
DAFJS10	*1072639	928251.30	-13.46	892697	-16.78	888413.40	-17.17	878454	-18.10
DAFJS11	*671274	596542.60	-11.13	596225	-11.18	600534.80	-10.54	591252	-11.92
DAFJS12	*595425	545316.50	-8.42	545228	-8.43	547187.90	-8.10	544438	-8.56
DAFJS13	*941665	876727.00	-6.90	876727	-6.90	868319.50	-7.79	861432	-8.52
DAFJS14	*1726319	1580002.10	-8.48	1577084	-8.64	1593036.10	-7.72	1582708	-8.32
DAFJS15	*819675	742426.00	-9.42	726665	-11.35	748278.00	-8.71	742111	-9.46
DAFJS16	*1080644	988626.10	-8.52	975163	-9.76	1007616.30	-6.76	991870	-8.21
DAFJS17	*1984447	1675212.90	-15.58	1672217	-15.73	1709995.40	-13.83	1691507	-14.76
DAFJS18	*429178	389779.30	-9.18	384568	-10.39	391223.00	-8.84	387881	-9.62
DAFJS19	*894157	751436.30	-15.96	750844	-16.03	750787.00	-16.03	738799	-17.37
DAFJS20	*955193	835637.70	-12.52	828173	-13.30	860534.60	-9.91	852285	-10.77
DAFJS21	*1789323	1545123.40	-13.65	1538564	-14.01	1596698.00	-10.77	1585909	-11.37
DAFJS22	*1941166	1614673.00	-16.82	1565476	-19.35	1639132.50	-15.56	1617087	-16.70
DAFJS23	*1547095	1355501.00	-12.38	1355501	-12.38	1401674.50	-9.40	1378545	-10.89
DAFJS24	*939479	892025.00	-5.05	891204	-5.14	910241.60	-3.11	909284	-3.21
DAFJS25	*1855474	1669245.00	-10.04	1669245	-10.04	1761569.10	-5.06	1726490	-6.95
DAFJS26	*1169559	987707.10	-15.55	985798	-15.71	1037468.70	-11.29	1028980	-12.02
DAFJS27	*1370588	1228340.60	-10.38	1228229	-10.39	1249992.20	-8.80	1234049	-9.96
DAFJS28	*493245	451818.80	-8.40	447590	-9.26	453098.70	-8.14	449639	-8.84
DAFJS29	*1312259	1103131.00	-15.94	1103131	-15.94	1136490.40	-13.39	1121644	-14.53
DAFJS30	*651746	612090.40	-6.08	589720	-9.52	601648.70	-7.69	596701	-8.45
YFJS01	*1078525	946395.50	-12.25	937930	-13.04	931842.60	-13.60	920641	-14.64
YFJS02	*985698	973057.00	-1.28	973057	-1.28	972642.20	-1.32	971294	-1.46
YFJS03	915340	956532.80	4.50	951763	3.98	916183.00	0.09	916183	0.09
YFJS04	*388991	365935.00	-5.93	365935	-5.93	352761.20	-9.31	352610	-9.35
YFJS05	*723663	717565.70	-0.84	716793	-0.95	716443.30	-1.00	715089	-1.18
YFJS06	*967601	955129.00	-1.29	955129	-1.29	919544.80	-4.97	912536	-5.69
YFJS07	*1085369	1099970.00	1.35	1099970	1.35	1051093.70	-3.16	1046924	-3.54
YFJS08	*873346	874305.00	0.11	874305	0.11	871510.80	-0.21	867730	-0.64
YFJS09	*862637	836818.70	-2.99	831452	-3.62	820669.80	-4.86	817340	-5.25
YFJS10	*1055845	1160812.00	9.94	1160812	9.94	1066003.40	0.96	1058652	0.27
YFJS11	*462185	459065.30	-0.67	457613	-0.99	453481.80	-1.88	451783	-2.25
YFJS12	*1107061	1024383.00	-7.47	1024383	-7.47	960290.80	-13.26	948247	-14.35
YFJS13	*716235	710383.30	-0.82	693736	-3.14	665870.70	-7.03	659996	-7.85
YFJS14	*4105898	3800029.70	-7.45	3696869	-9.96	3802489.10	-7.39	3762242	-8.37
YFJS15	*1718120	1556372.00	-9.41	1556372	-9.41	1581320.60	-7.96	1572551	-8.47
YFJS16	*2801929	2751015.00	-1.82	2751015	-1.82	2752018.20	-1.78	2702565	-3.55
YFJS17	*1849104	1672768.00	-9.54	1672768	-9.54	1732423.00	-6.31	1705111	-7.79
YFJS18	*1889850	1636590.20	-13.40	1635159	-13.48	1723728.90	-8.79	1701929	-9.94
YFJS19	*2037505	1906795.00	-6.42	1906795	-6.42	2000490.20	-1.82	1968497	-3.39
YFJS20	*1619887	1379946.40	-14.81	1376635	-15.02	1381649.50	-14.71	1337624	-17.42

Table S10: Result of applying the metaheuristics GVNS and GRASP-LS-SRRN to the 50 large-sized instances based on the instances introduced in [2], with learning rate $\alpha = 0.2$.

Instance	CPLEX	GVNS				GRASP-LS-SRRN			
	E	E	gap (%)	E	gap (%)	E	gap (%)	E	gap (%)
DAFJS01	*343747	302442.00	-12.02	302442	-12.02	301770.20	-12.21	300226	-12.66
DAFJS02	*833805	848023.00	1.71	848023	1.71	791119.70	-5.12	790009	-5.25
DAFJS03	*274518	250024.00	-8.92	250024	-8.92	246838.10	-10.08	242748	-11.57
DAFJS04	*651093	607357.20	-6.72	591938	-9.09	598343.50	-8.10	596308	-8.41
DAFJS05	*1163847	944824.30	-18.82	923040	-20.69	910763.50	-21.75	903549	-22.37
DAFJS06	*429697	378696.60	-11.87	373905	-12.98	366738.90	-14.65	361993	-15.76
DAFJS07	*1203685	1167725.00	-2.99	1167725	-2.99	1170979.80	-2.72	1145251	-4.85
DAFJS08	*1115377	1017545.40	-8.77	1002267	-10.14	1021910.20	-8.38	1008773	-9.56
DAFJS09	*243071	221318.60	-8.95	221239	-8.98	216696.60	-10.85	216202	-11.05
DAFJS10	*918988	817412.00	-11.05	817412	-11.05	764097.40	-16.85	755553	-17.78
DAFJS11	*548825	501103.90	-8.70	500750	-8.76	513658.30	-6.41	508263	-7.39
DAFJS12	*517092	451298.70	-12.72	448080	-13.35	459427.30	-11.15	456208	-11.77
DAFJS13	*849340	741704.00	-12.67	741704	-12.67	738750.90	-13.02	731973	-13.82
DAFJS14	*1455826	1354338.00	-6.97	1354338	-6.97	1364178.40	-6.30	1356675	-6.81
DAFJS15	*715313	635879.20	-11.10	633116	-11.49	648976.50	-9.27	642296	-10.21
DAFJS16	*942925	834037.70	-11.55	832294	-11.73	863943.70	-8.38	851458	-9.70
DAFJS17	*1708701	1412778.70	-17.32	1399142	-18.12	1416736.10	-17.09	1402926	-17.90
DAFJS18	*401530	341110.00	-15.05	341110	-15.05	328030.60	-18.30	324916	-19.08
DAFJS19	*818261	643783.00	-21.32	643783	-21.32	661350.60	-19.18	653452	-20.14
DAFJS20	*823982	746892.00	-9.36	732822	-11.06	736815.60	-10.58	729864	-11.42
DAFJS21	*1448149	1307306.40	-9.73	1297726	-10.39	1347854.90	-6.93	1331279	-8.07
DAFJS22	*1639315	1318134.10	-19.59	1299489	-20.73	1368721.60	-16.51	1351612	-17.55
DAFJS23	*1351399	1221252.00	-9.63	1221252	-9.63	1252537.80	-7.32	1237151	-8.45
DAFJS24	*875168	787787.20	-9.98	777520	-11.16	802608.70	-8.29	798804	-8.73
DAFJS25	*1616450	1438074.60	-11.04	1424121	-11.90	1513013.00	-6.40	1494410	-7.55
DAFJS26	*975574	851686.30	-12.70	851321	-12.74	889189.20	-8.85	880468	-9.75
DAFJS27	*1119678	1040129.50	-7.10	1025875	-8.38	1060105.20	-5.32	1042305	-6.91
DAFJS28	*443205	384560.10	-13.23	384508	-13.24	387223.80	-12.63	383366	-13.50
DAFJS29	*1075753	988649.00	-8.10	985749	-8.37	1002782.20	-6.78	990368	-7.94
DAFJS30	*554958	516564.00	-6.92	516564	-6.92	525346.00	-5.34	521327	-6.06
YFJS01	*1042669	866443.10	-16.90	866024	-16.94	826505.50	-20.73	823776	-20.99
YFJS02	*937044	883674.10	-5.70	882643	-5.81	873944.30	-6.73	873416	-6.79
YFJS03	*862240	897821.60	4.13	882468	2.35	862769.60	0.06	862728	0.06
YFJS04	*340854	349822.00	2.63	349822	2.63	326378.00	-4.25	326378	-4.25
YFJS05	*648858	670859.00	3.39	670859	3.39	649417.20	0.09	649050	0.03
YFJS06	*868915	860799.00	-0.93	860799	-0.93	843378.80	-2.94	835453	-3.85
YFJS07	*990469	957945.00	-3.28	957945	-3.28	946961.10	-4.39	940976	-5.00
YFJS08	*871262	879001.00	0.89	879001	0.89	820072.00	-5.88	819528	-5.94
YFJS09	*842391	768992.00	-8.71	768992	-8.71	778492.50	-7.59	767276	-8.92
YFJS10	*970637	976935.50	0.65	973152	0.26	985981.80	1.58	976164	0.57
YFJS11	*420053	419622.00	-0.10	419622	-0.10	413860.20	-1.47	411809	-1.96
YFJS12	*925474	899858.00	-2.77	899858	-2.77	871025.70	-5.88	865510	-6.48
YFJS13	*644327	628330.90	-2.48	621891	-3.48	616214.20	-4.36	612150	-4.99
YFJS14	*3463954	3213944.50	-7.22	3201356	-7.58	3311849.10	-4.39	3244695	-6.33
YFJS15	*1570383	1415745.80	-9.85	1414925	-9.90	1394064.60	-11.23	1387770	-11.63
YFJS16	*2457112	2387311.90	-2.84	2386816	-2.86	2391298.00	-2.68	2391298	-2.68
YFJS17	*1584996	1490004.60	-5.99	1489859	-6.00	1510152.30	-4.72	1471800	-7.14
YFJS18	*1658190	1470003.80	-11.35	1468469	-11.44	1477819.80	-10.88	1437443	-13.31
YFJS19	*1794759	1638413.00	-8.71	1638413	-8.71	1755823.10	-2.17	1736872	-3.23
YFJS20	*1530027	1284146.80	-16.07	1235496	-19.25	1211745.30	-20.80	1199598	-21.60

Table S11: Result of applying the metaheuristics GVNS and GRASP-LS-SRRN to the 50 large-sized instances based on the instances introduced in [2], with learning rate $\alpha = 0.3$.

Main instance characteristics								MILP formulation			
Instance	$\|\mathcal{F}\|$	$\|\mathcal{O}\|$	n	$\|\widehat{A}\|$	$\sum_{i\in\mathcal{O}}\mathcal{F}_i$	ω_1	ω_2	#binary variables	#continuous variables	#constraints	#additional constraints
miniDAFJS01	5	14	2	14	44	0.54	0.54	431	113	3,963	39
miniDAFJS02	5	11	2	9	35	0.57	0.55	281	89	2,179	30
miniDAFJS03	5	10	2	12	31	0.50	0.53	223	79	1,575	26
miniDAFJS04	5	9	2	9	29	0.25	0.56	199	73	1,363	24
miniDAFJS05	5	15	2	15	38	0.39	0.38	343	103	3,061	33
miniDAFJS06	5	14	2	14	46	0.20	0.57	489	117	4,961	41
miniDAFJS07	5	11	2	10	34	0.23	0.52	269	87	2,080	29
miniDAFJS08	5	9	2	8	24	0.42	0.42	141	63	874	19
miniDAFJS09	5	15	2	13	47	0.63	0.53	507	121	5,243	42
miniDAFJS10	5	11	2	10	32	0.28	0.48	235	83	1,676	27
miniDAFJS11	5	18	2	16	43	0.45	0.35	447	119	4,579	38
miniDAFJS12	5	12	2	12	38	0.55	0.54	331	97	2,779	33
miniDAFJS13	5	10	2	8	27	0.58	0.43	171	71	1,099	22
miniDAFJS14	5	14	2	12	44	0.50	0.54	433	113	4,009	39
miniDAFJS15	5	11	2	11	35	0.40	0.55	291	89	2,403	30
miniDAFJS16	5	13	2	12	42	0.18	0.56	395	107	3,500	37
miniDAFJS17	5	11	2	11	30	0.13	0.43	219	79	1,627	25
miniDAFJS18	5	11	2	10	34	0.38	0.52	263	87	1,954	29
miniDAFJS19	5	12	2	10	36	0.30	0.50	303	93	2,505	31
miniDAFJS20	5	13	2	11	40	0.54	0.52	385	103	3,635	35
miniDAFJS21	5	19	3	20	60	0.52	0.54	785	155	9,592	55
miniDAFJS22	5	18	3	18	57	0.22	0.54	717	147	8,501	52
miniDAFJS23	5	21	3	18	66	0.53	0.54	935	171	12,260	61
miniDAFJS24	5	18	3	17	56	0.36	0.53	693	145	8,082	51
miniDAFJS25	5	17	3	17	51	0.12	0.50	581	133	6,271	46
miniDAFJS26	5	17	3	15	53	0.36	0.53	621	137	6,817	48
miniDAFJS27	5	19	3	16	57	0.46	0.50	773	149	10,434	52
miniDAFJS28	5	16	3	15	48	0.54	0.50	511	125	5,102	43
miniDAFJS29	5	14	3	15	47	0.33	0.59	493	119	4,858	42
miniDAFJS30	5	22	3	21	61	0.32	0.44	847	163	11,322	56
miniYFJS01	7	16	4	12	54	0.25	0.40	467	135	3,805	47
miniYFJS02	7	16	4	12	44	0.33	0.29	331	115	2,499	37
miniYFJS03	7	16	4	12	45	0.08	0.30	371	117	3,121	38
miniYFJS04	7	16	4	12	53	0.25	0.39	485	133	4,329	46
miniYFJS05	7	16	4	12	55	0.50	0.41	505	137	4,505	48
miniYFJS06	7	16	4	12	51	0.42	0.36	451	129	4,009	44
miniYFJS07	7	16	4	12	48	0.17	0.33	391	123	3,133	41
miniYFJS08	7	16	4	12	49	0.50	0.34	405	125	3,263	42
miniYFJS09	7	16	4	12	51	0.33	0.36	443	129	3,805	44
miniYFJS10	7	16	4	12	59	0.17	0.45	561	145	5,043	52
miniYFJS11	7	20	5	15	56	0.13	0.30	513	147	4,506	49
miniYFJS12	7	20	5	15	68	0.13	0.40	777	171	8,688	61
miniYFJS13	7	20	5	15	69	0.40	0.41	785	173	8,602	62
miniYFJS14	7	20	5	15	59	0.60	0.33	561	153	5,052	52
miniYFJS15	7	20	5	15	53	0.33	0.28	475	141	4,194	46
miniYFJS16	7	20	5	15	63	0.40	0.36	673	161	7,138	56
miniYFJS17	7	20	5	15	57	0.27	0.31	535	149	4,846	50
miniYFJS18	7	20	5	15	51	0.07	0.26	439	137	3,754	44
miniYFJS19	7	20	5	15	58	0.47	0.32	563	151	5,306	51
miniYFJS20	7	20	5	15	62	0.53	0.35	693	159	7,590	55
miniYFJS21	7	24	6	18	72	0.28	0.33	821	187	8,815	65
miniYFJS22	7	24	6	18	82	0.28	0.40	1,071	207	13,361	75
miniYFJS23	7	24	6	18	78	0.17	0.38	979	199	11,659	71
miniYFJS24	7	24	6	18	62	0.28	0.26	643	167	6,435	55
miniYFJS25	7	24	6	18	76	0.17	0.36	905	195	10,055	69
miniYFJS26	7	24	6	18	67	0.33	0.30	753	177	8,165	60
miniYFJS27	7	24	6	18	81	0.39	0.40	1,025	205	12,103	74
miniYFJS28	7	24	6	18	67	0.22	0.30	721	177	7,325	60
miniYFJS29	7	24	6	18	80	0.39	0.39	1,007	203	11,925	73
miniYFJS30	7	24	6	18	72	0.44	0.33	865	187	10,105	65

Table S12: Main features of the proposed sixty small-sized instances.

Instance	E	Effort measurement		
		#iterations	#B&B	CPU
miniDAFJS01	409516	515019	12445	44.60
miniDAFJS02	311058	150695	5201	11.45
miniDAFJS03	514080	95028	4138	6.39
miniDAFJS04	210783	8930	683	0.52
miniDAFJS05	496996	255940	8850	35.21
miniDAFJS06	469580	326805	5320	49.30
miniDAFJS07	731271	36149	1572	1.90
miniDAFJS08	196320	4138	344	0.28
miniDAFJS09	730958	758775	16769	96.47
miniDAFJS10	355354	17064	912	1.13
miniDAFJS11	197969	7116183	217273	840.68
miniDAFJS12	310413	427447	7841	37.57
miniDAFJS13	82093	19632	1211	0.88
miniDAFJS14	284161	876381	24560	100.29
miniDAFJS15	464428	96225	3917	10.79
miniDAFJS16	600539	143447	4093	21.04
miniDAFJS17	385868	12970	486	1.60
miniDAFJS18	162179	121462	4554	14.04
miniDAFJS19	384487	40066	1413	2.50
miniDAFJS20	777932	239726	5030	50.28
miniDAFJS21	[337869.35, 354010] 4.56%	25145123	528446	3600.00
miniDAFJS22	603100	11444515	319287	1766.48
miniDAFJS23	[323954.82, 366852] 11.69%	26925157	239725	3600.00
miniDAFJS24	308993	4912883	133608	835.12
miniDAFJS25	527221	1421853	14885	147.53
miniDAFJS26	227795	13942515	388944	1648.39
miniDAFJS27	[448476.86, 464057] 3.36%	23590927	452323	3600.00
miniDAFJS28	287236	22890065	946024	2637.30
miniDAFJS29	438458	377263	13192	55.48
miniDAFJS30	[625032.56, 678276] 7.85%	24143289	282689	3600.00
miniYFJS01	905588	34299	1147	1.99
miniYFJS02	762944	11148	520	0.98
miniYFJS03	575262	118754	4075	14.55
miniYFJS04	710795	62372	2376	5.44
miniYFJS05	210624	16054	687	1.75
miniYFJS06	851682	70185	2739	10.45
miniYFJS07	1188929	56967	3024	13.47
miniYFJS08	355526	29397	1244	4.17
miniYFJS09	443890	129731	4264	31.69
miniYFJS10	688192	412935	6841	115.89
miniYFJS11	1227681	674229	11204	168.29
miniYFJS12	[298667.60, 299343] 0.23%	19235655	334901	3600.00
miniYFJS13	317814	86895	3380	32.32
miniYFJS14	652589	633541	19275	106.53
miniYFJS15	951706	198711	4230	26.60
miniYFJS16	516296	673908	18935	118.34
miniYFJS17	933706	561401	22129	99.26
miniYFJS18	791358	225800	4159	31.29
miniYFJS19	706846	2480756	85867	333.62
miniYFJS20	699032	601285	12164	139.24
miniYFJS21	611668	12046374	238234	2587.82
miniYFJS22	522949	17833406	337418	3336.38
miniYFJS23	[1159817.47,1254568] 7.55%	21493974	319997	3600.00
miniYFJS24	[406944.15, 409399] 0.60%	26017988	720352	3600.00
miniYFJS25	[1072493.88,1114739] 3.79%	19915497	339431	3600.00
miniYFJS26	[1444851.59,1454196] 0.64%	24256548	435425	3600.00
miniYFJS27	1066459	1063622	30389	244.38
miniYFJS28	834489	1167115	32175	197.27
miniYFJS29	799019	2034532	36961	315.66
miniYFJS30	355579	2075355	71933	366.82

Table S13: Result of applying CPLEX, with a 1-hour limit, to the 60 small-sized instances based on the instances introduced in [1], with learning rate $\alpha = 0.1$.

Instance	E	Effort measurement		
		#iterations	#B&B	CPU
miniDAFJS01	375660	499615	12671	48.06
miniDAFJS02	288599	168503	6156	13.72
miniDAFJS03	484797	111335	5185	9.76
miniDAFJS04	203524	19195	1005	0.88
miniDAFJS05	473622	504493	9695	57.84
miniDAFJS06	444208	2863933	83692	651.31
miniDAFJS07	710142	65182	2122	10.74
miniDAFJS08	188010	2493	192	0.35
miniDAFJS09	680728	629490	17636	142.15
miniDAFJS10	339724	37216	1485	3.36
miniDAFJS11	184256	12437385	438951	1619.15
miniDAFJS12	303195	898660	27534	78.71
miniDAFJS13	77621	37199	2378	1.54
miniDAFJS14	269270	1334713	43483	134.13
miniDAFJS15	441412	132900	4488	10.74
miniDAFJS16	566735	266513	5801	29.21
miniDAFJS17	369925	40423	1760	3.37
miniDAFJS18	155294	185157	6246	13.65
miniDAFJS19	365490	203889	4216	17.99
miniDAFJS20	732288	644172	19124	65.05
miniDAFJS21	[307560.64, 327253] 6.02%	25938670	436351	3600.00
miniDAFJS22	[498118.21, 563519] 11.61%	29051461	450741	3600.00
miniDAFJS23	[293508.64, 348906] 15.88%	25142900	230941	3600.00
miniDAFJS24	[264750.38, 283921] 6.75%	32693765	598426	3600.00
miniDAFJS25	490446	1573635	18800	179.54
miniDAFJS26	[201662.20, 217068] 7.10%	34274841	750395	3600.00
miniDAFJS27	[401361.60, 433868] 7.49%	25970667	372312	3600.00
miniDAFJS28	[256753.37, 270568] 5.11%	41825472	1012911	3600.00
miniDAFJS29	417056	497170	14050	45.37
miniDAFJS30	[556081.43, 643875] 13.64%	28501320	314336	3600.00
miniYFJS01	873923	76674	3156	11.09
miniYFJS02	727141	16699	1009	1.48
miniYFJS03	528439	204118	6145	19.00
miniYFJS04	689509	64435	2430	10.13
miniYFJS05	205710	22309	1441	3.38
miniYFJS06	834944	131949	5629	16.57
miniYFJS07	1106387	50244	2367	6.96
miniYFJS08	336964	264839	12796	33.23
miniYFJS09	423411	370247	11716	58.30
miniYFJS10	658796	732386	15370	97.58
miniYFJS11	1153056	305301	4404	35.88
miniYFJS12	[275820.84, 284212] 2.95%	24678369	407468	3600.00
miniYFJS13	293352	358387	10933	71.91
miniYFJS14	616634	2231083	64101	266.56
miniYFJS15	880131	150246	3540	23.85
miniYFJS16	485139	252481	8249	50.57
miniYFJS17	895041	1432615	49963	203.59
miniYFJS18	755926	404612	6081	46.17
miniYFJS19	662479	7363461	207021	932.52
miniYFJS20	661088	1941072	54887	448.45
miniYFJS21	[523754.47, 576956] 9.22%	27394246	260475	3600.00
miniYFJS22	481375	5770616	117564	1242.48
miniYFJS23	[1070376.80,1183726] 9.58%	22569626	243774	3600.00
miniYFJS24	[356593.10, 382974] 6.89%	39123114	597929	3600.00
miniYFJS25	[988526.49,1054743] 6.28%	22460220	371274	3600.00
miniYFJS26	1350819	11827818	305100	1553.69
miniYFJS27	998238	7131454	154568	1293.90
miniYFJS28	791090	7926984	207604	1129.67
miniYFJS29	[719250.33, 736775] 2.38%	27192253	506496	3600.00
miniYFJS30	[334284.54, 337541] 0.96%	26526146	695760	3600.00

Table S14: Result of applying CPLEX, with a 1-hour limit, to the 60 small-sized instances based on the instances introduced in [1], with learning rate $\alpha = 0.2$.

Instance	E	Effort measurement		
		#iterations	#B&B	CPU
miniDAFJS01	342296	994716	18794	94.57
miniDAFJS02	270626	168403	6283	13.50
miniDAFJS03	455596	94852	3042	6.84
miniDAFJS04	196152	29568	1643	1.27
miniDAFJS05	452344	3125594	75091	323.51
miniDAFJS06	427759	14111087	423282	1607.35
miniDAFJS07	687145	168464	5222	13.96
miniDAFJS08	179781	8556	410	0.31
miniDAFJS09	640449	1476635	31209	159.91
miniDAFJS10	321378	75786	2441	6.77
miniDAFJS11	[170312.94, 173093] 1.61%	28185309	738670	3600.00
miniDAFJS12	295741	2243665	90246	196.84
miniDAFJS13	72867	32819	2526	1.42
miniDAFJS14	253244	1404317	44572	122.48
miniDAFJS15	413722	156050	6195	12.54
miniDAFJS16	546718	2440862	72476	308.78
miniDAFJS17	356866	58884	2262	4.70
miniDAFJS18	148363	265756	6996	18.94
miniDAFJS19	349140	186852	5523	18.98
miniDAFJS20	694262	738617	17826	81.59
miniDAFJS21	[231590.83, 314402] 26.34%	25364560	305881	3600.00
miniDAFJS22	[489261.57, 522881] 6.43%	26782104	434648	3600.00
miniDAFJS23	[249182.96, 325738] 23.50%	26312035	196387	3600.00
miniDAFJS24	[225332.14, 271273] 16.94%	34074626	520172	3600.00
miniDAFJS25	[406871.49, 470740] 13.57%	29328122	299472	3600.00
miniDAFJS26	[180372.90, 203355] 11.30%	35710194	787146	3600.00
miniDAFJS27	[355815.86, 405306] 12.21%	32019281	351350	3600.00
miniDAFJS28	[246641.75, 257078] 4.06%	45783801	1543356	3600.00
miniDAFJS29	392199	1183134	39432	100.37
miniDAFJS30	[454967.43, 576770] 21.12%	31754651	262303	3600.00
miniYFJS01	830595	135607	3836	18.49
miniYFJS02	696436	83820	2825	9.49
miniYFJS03	486014	178866	7716	21.80
miniYFJS04	665706	72979	2652	12.66
miniYFJS05	200793	408299	16784	65.85
miniYFJS06	800252	128688	4411	17.13
miniYFJS07	1033902	23634	1101	2.36
miniYFJS08	320851	465300	14944	51.52
miniYFJS09	407324	878085	20485	119.07
miniYFJS10	638089	1176627	24902	155.85
miniYFJS11	1098125	364482	9242	47.81
miniYFJS12	[253588.61, 268200] 5.45%	24949090	499104	3600.00
miniYFJS13	268032	564389	12125	86.60
miniYFJS14	577537	3437459	122848	411.53
miniYFJS15	814151	169578	4640	32.40
miniYFJS16	453123	544092	17674	173.69
miniYFJS17	853392	3309698	93701	723.92
miniYFJS18	725642	428463	8971	105.75
miniYFJS19	614642	3396354	71502	536.40
miniYFJS20	627953	7173422	194845	1674.87
miniYFJS21	[474214.42, 549549] 13.71%	30843884	318218	3600.00
miniYFJS22	442403	13497239	194056	2320.11
miniYFJS23	[978430.90,1117105] 12.41%	21444256	313009	3600.00
miniYFJS24	[335780.63, 357101] 5.97%	41853727	748103	3600.00
miniYFJS25	[881059.71,1003499] 12.20%	27492326	236106	3600.00
miniYFJS26	[980579.55,1260093] 22.18%	30463931	507486	3600.00
miniYFJS27	[872316.02, 938641] 7.07%	24612555	326687	3600.00
miniYFJS28	751899	23066402	512159	2667.33
miniYFJS29	[599096.89, 682925] 12.27%	32825637	341664	3600.00
miniYFJS30	[308445.05, 318788] 3.24%	40057912	712217	3600.00

Table S15: Result of applying CPLEX, with a 1-hour limit, to the 60 small-sized instances based on the instances introduced in [1], with learning rate $\alpha = 0.3$.

Instance	CPLEX	GVNS				GRASP-LS-SRRN			
	E	E	gap (%)	E	gap (%)	E	gap (%)	E	gap (%)
miniDAFJS01	409516	413638.00	1.01	413638	1.01	410323.00	0.20	410323	0.20
miniDAFJS02	311058	314457.00	1.09	314457	1.09	311112.00	0.02	311112	0.02
miniDAFJS03	514080	514080.00	0.00	514080	0.00	514080.00	0.00	514080	0.00
miniDAFJS04	210783	211416.00	0.30	211416	0.30	210801.00	0.01	210801	0.01
miniDAFJS05	496996	497117.00	0.02	497117	0.02	497117.00	0.02	497117	0.02
miniDAFJS06	469580	478025.00	1.80	478025	1.80	478025.00	1.80	478025	1.80
miniDAFJS07	731271	731271.00	0.00	731271	0.00	731271.00	0.00	731271	0.00
miniDAFJS08	196320	196356.00	0.02	196356	0.02	196356.00	0.02	196356	0.02
miniDAFJS09	730958	731551.00	0.08	731551	0.08	731551.00	0.08	731551	0.08
miniDAFJS10	355354	355858.00	0.14	355858	0.14	355879.00	0.15	355879	0.15
miniDAFJS11	197969	202247.00	2.16	202247	2.16	198279.00	0.16	198279	0.16
miniDAFJS12	310413	313322.20	0.94	310527	0.04	310527.00	0.04	310527	0.04
miniDAFJS13	82093	83356.00	1.54	83356	1.54	82173.00	0.10	82173	0.10
miniDAFJS14	284161	284515.00	0.12	284515	0.12	284677.00	0.18	284677	0.18
miniDAFJS15	464428	465062.00	0.14	465062	0.14	465062.00	0.14	465062	0.14
miniDAFJS16	600539	603119.00	0.43	603119	0.43	603119.00	0.43	603119	0.43
miniDAFJS17	385868	386003.00	0.03	386003	0.03	386003.00	0.03	386003	0.03
miniDAFJS18	162179	163005.00	0.51	163005	0.51	163849.00	1.03	163849	1.03
miniDAFJS19	384487	391644.10	1.86	390775	1.64	384671.00	0.05	384671	0.05
miniDAFJS20	777932	787739.00	1.26	787739	1.26	777932.00	0.00	777932	0.00
miniDAFJS21	*354010	354636.00	0.18	354636	0.18	349691.00	-1.22	349691	-1.22
miniDAFJS22	603100	630213.00	4.50	630213	4.50	603118.00	0.00	603118	0.00
miniDAFJS23	*366852	375337.60	2.31	374950	2.21	365429.00	-0.39	365429	-0.39
miniDAFJS24	308993	309242.00	0.08	309242	0.08	309242.00	0.08	309242	0.08
miniDAFJS25	527221	553069.00	4.90	553069	4.90	527309.00	0.02	527309	0.02
miniDAFJS26	227795	229259.00	0.64	229259	0.64	228188.00	0.17	228188	0.17
miniDAFJS27	*464057	463301.00	-0.16	463301	-0.16	463301.00	-0.16	463301	-0.16
miniDAFJS28	287236	287567.10	0.12	287565	0.11	287565.00	0.11	287565	0.11
miniDAFJS29	438458	443619.00	1.18	443619	1.18	440259.00	0.41	440259	0.41
miniDAFJS30	*678276	688514.00	1.51	688514	1.51	675172.60	-0.46	675160	-0.46
miniYFJS01	905588	905642.00	0.01	905642	0.01	905642.00	0.01	905642	0.01
miniYFJS02	762944	862146.00	13.00	862146	13.00	774160.20	1.47	763149	0.03
miniYFJS03	575262	622220.00	8.16	622220	8.16	578239.00	0.52	578239	0.52
miniYFJS04	710795	712730.00	0.27	712730	0.27	712730.00	0.27	712730	0.27
miniYFJS05	210624	211030.00	0.19	211030	0.19	211030.00	0.19	211030	0.19
miniYFJS06	851682	852737.00	0.12	852737	0.12	852737.00	0.12	852737	0.12
miniYFJS07	1188929	1190246.00	0.11	1190246	0.11	1191113.00	0.18	1191113	0.18
miniYFJS08	355526	357719.50	0.62	357680	0.61	357518.00	0.56	357518	0.56
miniYFJS09	443890	447914.00	0.91	447914	0.91	445390.00	0.34	445390	0.34
miniYFJS10	688192	693469.00	0.77	693469	0.77	688604.00	0.06	688604	0.06
miniYFJS11	1227681	1377797.00	12.23	1377797	12.23	1230038.00	0.19	1230038	0.19
miniYFJS12	*299343	302076.00	0.91	302076	0.91	299545.00	0.07	299545	0.07
miniYFJS13	317814	320235.00	0.76	320235	0.76	318762.00	0.30	318762	0.30
miniYFJS14	652589	733519.20	12.40	666766	2.17	653134.00	0.08	653134	0.08
miniYFJS15	951706	1004209.60	5.52	955340	0.38	954557.00	0.30	954557	0.30
miniYFJS16	516296	521126.00	0.94	521126	0.94	519063.00	0.54	519063	0.54
miniYFJS17	933706	939243.00	0.59	939243	0.59	933706.00	0.00	933706	0.00
miniYFJS18	791358	920167.00	16.28	920167	16.28	791652.00	0.04	791652	0.04
miniYFJS19	706846	764660.00	8.18	764660	8.18	709315.00	0.35	709315	0.35
miniYFJS20	699032	722917.00	3.42	722917	3.42	700788.00	0.25	700788	0.25
miniYFJS21	611668	623595.00	1.95	623595	1.95	612128.00	0.08	612128	0.08
miniYFJS22	522949	534391.00	2.19	534391	2.19	523941.00	0.19	523941	0.19
miniYFJS23	*1254568	1322790.60	5.44	1279685	2.00	1255291.40	0.06	1255223	0.05
miniYFJS24	*409399	450063.00	9.93	450063	9.93	409959.00	0.14	409959	0.14
miniYFJS25	*1114739	1204125.00	8.02	1204125	8.02	1115435.50	0.06	1114946	0.02
miniYFJS26	*1454196	1481472.00	1.88	1481472	1.88	1455628.50	0.10	1455465	0.09
miniYFJS27	1066459	1068078.00	0.15	1068078	0.15	1067143.00	0.06	1067143	0.06
miniYFJS28	834489	847781.00	1.59	847781	1.59	834705.00	0.03	834705	0.03
miniYFJS29	799019	871548.00	9.08	871548	9.08	799677.00	0.08	799584	0.07
miniYFJS30	355579	364525.00	2.52	364525	2.52	356172.00	0.17	356172	0.17

Table S16: Result of applying the metaheuristics GVNS and GRASP-LS-SRRN to the 60 small-sized instances based on the instances introduced in [1], with learning rate $\alpha = 0.1$.

Instance	CPLEX	GVNS				GRASP-LS-SRRN			
	E	E	gap (%)	E	gap (%)	E	gap (%)	E	gap (%)
miniDAFJS01	375660	382091.00	1.71	382091	1.71	376053.00	0.10	376053	0.10
miniDAFJS02	288599	294433.00	2.02	294433	2.02	288617.00	0.01	288617	0.01
miniDAFJS03	484797	484813.00	0.00	484813	0.00	484813.00	0.00	484813	0.00
miniDAFJS04	203524	204881.00	0.67	204881	0.67	203524.00	0.00	203524	0.00
miniDAFJS05	473622	495677.00	4.66	495677	4.66	473766.00	0.03	473766	0.03
miniDAFJS06	444208	444552.00	0.08	444552	0.08	445388.00	0.27	445388	0.27
miniDAFJS07	710142	727547.00	2.45	727547	2.45	710142.00	0.00	710142	0.00
miniDAFJS08	188010	188046.00	0.02	188046	0.02	188046.00	0.02	188046	0.02
miniDAFJS09	680728	681321.00	0.09	681321	0.09	681321.00	0.09	681321	0.09
miniDAFJS10	339724	340051.00	0.10	340051	0.10	340051.00	0.10	340051	0.10
miniDAFJS11	184256	184394.00	0.07	184394	0.07	184640.00	0.21	184640	0.21
miniDAFJS12	303195	311986.70	2.90	310767	2.50	303250.00	0.02	303250	0.02
miniDAFJS13	77621	78160.00	0.69	78160	0.69	78160.00	0.69	78160	0.69
miniDAFJS14	269270	269930.00	0.25	269930	0.25	269745.00	0.18	269745	0.18
miniDAFJS15	441412	441454.00	0.01	441454	0.01	442981.00	0.36	442981	0.36
miniDAFJS16	566735	566735.00	0.00	566735	0.00	566735.00	0.00	566735	0.00
miniDAFJS17	369925	370065.00	0.04	370065	0.04	370065.00	0.04	370065	0.04
miniDAFJS18	155294	155339.00	0.03	155339	0.03	155339.00	0.03	155339	0.03
miniDAFJS19	365490	384522.00	5.21	384522	5.21	378986.00	3.69	378986	3.69
miniDAFJS20	732288	739639.00	1.00	739639	1.00	735608.00	0.45	735608	0.45
miniDAFJS21	*327253	332360.00	1.56	332360	1.56	326114.00	-0.35	326114	-0.35
miniDAFJS22	*563519	565335.00	0.32	565335	0.32	563249.00	-0.05	563249	-0.05
miniDAFJS23	*348906	354673.00	1.65	354673	1.65	337473.00	-3.28	337473	-3.28
miniDAFJS24	*283921	284242.00	0.11	284242	0.11	284242.00	0.11	284242	0.11
miniDAFJS25	490446	526532.00	7.36	526532	7.36	492823.00	0.48	490611	0.03
miniDAFJS26	*217068	214739.00	-1.07	214739	-1.07	214476.00	-1.19	214476	-1.19
miniDAFJS27	*433868	456323.00	5.18	456323	5.18	433760.00	-0.02	433760	-0.02
miniDAFJS28	*270568	273859.70	1.22	271295	0.27	270707.00	0.05	270707	0.05
miniDAFJS29	417056	437768.00	4.97	437768	4.97	417539.00	0.12	417539	0.12
miniDAFJS30	*643875	665394.00	3.34	665394	3.34	625933.10	-2.79	623480	-3.17
miniYFJS01	873923	875149.00	0.14	875149	0.14	874082.00	0.02	874082	0.02
miniYFJS02	727141	749146.00	3.03	749146	3.03	727504.00	0.05	727504	0.05
miniYFJS03	528439	590252.00	11.70	590252	11.70	529126.00	0.13	529126	0.13
miniYFJS04	689509	691087.00	0.23	691087	0.23	691087.00	0.23	691087	0.23
miniYFJS05	205710	210885.00	2.52	210885	2.52	206068.00	0.17	206068	0.17
miniYFJS06	834944	849443.00	1.74	849443	1.74	836503.00	0.19	836503	0.19
miniYFJS07	1106387	1124647.00	1.65	1124647	1.65	1109031.80	0.24	1107391	0.09
miniYFJS08	336964	339172.00	0.66	339172	0.66	339161.00	0.65	339161	0.65
miniYFJS09	423411	423471.00	0.01	423471	0.01	423471.00	0.01	423471	0.01
miniYFJS10	658796	659716.00	0.14	659716	0.14	658916.00	0.02	658916	0.02
miniYFJS11	1153056	1183898.00	2.67	1183898	2.67	1156157.00	0.27	1156157	0.27
miniYFJS12	*284212	284799.60	0.21	284734	0.18	284145.00	-0.02	284145	-0.02
miniYFJS13	293352	307481.00	4.82	307481	4.82	294365.00	0.35	294365	0.35
miniYFJS14	616634	626666.00	1.63	626666	1.63	617388.00	0.12	617388	0.12
miniYFJS15	880131	889157.50	1.03	881998	0.21	881758.00	0.18	881758	0.18
miniYFJS16	485139	515540.00	6.27	515540	6.27	485927.00	0.16	485927	0.16
miniYFJS17	895041	896687.00	0.18	895647	0.07	895404.60	0.04	895041	0.00
miniYFJS18	755926	836340.00	10.64	836340	10.64	756069.00	0.02	756069	0.02
miniYFJS19	662479	663841.00	0.21	663841	0.21	663548.00	0.16	663548	0.16
miniYFJS20	661088	681839.00	3.14	681839	3.14	662440.00	0.20	662440	0.20
miniYFJS21	*576956	589895.00	2.24	589895	2.24	576245.40	-0.12	576127	-0.14
miniYFJS22	481375	490513.00	1.90	490513	1.90	482634.60	0.26	482294	0.19
miniYFJS23	*1183726	1290344.00	9.01	1290344	9.01	1181564.20	-0.18	1180864	-0.24
miniYFJS24	*382974	422483.00	10.32	422483	10.32	383865.00	0.23	383865	0.23
miniYFJS25	*1054743	1107659.00	5.02	1107659	5.02	1054858.00	0.01	1054841	0.01
miniYFJS26	1350819	1381770.00	2.29	1381770	2.29	1352062.80	0.09	1352054	0.09
miniYFJS27	998238	999037.00	0.08	999037	0.08	998802.90	0.06	998766	0.05
miniYFJS28	791090	791794.00	0.09	791794	0.09	791297.00	0.03	791297	0.03
miniYFJS29	*736775	797145.00	8.19	797145	8.19	736274.10	-0.07	736140	-0.09
miniYFJS30	*337541	340140.00	0.77	340140	0.77	338335.00	0.24	338335	0.24

Table S17: Result of applying the metaheuristics GVNS and GRASP-LS-SRRN to the 60 small-sized instances based on the instances introduced in [1], with learning rate $\alpha = 0.2$.

Instance	CPLEX	GVNS				GRASP-LS-SRRN			
	E	E	gap (%)	E	gap (%)	E	gap (%)	E	gap (%)
miniDAFJS01	342296	356967.00	4.29	356967	4.29	342891.00	0.17	342891	0.17
miniDAFJS02	270626	287239.00	6.14	287239	6.14	270626.00	0.00	270626	0.00
miniDAFJS03	455596	455596.00	0.00	455596	0.00	455596.00	0.00	455596	0.00
miniDAFJS04	196152	201078.00	2.51	201078	2.51	196362.00	0.11	196362	0.11
miniDAFJS05	452344	452498.00	0.03	452498	0.03	452498.00	0.03	452498	0.03
miniDAFJS06	427759	438080.00	2.41	438080	2.41	431219.00	0.81	431219	0.81
miniDAFJS07	687145	687145.00	0.00	687145	0.00	687145.00	0.00	687145	0.00
miniDAFJS08	179781	179817.00	0.02	179817	0.02	179817.00	0.02	179817	0.02
miniDAFJS09	640449	653065.00	1.97	653065	1.97	641047.00	0.09	641047	0.09
miniDAFJS10	321378	343638.00	6.93	343638	6.93	325640.00	1.33	325640	1.33
miniDAFJS11	*173093	176812.00	2.15	176812	2.15	173065.00	-0.02	173065	-0.02
miniDAFJS12	295741	295770.00	0.01	295770	0.01	298484.00	0.93	298484	0.93
miniDAFJS13	72867	72898.00	0.04	72898	0.04	72867.00	0.00	72867	0.00
miniDAFJS14	253244	255690.00	0.97	255690	0.97	253274.00	0.01	253274	0.01
miniDAFJS15	413722	413842.00	0.03	413842	0.03	413842.00	0.03	413842	0.03
miniDAFJS16	546718	552320.00	1.02	552320	1.02	546720.00	0.00	546720	0.00
miniDAFJS17	356866	356956.00	0.03	356956	0.03	356956.00	0.03	356956	0.03
miniDAFJS18	148363	148590.00	0.15	148590	0.15	148590.00	0.15	148590	0.15
miniDAFJS19	349140	365170.00	4.59	365170	4.59	359493.00	2.97	359493	2.97
miniDAFJS20	694262	702024.00	1.12	702024	1.12	695030.00	0.11	695030	0.11
miniDAFJS21	*314402	307130.00	-2.31	307130	-2.31	302672.00	-3.73	302672	-3.73
miniDAFJS22	*522881	523573.00	0.13	523573	0.13	522961.00	0.02	522961	0.02
miniDAFJS23	*325738	317927.00	-2.40	317927	-2.40	314738.00	-3.38	314738	-3.38
miniDAFJS24	*271273	272273.00	0.37	272273	0.37	263677.00	-2.80	263677	-2.80
miniDAFJS25	*470740	469036.00	-0.36	469036	-0.36	462352.00	-1.78	462352	-1.78
miniDAFJS26	*203355	209459.00	3.00	209459	3.00	203157.80	-0.10	203111	-0.12
miniDAFJS27	*405306	413389.00	1.99	413389	1.99	405850.40	0.13	405629	0.08
miniDAFJS28	*257078	258011.40	0.36	257317	0.09	256803.00	-0.11	256803	-0.11
miniDAFJS29	392199	410139.00	4.57	410139	4.57	392532.00	0.08	392532	0.08
miniDAFJS30	*576770	600786.00	4.16	600786	4.16	569211.00	-1.31	569211	-1.31
miniYFJS01	830595	838934.00	1.00	838934	1.00	830691.00	0.01	830691	0.01
miniYFJS02	696436	728581.00	4.62	728581	4.62	696456.00	0.00	696456	0.00
miniYFJS03	486014	517445.00	6.47	517445	6.47	488771.00	0.57	486971	0.20
miniYFJS04	665706	666890.00	0.18	666890	0.18	666890.00	0.18	666890	0.18
miniYFJS05	200793	201418.00	0.31	201418	0.31	201418.00	0.31	201418	0.31
miniYFJS06	800252	800852.00	0.07	800852	0.07	800852.00	0.07	800852	0.07
miniYFJS07	1033902	1035602.00	0.16	1035602	0.16	1034236.00	0.03	1034236	0.03
miniYFJS08	320851	323162.00	0.72	323162	0.72	323162.00	0.72	323162	0.72
miniYFJS09	407324	408844.00	0.37	408844	0.37	407698.00	0.09	407698	0.09
miniYFJS10	638089	638902.00	0.13	638902	0.13	638902.00	0.13	638902	0.13
miniYFJS11	1098125	1154301.00	5.12	1154301	5.12	1101131.00	0.27	1101131	0.27
miniYFJS12	*268200	273098.00	1.83	273098	1.83	267679.00	-0.19	267679	-0.19
miniYFJS13	268032	268357.00	0.12	268357	0.12	268357.00	0.12	268357	0.12
miniYFJS14	577537	589839.00	2.13	589839	2.13	578859.00	0.23	578859	0.23
miniYFJS15	814151	815874.00	0.21	815826	0.21	815826.00	0.21	815826	0.21
miniYFJS16	453123	455546.00	0.53	455546	0.53	454085.00	0.21	454085	0.21
miniYFJS17	853392	865438.90	1.41	863680	1.21	856446.40	0.36	854667	0.15
miniYFJS18	725642	757732.00	4.42	757732	4.42	725832.00	0.03	725832	0.03
miniYFJS19	614642	615346.00	0.11	615346	0.11	615123.00	0.08	615123	0.08
miniYFJS20	627953	659340.00	5.00	659340	5.00	628394.20	0.07	628249	0.05
miniYFJS21	*549549	558778.00	1.68	558778	1.68	542229.00	-1.33	542229	-1.33
miniYFJS22	442403	472029.00	6.70	472029	6.70	443353.90	0.21	443277	0.20
miniYFJS23	*1117105	1178813.00	5.52	1178813	5.52	1100760.00	-1.46	1100760	-1.46
miniYFJS24	*357101	371284.00	3.97	371284	3.97	358096.00	0.28	358096	0.28
miniYFJS25	*1003499	1056313.00	5.26	1056313	5.26	1002516.00	-0.10	1002516	-0.10
miniYFJS26	*1260093	1281083.00	1.67	1281083	1.67	1255513.10	-0.36	1254811	-0.42
miniYFJS27	*938641	939840.00	0.13	939840	0.13	939427.20	0.08	939410	0.08
miniYFJS28	751899	759167.00	0.97	759167	0.97	752224.00	0.04	752224	0.04
miniYFJS29	*682925	758911.00	11.13	758911	11.13	682814.90	-0.02	682424	-0.07
miniYFJS30	*318788	320347.00	0.49	320347	0.49	319827.00	0.33	319827	0.33

Table S18: Result of applying the metaheuristics GVNS and GRASP-LS-SRRN to the 60 small-sized instances based on the instances introduced in [1], with learning rate $\alpha = 0.3$.

References

[1] K. A. G. Araujo, E. G. Birgin, and D. P. Ronconi. Models, constructive heuristics, and benchmark instances for the flexible job shop scheduling problem with nonlinear routes and position-based learning effect. Technical Report MCDO02022024, University of São Paulo, São Paulo, SP, Brazil, 2024.

[2] E. G. Birgin, P. Feofiloff, C. G. Fernandes, E. L. de Melo, M. T. I. Oshiro, and D. P. Ronconi. A MILP model for an extended version of the flexible job shop problem. *Optimization Letters*, 8(4):1417–1431, 2014.