

A biased random-key genetic algorithm for the home health care problem

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Supplementary material

New best lower bounds produced with CPLEX 20.10

Table A1: New best lower bounds found by CPLEX 12.10. The first column identifies the instance being solved, and the following two columns present the previous lower bound and the processing time reported by Mankowska et al. (2014). Column LB^+ presents our new best lower bound, followed by the cost of the initial feasible solution used to warm-start the search and the solution value when the solver reached the time limit of two hours of processing. The following three columns present the relative gap to optimality of the final solution to the LB^+ , the runtime of the solver, and the average improvement of LB^+ compared to Mankowska et al. LB . Column “# nodes” highlights how many branch-and-cut nodes were explored. The last three columns present the problem size in terms of the number of rows/constraints, the number of columns/variables, and the number of non-zero elements on the matrix. Values in bold indicate the best lower bound available, and values marked with an asterisk indicate that an optimal solution was found.

Instance	Previous results		New results							Problem size		
	LB	Time (sec.)	LB^+	Initial sol.	Final sol.	Gap (%)	Time (sec.)	Impr. (%)	# nodes	# rows	# cols.	# non-zeros
A1	218.2	2.9	218.2	*227.0	218.2	0.0	1.0	0.0	43	135	31	270
A2	246.6	7.4	246.6	*246.6	246.6	0.0	1.0	0.0	463	130	30	260
A3	305.8	10.3	305.9	*305.9	305.9	0.0	1.0	0.0	2,192	123	27	246
A4	186.9	11.8	186.9	*186.9	186.9	0.0	1.0	0.0	1,998	128	28	256
A5	189.5	2.9	189.5	*192.0	189.5	0.0	1.0	0.0	674	135	31	270
A6	200.1	2.9	200.1	*200.1	200.1	0.0	1.0	0.0	375	131	31	262
A7	225.4	1.5	225.4	*225.4	225.4	0.0	1.0	0.0	222	127	27	254
A8	232.0	5.9	232.0	*232.0	232.0	0.0	1.0	0.0	175	105	25	210
A9	222.3	29.4	222.3	*234.2	222.3	0.0	1.3	0.0	2,315	201	35	402
A10	225.0	1.5	225.0	*225.0	225.0	0.0	1.0	0.0	0	68	23	136
	225.2	7.7	225.2	227.5	225.2	0.0	1.0	0.0	846	128	29	257
B1	378.7	52987.5	*428.1	428.6	*428.1	0.0	5970.3	13.0	3,149,921	1,249	98	2,498
B2	427.9	52987.5	*476.0	483.6	*476.0	0.0	469.5	11.2	268,511	841	88	1,682
B3	391.2	52987.5	371.4	402.8	399.1	6.9	7200.0	-5.1	1,865,152	1,274	99	2,548
B4	330.4	52987.5	*411.3	432.2	*411.3	0.0	509.9	24.5	220,784	847	89	1,694
B5	311.0	52987.5	363.7	380.7	366.3	0.7	7200.0	16.9	2,044,932	1,091	90	2,182
B6	274.2	52987.5	372.8	472.8	467.3	20.2	7200.0	36.0	1,134,634	1,299	100	2,598
B7	310.6	52987.5	*328.6	*328.7	*328.7	0.0	598.7	5.8	170,681	1,443	108	2,886
B8	332.4	52987.5	*357.6	359.7	*357.7	0.0	533.7	7.6	228,650	1,325	104	2,650
B9	293.7	52987.5	336.9	404.1	402.7	16.3	7200.0	14.7	748,709	1,763	116	3,526
B10	381.0	52987.5	413.7	469.6	469.6	11.9	7200.0	8.6	1,458,151	1,730	109	3,460
	343.1	52,987.5	386.0	416.3	410.7	5.6	4408.2	13.3	1,129,013	1,286	100	2,572

Table A1: Continued.

Instance	Previous results		New results							Problem size			
	LB	Time (sec.)	LB ⁺	Initial sol.	Final sol.	Gap (%)	Time (sec.)	Impr. (%)	# nodes	# rows	# cols.	# non-zeros	
C1	401.1	52987.5	477.3	965.2	951.0	49.8	7200.0	19.0	24,016	10,059	327	20,118	
C2	314.9	52987.5	377.4	584.3	577.9	34.7	7200.0	19.9	46,361	8,518	323	17,036	
C3	323.5	52987.5	396.4	559.9	559.0	29.1	7200.0	22.5	44,907	8,318	320	16,636	
C4	329.4	52987.5	367.4	537.2	513.3	28.4	7200.0	11.5	47,961	8,401	309	16,802	
C5	404.2	52987.5	496.9	692.2	667.9	25.6	7200.0	22.9	43,036	6,527	277	13,054	
C6	308.2	52987.5	366.1	843.7	838.9	56.4	7200.0	18.8	59,725	8,475	315	16,950	
C7	315.7	52987.5	365.2	538.4	525.7	30.5	7200.0	15.7	26,149	11,895	374	23,790	
C8	336.3	52987.5	377.1	481.0	473.1	20.3	7200.0	12.1	82,757	8,702	322	17,404	
C9	306.5	52987.5	361.5	545.2	542.5	33.4	7200.0	18.0	44,903	10,627	361	21,254	
C10	386.4	52987.5	449.8	619.4	601.5	25.2	7200.0	16.4	64,989	7,586	297	15,172	
	342.6	52,987.5	403.5	636.6	625.1	33.3	7200.0	17.7	48,480	8,911	323	17,822	
D1	456.7	52987.5	514.4	1199.5	1199.5	57.1	7200.0	12.6	6,223	31,400	684	62,800	
D2	336.8	52987.5	386.0	706.8	693.9	44.4	7200.0	14.6	19,698	21,890	581	43,780	
D3	355.7	52987.5	379.5	650.3	650.3	41.6	7200.0	6.7	1,386	33,255	718	66,510	
D4	379.9	52987.5	408.5	822.8	822.8	50.4	7200.0	7.5	4,927	25,492	626	50,984	
D5	372.2	52987.5	404.3	732.5	730.5	44.7	7200.0	8.6	4,644	28,839	661	57,678	
D6	368.8	52987.5	391.8	735.4	735.4	46.7	7200.0	6.2	1,213	33,285	729	66,570	
D7	333.4	52987.5	359.0	599.8	599.8	40.1	7200.0	7.7	4,746	37,734	762	75,468	
D8	373.3	52987.5	406.8	661.8	661.8	38.5	7200.0	9.0	3,660	28,124	642	56,248	
D9	362.4	52987.5	387.6	715.9	715.9	45.9	7200.0	7.0	2,570	26,518	662	53,036	
D10	434.4	52987.5	479.3	1216.0	1203.0	60.2	7200.0	10.3	9,013	21,327	573	42,654	
	377.4	52,987.5	411.7	804.1	801.3	47.0	7200.0	9.0	5,808	28,786	664	57,573	
E1	406.0	52987.5	421.8	1375.3	1375.3	69.3	7200.0	3.9	797	61,719	1,059	123,438	
E2	411.9	52987.5	423.7	905.0	905.0	53.2	7200.0	2.9	639	59,793	1,073	119,586	
E3	437.2	52987.5	445.2	818.2	818.2	45.6	7200.0	1.8	601	62,443	1,101	124,886	
E4	384.3	52987.5	398.5	732.7	732.7	45.6	7200.1	3.7	625	72,830	1,180	145,660	
E5	392.4	52987.5	403.6	810.7	810.7	50.2	7200.0	2.9	587	67,981	1,141	135,962	
E6	390.2	52987.5	404.5	814.0	814.0	50.3	7200.0	3.7	581	67,555	1,160	135,110	
E7	374.4	52987.5	384.7	735.8	735.8	47.7	7200.1	2.8	911	77,000	1,240	154,000	
E8	407.7	52987.5	425.9	761.8	761.8	44.1	7200.0	4.5	637	62,453	1,079	124,906	
E9	422.1	52987.5	431.2	969.6	969.6	55.5	7200.0	2.2	610	57,914	1,082	115,828	
E10	419.1	52987.5	441.8	867.2	867.2	49.1	7200.0	5.4	550	64,388	1,114	128,776	
	404.5	52,987.5	418.1	879.0	879.0	51.1	7200.0	3.4	654	65,408	1,123	130,815	
F1	445.1	52987.5	546.7	1504.1	1504.1	63.7	7200.7	22.8	519	412,064	3,316	824,128	
F2	457.9	52987.5	535.0	1459.5	1459.5	63.3	7200.2	16.8	505	404,375	3,300	808,750	
F3	481.8	52987.5	541.6	1327.9	1327.9	59.2	7200.2	12.4	479	415,629	3,375	831,258	
F4	417.4	52987.5	524.0	1162.8	1162.8	54.9	7200.2	25.5	511	481,774	3,714	963,548	
F5	452.3	52987.5	529.0	1391.9	1391.9	62.0	7200.2	17.0	487	480,978	3,602	961,956	
F6	367.1	52987.5	498.6	1441.3	1441.3	65.4	7200.1	35.8	510	360,717	3,214	721,434	
F7	408.1	52987.5	502.5	1177.9	1177.9	57.3	7200.3	23.1	520	426,764	3,301	853,528	
F8	454.3	52987.5	532.9	1169.2	1169.2	54.4	7200.2	17.3	532	397,617	3,282	795,234	
F9	426.8	52987.5	535.9	1346.7	1346.7	60.2	7200.1	25.6	504	434,158	3,526	868,316	
F10	441.8	52987.5	540.2	1470.0	1470.0	63.3	7200.2	22.3	499	476,660	3,561	953,320	
	435.3	52,987.5	528.6	1345.1	1345.1	60.4	7200.2	21.9	507	429,074	3,419	858,147	
G1	455.0	52987.5	584.6	2037.0	2037.0	71.3	7200.2	28.5	352	1,309,443	6,620	2,618,886	
G2	463.1	52987.5	600.6	2083.9	2083.9	71.2	7200.2	29.7	500	1,449,352	6,915	2,898,704	

Table A1: Continued.

Instance	Previous results		New results							Problem size			
	LB	Time (sec.)	LB ⁺	Initial sol.	Final sol.	Gap (%)	Time (sec.)	Impr. (%)	# nodes	# rows	# cols.	# non-zeros	
G3	464.3	52987.5	584.8	1608.2	1608.2	63.6	7200.2	25.9	257	1,227,143	6,485	2,454,286	
G4	461.5	52987.5	591.9	1723.0	1723.0	65.6	7200.7	28.2	461	1,435,781	7,043	2,871,562	
G5	449.4	52987.5	616.5	1809.8	1809.8	65.9	7200.6	37.2	32	1,280,623	6,443	2,561,246	
G6	471.5	52987.5	583.5	1949.1	1949.1	70.1	7201.9	23.8	304	1,482,588	7,147	2,965,176	
G7	459.1	52987.5	604.8	1777.5	1777.5	66.0	7200.2	31.7	496	1,270,343	6,642	2,540,686	
G8	472.4	52987.5	618.3	1754.2	1754.2	64.8	7200.6	30.9	483	1,223,060	6,531	2,446,120	
G9	473.3	52987.5	637.4	2120.5	2120.5	69.9	7200.6	34.7	100	1,230,118	6,515	2,460,236	
G10	451.6	52987.5	621.0	2022.3	2022.3	69.3	7200.5	37.5	38	1,186,772	6,232	2,373,544	
	462.1	52,987.5	604.3	1888.5	1888.5	67.8	7200.6	30.8	302	1,309,522	6,657	2,619,045	

Detailed results regarding BRKGA-MP-IPR convergence

Table B2: Solution improvement during the search with the BRKGA-MP-IPR based metaheuristic. The first column presents the instance name, and each one of the next pair of columns presents the average runtime in seconds, and the average solution cost after completing 5%, 25%, 50%, 75%, and 100% of the evolutionary process. The values present the average of 15 runs of the metaheuristic on each instance.

Instance	95 gens (5%)		475 gens (25%)		950 gens (50%)		1425 gens (75%)		1900 gens (100%)	
	Time (sec)	Cost (avg)	Time (sec)	Cost (avg)	Time (sec)	Cost (avg)	Time (sec)	Cost (avg)	Time (sec)	Cost (avg)
A1	5.0	227.0	24.7	227.0	49.4	227.0	74.0	227.0	98.6	227.0
A2	4.9	246.6	24.4	246.6	48.7	246.6	73.1	246.6	97.3	246.6
A3	5.0	305.9	25.0	305.9	49.9	305.9	74.8	305.9	99.6	305.9
A4	4.9	186.9	24.4	186.9	48.9	186.9	73.2	186.9	97.6	186.9
A5	4.9	192.0	24.4	192.0	48.8	192.0	73.1	192.0	97.4	192.0
A6	5.0	200.1	24.6	200.1	49.1	200.1	73.6	200.1	98.1	200.1
A7	4.9	225.4	24.4	225.4	48.7	225.4	72.9	225.4	97.2	225.4
A8	5.0	232.1	24.7	232.1	49.3	232.1	73.9	232.1	98.4	232.1
A9	4.9	234.2	24.2	234.2	48.3	234.2	72.5	234.2	96.5	234.2
A10	4.9	225.0	24.1	225.0	48.2	225.0	72.2	225.0	96.2	225.0
	4.9	227.5	24.5	227.5	48.9	227.5	73.3	227.5	97.7	227.5
B1	5.3	428.1	26.0	428.1	52.0	428.1	78.0	428.1	103.9	428.1
B2	5.3	483.6	26.4	483.6	52.8	483.6	79.2	483.6	105.5	483.6
B3	5.3	402.8	26.2	402.8	52.2	402.8	78.3	402.8	104.4	402.8
B4	5.4	432.2	26.6	420.3	53.0	420.3	79.5	420.3	105.9	420.3
B5	5.2	372.2	25.6	372.2	51.1	372.2	76.7	372.2	102.2	372.2
B6	5.4	471.0	27.0	471.0	53.9	471.0	80.9	471.0	107.8	471.0
B7	5.3	328.7	26.2	328.7	52.3	328.7	78.4	328.7	104.5	328.7
B8	5.4	359.7	26.6	359.7	53.1	359.7	79.6	359.7	106.0	359.7
B9	5.4	402.7	26.9	402.7	53.7	402.7	80.5	402.7	107.3	402.7
B10	5.4	469.6	26.8	469.6	53.5	469.6	80.2	469.6	106.8	469.6
	5.3	415.0	26.4	413.9	52.8	413.9	79.1	413.9	105.4	413.9
C1	6.4	967.0	31.9	965.2	63.7	965.2	95.5	965.2	127.2	965.2
C2	6.9	582.2	33.9	582.2	67.8	582.2	101.6	582.2	135.4	582.2
C3	6.6	550.5	32.6	548.8	65.2	548.8	97.7	548.8	130.2	548.8
C4	6.5	519.9	32.0	519.8	63.9	519.8	95.8	519.8	127.6	519.8
C5	6.6	670.6	32.6	670.6	65.1	670.6	97.7	670.6	130.1	670.6
C6	6.5	842.7	32.1	840.7	64.2	840.7	96.2	840.7	128.2	840.7
C7	6.8	530.4	33.5	528.5	66.9	528.5	100.2	528.5	133.5	528.5
C8	6.8	475.5	33.5	472.0	66.8	472.0	100.2	472.0	133.5	472.0
C9	6.6	535.2	32.8	531.2	65.5	531.2	98.1	531.2	130.7	531.2
C10	6.6	611.7	32.6	611.0	65.2	611.0	97.7	611.0	130.2	610.9
	6.6	628.6	32.8	627.0	65.4	627.0	98.1	627.0	130.7	627.0
D1	8.6	1205.3	42.4	1179.9	84.7	1179.9	127.0	1179.9	169.3	1179.9
D2	7.9	714.3	39.0	684.3	77.9	684.3	116.8	684.3	155.5	684.3
D3	8.6	645.7	42.6	636.9	85.2	635.5	127.7	633.4	170.2	633.4
D4	8.1	822.9	40.1	804.4	80.0	804.4	120.0	804.4	159.8	804.4
D5	8.4	702.0	41.5	683.3	82.8	682.8	124.2	682.8	165.5	682.8
D6	8.6	736.9	42.8	717.0	85.4	717.0	128.1	712.1	170.7	712.1

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Instance	95 gens (5%)		475 gens (25%)		950 gens (50%)		1425 gens (75%)		1900 gens (100%)	
	Time (sec)	Cost (avg)	Time (sec)	Cost (avg)	Time (sec)	Cost (avg)	Time (sec)	Cost (avg)	Time (sec)	Cost (avg)
D7	9.0	597.1	44.5	588.7	89.0	585.6	133.4	585.6	177.8	585.6
D8	8.7	669.7	42.9	660.7	85.7	660.7	128.5	658.4	171.2	658.4
D9	8.2	732.1	40.7	696.7	81.2	696.2	121.9	696.2	162.4	696.2
D10	7.9	1254.0	39.3	1211.5	78.5	1201.7	117.7	1201.7	156.8	1201.7
	8.4	808.0	41.6	786.3	83.0	784.8	124.5	783.9	165.9	783.9
E1	11.1	1404.2	54.9	1319.4	109.5	1318.9	164.3	1318.9	219.0	1318.9
E2	11.1	960.5	54.7	824.4	109.1	824.2	163.6	824.2	218.1	824.2
E3	10.9	845.6	54.3	785.1	108.5	785.1	162.8	785.1	216.9	785.1
E4	11.2	754.1	55.5	711.8	111.1	710.5	166.7	707.6	222.2	703.1
E5	11.0	857.7	54.4	770.0	108.7	770.0	163.0	766.0	217.2	760.5
E6	11.3	861.9	55.9	772.8	111.6	772.1	167.4	772.1	223.3	772.1
E7	11.7	766.7	57.9	711.0	115.6	708.8	173.4	708.8	231.2	708.8
E8	11.0	796.8	54.3	726.6	108.5	725.6	162.8	725.6	217.1	725.6
E9	10.9	1017.7	53.7	906.6	106.8	877.1	160.0	877.1	213.4	877.1
E10	11.1	916.5	55.1	825.1	109.9	824.5	164.8	820.5	219.6	815.0
	11.1	918.2	55.1	835.3	109.9	831.7	164.9	830.6	219.8	829.0
F1	27.0	1791.0	134.5	1353.3	268.2	1351.2	402.0	1348.7	535.8	1342.1
F2	28.8	1788.6	141.6	1318.0	282.4	1296.0	423.2	1296.0	564.1	1296.0
F3	27.7	1576.0	137.8	1205.6	274.9	1204.1	411.8	1201.1	549.0	1201.1
F4	32.3	1420.0	160.7	1097.3	320.8	1093.9	480.7	1093.9	640.9	1093.9
F5	29.9	1685.3	148.5	1302.6	296.3	1295.9	444.2	1294.6	592.3	1286.8
F6	26.4	1727.6	131.3	1313.6	261.7	1307.1	392.0	1301.2	522.5	1295.6
F7	31.9	1449.8	157.0	1095.4	312.8	1092.3	468.7	1088.4	624.7	1088.2
F8	28.9	1462.8	142.4	1107.7	283.5	1102.1	424.8	1098.7	566.3	1098.7
F9	30.1	1671.5	149.5	1277.5	297.6	1263.1	445.7	1262.1	594.0	1262.1
F10	29.2	1803.0	145.8	1359.2	291.3	1358.0	436.8	1358.0	582.4	1358.0
	29.2	1637.5	144.9	1243.0	288.9	1236.4	433.0	1234.3	577.2	1232.3
G1	61.3	2410.5	302.5	1800.2	601.5	1730.8	900.3	1728.3	1198.9	1728.3
G2	66.5	2593.1	327.0	1838.6	650.8	1759.3	974.3	1729.2	1297.8	1714.0
G3	60.6	2025.1	298.6	1476.2	593.3	1456.1	887.1	1443.5	1180.6	1441.9
G4	68.9	2107.6	339.7	1514.2	675.6	1495.6	1010.3	1494.7	1345.7	1490.1
G5	58.9	2362.1	288.3	1684.3	571.8	1628.1	854.7	1623.4	1137.4	1623.4
G6	71.6	2328.8	355.4	1713.5	707.5	1657.5	1057.8	1657.5	1408.2	1657.5
G7	62.4	2252.0	306.6	1625.6	608.6	1569.2	909.5	1569.0	1210.5	1569.0
G8	61.1	2109.2	299.9	1535.4	595.6	1478.0	890.3	1477.6	1185.1	1477.6
G9	62.1	2607.7	305.9	1943.1	608.6	1857.7	909.8	1834.3	1210.9	1827.7
G10	57.0	2641.8	281.0	1924.2	558.4	1814.2	834.3	1797.1	1110.0	1797.1
	63.0	2343.8	310.5	1705.5	617.2	1644.6	922.8	1635.5	1228.5	1632.7

Comparison of local-search based methods of the literature

Table C3: Gap values are relative to the best solution produced by each solution method with respect to the value of LB^+ . Values in bold indicate the best-known solution value produced by the methods, and values marked with an asterisk indicate that an optimal solution was found. Mankowska et al. (2014) and Kummer et al. (2019) methods do not employ multiple runs of their algorithms. Lasfargeas et al. (2019) run a VNS based metaheuristic 40 times on each instance, and we run our BRKGA-MP-IPR only 15 times. Both methods use different random seeds on each one of the runs on each instance. All reported running times are in seconds.

Instance	LB^+	Mankowska et al. (2014)				Lasfargeas et al. (2019)					Kummer et al. (2019)			BRKGA-MP-IPR				
		Best	Gap	Method	Time	Best	Gap	Mean	SD	Time	Best	Gap	Time	Best	Gap	Mean	SD	Time
A1	*218.2	*218.2	0.0	CPLEX	2.9	*218.2	0.0	224.3	14.6	1.0	*218.2	0.0	0.2	227.0	3.9	227.0	0.0	98.6
A2	*246.6	*246.6	0.0	CPLEX	7.4	*246.6	0.0	258.1	31.6	1.0	*246.6	0.0	0.3	*246.6	0.0	246.6	0.0	97.3
A3	*305.9	*305.9	0.0	CPLEX	10.3	*305.9	0.0	358.8	38.5	1.0	*305.9	0.0	0.6	*305.9	0.0	305.9	0.0	99.6
A4	*186.9	*186.9	0.0	CPLEX	11.8	*186.9	0.0	196.4	11.1	1.0	*186.9	0.0	2.1	*186.9	0.0	186.9	0.0	97.6
A5	*189.5	*189.5	0.0	CPLEX	2.9	*189.5	0.0	216.5	36.6	1.0	*189.5	0.0	0.3	192.0	1.3	192.0	0.0	97.4
A6	*200.1	*200.1	0.0	CPLEX	2.9	*200.1	0.0	200.1	0.0	1.0	*200.1	0.0	0.2	*200.1	0.0	200.1	0.0	98.1
A7	*225.4	*225.4	0.0	CPLEX	1.5	*225.4	0.0	232.4	24.2	1.0	*225.4	0.0	0.2	*225.4	0.0	225.4	0.0	97.2
A8	*232.0	*232.0	0.0	CPLEX	5.9	*232.0	0.0	281.4	47.6	1.0	*232.0	0.0	0.2	*232.0	0.0	232.1	0.0	98.4
A9	*222.3	*222.3	0.0	CPLEX	29.4	*222.3	0.0	225.4	4.0	1.0	*222.3	0.0	1.5	234.2	5.1	234.2	0.0	96.5
A10	*225.0	*225.0	0.0	CPLEX	1.5	*225.0	0.0	225.0	0.0	1.0	*225.0	0.0	0.1	*225.0	0.0	225.0	0.0	96.2
	225.2	225.2	0.0		7.7	225.2	0.0	241.8	20.8	1.0	225.2	0.0	0.5	227.5	1.0	227.5	0.0	97.7
B1	*428.1	458.9	6.7	AVNS-TL	1.0	434.1	1.4	552.8	93.4	104.9	431.1	0.7	67.3	*428.1	0.0	428.1	0.0	103.9
B2	*476.0	476.2	0.0	CPLEX	52987.5	*476.0	0.0	561.3	61.4	54.7	*476.0	0.0	10.6	483.6	1.6	483.6	0.0	105.5
B3	371.4	399.2	7.0	CPLEX	52987.5	399.1	6.9	527.6	72.5	125.4	421.9	12.0	180.7	402.8	7.8	402.8	0.0	104.4
B4	*411.3	576.0	28.6	CPLEX	52987.5	414.0	0.7	509.7	74.5	131.9	432.3	4.9	20.2	420.3	2.1	429.1	5.3	105.9
B5	363.7	391.1	7.0	AVNS-TL	1.0	385.6	5.7	496.9	98.1	27.1	369.4	1.6	100.8	372.2	2.3	373.0	2.2	102.2
B6	372.8	534.7	30.3	MN	1.0	447.8	16.7	611.8	129.9	86.3	531.9	29.9	111.9	471.0	20.8	471.0	0.0	107.8
B7	*328.6	355.5	7.6	MN	1.0	*328.7	0.0	398.8	64.8	121.5	*328.7	0.0	20.8	*328.7	0.0	328.7	0.0	104.5
B8	*357.6	357.8	0.0	CPLEX	52987.5	359.7	0.6	488.7	116.2	156.6	*357.7	0.0	78.1	359.7	0.6	359.7	0.0	106.0
B9	336.9	403.8	16.6	CPLEX	52987.5	404.1	16.6	483.4	60.3	122.6	446.6	24.6	261.1	402.7	16.3	403.2	0.7	107.3
B10	413.7	500.4	17.3	MN	1.0	462.7	10.6	616.8	147.7	17.2	469.6	11.9	170.5	469.6	11.9	469.6	0.0	106.8
	386.0	445.4	13.3		26494.3	411.2	6.1	524.8	91.9	94.8	426.5	9.5	102.2	413.9	6.7	414.9	0.8	105.4
C1	477.3	1123.6	57.5	AVNS-TL	1.0	974.2	51.0	1350.4	365.3	190.0	1006.7	52.6	1141.6	965.2	50.5	966.6	1.9	127.2
C2	377.4	673.8	44.0	MN	1.0	605.1	37.6	685.5	55.6	210.1	597.1	36.8	215.5	582.2	35.2	582.9	1.2	135.4
C3	396.4	642.4	38.3	AVNS-TL	1.0	562.9	29.6	698.2	82.7	216.9	618.3	35.9	346.0	548.8	27.8	551.4	1.5	130.2
C4	367.4	580.4	36.7	AVNS-TL	1.0	521.9	29.6	630.4	101.8	222.0	544.6	32.5	94.0	519.8	29.3	523.2	2.5	127.6
C5	496.9	754.6	34.2	AVNS-TL	1.0	683.1	27.3	822.6	119.3	226.9	667.5	25.6	184.0	670.6	25.9	675.3	4.4	130.1
C6	366.1	951.6	61.5	AVNS-TL	1.0	854.6	57.2	1010.6	146.4	228.9	852.0	57.0	915.9	840.7	56.4	842.4	1.4	128.2
C7	365.2	577.4	36.7	AVNS-TL	1.0	529.2	31.0	572.5	29.7	216.1	525.2	30.5	488.9	528.5	30.9	532.5	3.4	133.5
C8	377.1	540.6	30.3	AVNS-TL	1.0	471.0	19.9	522.8	29.8	218.8	479.4	21.4	457.3	472.0	20.1	475.1	1.5	133.5
C9	361.5	608.7	40.6	AVNS-TL	1.0	551.1	34.4	642.7	77.6	227.9	568.9	36.4	539.8	531.2	31.9	538.7	4.5	130.7

Table C3: Continued.

Instance	LB ⁺	Mankowska et al. (2014)				Lasfargeas et al. (2019)					Kummer et al. (2019)			BRKGA-MP-IPR				
		Best	Gap	Method	Time	Best	Gap	Mean	SD	Time	Best	Gap	Time	Best	Gap	Mean	SD	Time
C10	449.8	679.3	33.8	AVNS-TL	1.0	608.9	26.1	653.0	35.6	195.5	603.5	25.5	372.8	610.9	26.4	612.3	2.0	130.2
	403.5	713.2	43.4		1.0	636.2	36.6	758.9	104.4	215.3	646.3	37.6	475.6	627.0	35.6	630.0	2.4	130.7
D1	514.4	1321.8	61.1	AVNS-TL	7.4	1278.2	59.8	1498.8	199.0	282.4	1301.0	60.5	1912.2	1179.9	56.4	1195.9	7.1	169.3
D2	386.0	892.7	56.8	AVNS-TL	5.9	746.9	48.3	914.3	97.9	333.2	807.3	52.2	886.7	684.3	43.6	694.8	7.3	155.5
D3	379.5	819.4	53.7	AVNS-TL	5.9	678.6	44.1	817.8	80.9	306.9	675.3	43.8	1812.7	633.4	40.1	640.6	4.0	170.2
D4	408.5	877.4	53.4	AVNS-TL	5.9	809.7	49.6	1073.1	197.5	293.3	817.8	50.1	1543.2	804.4	49.2	829.6	14.2	159.8
D5	404.3	872.1	53.6	AVNS-TL	7.4	777.0	48.0	924.9	120.8	296.8	706.8	42.8	954.5	682.8	40.8	691.8	4.6	165.5
D6	391.8	835.2	53.1	AVNS-TL	7.4	768.6	49.0	886.6	97.4	305.3	762.3	48.6	1227.0	712.1	45.0	727.6	6.5	170.7
D7	359.0	706.3	49.2	AVNS-TL	8.8	600.1	40.2	680.4	31.6	332.0	671.7	46.5	835.6	585.6	38.7	592.4	5.0	177.8
D8	406.8	811.4	49.9	AVNS-TL	5.9	715.5	43.1	775.8	31.1	295.9	717.3	43.3	869.7	658.4	38.2	663.3	3.0	171.2
D9	387.6	842.7	54.0	MN	8.8	741.0	47.7	818.2	46.5	308.1	739.6	47.6	265.0	696.2	44.3	713.7	12.1	162.4
D10	479.3	1306.6	63.3	AVNS-TL	4.4	1424.6	66.4	1867.7	258.6	341.9	1330.4	64.0	826.1	1201.7	60.1	1223.5	21.1	156.8
	411.7	928.6	55.7		6.8	854.0	51.8	1025.8	116.1	309.6	853.0	51.7	1113.3	783.9	47.5	797.3	8.5	165.9
E1	421.8	1604.9	73.7	AVNS-TL	25.0	–	–	–	–	–	1349.2	68.7	5639.2	1318.9	68.0	1335.1	10.6	219.0
E2	423.7	1101.9	61.6	LS	14.7	–	–	–	–	–	941.3	55.0	4236.6	824.2	48.6	846.1	16.6	218.1
E3	445.2	986.4	54.9	AVNS-TL	20.6	–	–	–	–	–	913.5	51.3	2905.4	785.1	43.3	794.4	7.4	216.9
E4	398.5	871.0	54.2	AVNS-TL	28.0	–	–	–	–	–	851.4	53.2	5022.5	703.1	43.3	720.3	8.9	222.2
E5	403.6	1018.0	60.4	AVNS-TL	28.0	–	–	–	–	–	905.4	55.4	5837.6	760.5	46.9	777.2	11.0	217.2
E6	404.5	1003.0	59.7	AVNS-TL	28.0	–	–	–	–	–	878.8	54.0	4723.3	772.1	47.6	788.4	8.6	223.3
E7	384.7	921.1	58.2	AVNS-TL	29.4	–	–	–	–	–	832.9	53.8	3319.7	708.8	45.7	720.7	5.8	231.2
E8	425.9	884.6	51.9	AVNS-TL	28.0	–	–	–	–	–	832.7	48.9	4365.4	725.6	41.3	743.6	8.9	217.1
E9	431.2	1131.7	61.9	AVNS-TL	26.5	–	–	–	–	–	1129.1	61.8	1530.0	877.1	50.8	913.8	16.2	213.4
E10	441.8	1053.6	58.1	LS	16.2	–	–	–	–	–	1026.8	57.0	3433.8	815.0	45.8	828.2	9.8	219.6
	418.1	1057.6	60.5		24.4	–	–	–	–	–	966.1	56.7	4101.3	829.0	49.6	846.8	10.4	219.8
F1	546.7	1721.4	68.2	AVNS	1308.5	–	–	–	–	–	–	–	–	1342.1	59.3	1373.7	19.0	535.8
F2	535.0	1763.8	69.7	AVNS	1337.9	–	–	–	–	–	–	–	–	1296.0	58.7	1322.8	16.7	564.1
F3	541.6	1549.6	65.0	AVNS	1277.6	–	–	–	–	–	–	–	–	1201.1	54.9	1228.5	11.9	549.0
F4	524.0	1420.4	63.1	AVNS	1944.3	–	–	–	–	–	–	–	–	1093.9	52.1	1107.6	14.4	640.9
F5	529.0	1701.9	68.9	AVNS	1685.3	–	–	–	–	–	–	–	–	1286.8	58.9	1317.0	16.2	592.3
F6	498.6	1639.7	69.6	AVNS	1230.5	–	–	–	–	–	–	–	–	1295.6	61.5	1315.5	10.8	522.5
F7	502.5	1384.3	63.7	AVNS	1904.6	–	–	–	–	–	–	–	–	1088.2	53.8	1119.1	18.5	624.7
F8	532.9	1544.6	65.5	AVNS	1360.0	–	–	–	–	–	–	–	–	1098.7	51.5	1131.1	12.4	566.3
F9	535.9	1572.9	65.9	AVNS	2416.8	–	–	–	–	–	–	–	–	1262.1	57.5	1291.4	19.1	594.0
F10	540.2	1581.0	65.8	AVNS	1951.7	–	–	–	–	–	–	–	–	1358.0	60.2	1392.6	14.2	582.4
	528.6	1588.0	66.7		1641.7	–	–	–	–	–	–	–	–	1232.3	57.1	1259.9	15.3	577.2
G1	584.6	2248.0	74.0	AVNS	10597.5	–	–	–	–	–	–	–	–	1728.3	66.2	1749.3	20.4	1198.9
G2	600.6	2316.1	74.1	AVNS	10597.5	–	–	–	–	–	–	–	–	1714.0	65.0	1771.0	21.7	1297.8
G3	584.8	1885.3	69.0	AVNS	10519.5	–	–	–	–	–	–	–	–	1441.9	59.4	1474.4	15.7	1180.6

Table C3: Continued.

Instance	LB ⁺	Mankowska et al. (2014)				Lasfargeas et al. (2019)					Kummer et al. (2019)			BRKGA-MP-IPR				
		Best	Gap	Method	Time	Best	Gap	Mean	SD	Time	Best	Gap	Time	Best	Gap	Mean	SD	Time
G4	591.9	2023.2	70.7	AVNS	10597.5	–	–	–	–	–	–	–	–	1490.1	60.3	1523.1	19.0	1345.7
G5	616.5	2247.6	72.6	AVNS	10597.5	–	–	–	–	–	–	–	–	1623.4	62.0	1650.9	23.2	1137.4
G6	583.5	2144.4	72.8	AVNS	10597.5	–	–	–	–	–	–	–	–	1657.5	64.8	1682.8	18.0	1408.2
G7	604.8	1971.5	69.3	AVNS	10206.0	–	–	–	–	–	–	–	–	1569.0	61.5	1590.6	14.4	1210.5
G8	618.3	1987.4	68.9	AVNS	10597.5	–	–	–	–	–	–	–	–	1477.6	58.2	1503.0	17.0	1185.1
G9	637.4	2415.5	73.6	AVNS	10337.0	–	–	–	–	–	–	–	–	1827.7	65.1	1880.3	38.1	1210.9
G10	621.0	2373.4	73.8	AVNS	10307.5	–	–	–	–	–	–	–	–	1797.1	65.4	1822.4	16.6	1110.0
	604.3	2161.2	72.0		10495.5	–	–	–	–	–	–	–	–	1632.7	63.0	1664.8	20.4	1228.5

Extended results for BRKGA, BRKGA-TL and BRKGA-MP-IPR

Table D4: Comparison of a simpler variant of BRKGA and BRKGA-MP-IPR. Values in bold indicate the best-known solution value produced by the methods, and values marked with an asterisk indicate an optimal solution value.

Inst.	LB ⁺	K2020						BRKGA-TL								BRKGA-MP-IPR								
		Best	Gap (best)	Mean	Gap (mean)	SD	Time	Best	Gap (best)	Mean	Gap (mean)	SD	Diff. K2020	Time	Gens.	LI gen.	Best	Gap	Mean	Gap (mean)	SD	Diff. K2020	Diff. BRKGA-TL	Time
A1	*218.2	227.0	3.9	227.0	3.9	0.0	2.8	227.0	3.9	227.0	3.9	0.0	0.0	81.2	144,111	10.5	227.0	3.9	227.0	3.9	0.0	0.0	0.0	98.6
A2	*246.6	*246.6	0.0	246.6	0.0	0.0	2.7	*246.6	0.0	246.6	0.0	0.0	0.0	79.5	140,266	10.9	*246.6	0.0	246.6	0.0	0.0	0.0	0.0	97.3
A3	*305.9	*305.9	0.0	305.9	0.0	0.0	2.7	*305.9	0.0	305.9	0.0	0.0	0.0	79.6	143,560	7.8	*305.9	0.0	305.9	0.0	0.0	0.0	0.0	99.6
A4	*186.9	*186.9	0.0	186.9	0.0	0.0	2.7	*186.9	0.0	186.9	0.0	0.0	0.0	79.9	145,238	7.9	*186.9	0.0	186.9	0.0	0.0	0.0	0.0	97.6
A5	*189.5	192.0	1.3	192.0	1.3	0.0	2.8	192.0	1.3	192.0	1.3	0.0	0.0	79.7	138,962	8.5	192.0	1.3	192.0	1.3	0.0	0.0	0.0	97.4
A6	*200.1	*200.1	0.0	200.1	0.0	0.0	2.8	*200.1	0.0	200.1	0.0	0.0	0.0	79.7	140,048	9.9	*200.1	0.0	200.1	0.0	0.0	0.0	0.0	98.1
A7	*225.4	*225.4	0.0	225.4	0.0	0.0	2.5	*225.4	0.0	225.4	0.0	0.0	0.0	80.1	154,205	10.9	*225.4	0.0	225.4	0.0	0.0	0.0	0.0	97.2
A8	*232.0	*232.0	0.0	232.0	0.0	0.0	2.5	*232.1	0.0	232.0	0.0	0.0	0.0	79.6	152,986	9.7	*232.1	0.0	232.1	0.0	0.0	0.0	0.0	98.4
A9	*222.3	234.2	5.1	234.2	5.1	0.0	3.0	234.2	5.1	234.2	5.1	0.0	0.0	80.1	130,577	11.3	234.2	5.1	234.2	5.1	0.0	0.0	0.0	96.5
A10	*225.0	*225.0	0.0	225.0	0.0	0.0	2.6	*225.0	0.0	225.0	0.0	0.0	0.0	78.6	151,484	4.2	*225.0	0.0	225.0	0.0	0.0	0.0	0.0	96.2
	225.2	227.5	1.0	227.5	1.0	0.0	2.7	227.5	1.0	227.5	1.0	0.0	0.0	79.8	144,144	9.2	227.5	1.0	227.5	1.0	0.0	0.0	0.0	97.7
B1	*428.1	*428.1	0.0	428.3	0.0	0.2	10.0	*428.1	0.0	428.1	0.0	0.0	0.0	90.2	57,618	2470.3	*428.1	0.0	428.1	0.0	0.0	0.0	0.0	103.9
B2	*476.0	483.6	1.6	485.7	2.0	1.5	9.7	483.6	1.6	485.7	2.0	1.5	0.0	89.8	58,918	171.4	483.6	1.6	483.6	1.6	0.0	0.0	0.0	105.5
B3	371.4	402.8	7.8	402.8	7.8	0.0	10.4	402.8	7.8	402.8	7.8	0.0	0.0	90.5	55,058	187.1	402.8	7.8	402.8	7.8	0.0	0.0	0.0	104.4
B4	*411.3	420.3	2.1	431.9	4.8	3.5	9.5	420.3	2.1	425.4	3.3	6.5	0.0	89.9	60,078	7435.7	420.3	2.1	429.1	4.2	5.3	0.0	0.0	105.9
B5	363.7	372.2	2.3	374.2	2.8	3.0	9.5	372.2	2.3	373.6	2.7	2.5	0.0	89.9	60,923	2307.1	372.2	2.3	373.0	2.5	2.2	0.0	0.0	102.2
B6	372.8	471.0	20.8	471.9	21.0	1.4	10.3	471.0	20.8	471.4	20.9	1.4	0.0	90.5	54,797	6886.4	471.0	20.8	471.0	20.8	0.0	0.0	0.0	107.8
B7	*328.6	*328.7	0.0	328.7	0.0	0.0	11.0	*328.7	0.0	328.7	0.0	0.0	0.0	90.7	53,635	78.6	*328.7	0.0	328.7	0.0	0.0	0.0	0.0	104.5
B8	*357.6	359.7	0.6	359.7	0.6	0.0	10.6	359.7	0.6	359.7	0.6	0.0	0.0	90.5	53,849	48.7	359.7	0.6	359.7	0.6	0.0	0.0	0.0	106.0
B9	336.9	402.7	16.3	404.3	16.7	1.1	11.5	402.7	16.3	403.1	16.4	0.9	0.0	91.5	50,479	14350.3	402.7	16.3	403.2	16.4	0.7	0.0	0.0	107.3
B10	413.7	469.6	11.9	469.6	11.9	0.0	10.6	469.6	11.9	469.6	11.9	0.0	0.0	91.0	53,094	73.6	469.6	11.9	469.6	11.9	0.0	0.0	0.0	106.8
	386.0	413.9	6.7	415.7	6.8	1.1	10.3	413.9	6.7	414.8	6.6	1.3	0.0	90.5	55,845	3400.9	413.9	6.7	414.9	6.6	0.8	0.0	0.0	105.4
C1	477.3	965.2	50.5	975.6	51.1	7.6	42.8	965.2	50.5	973.9	51.0	7.4	0.0	121.0	20,399	4476.7	965.2	50.5	966.6	50.6	1.9	0.0	0.0	127.2
C2	377.4	583.4	35.3	590.5	36.1	9.9	45.2	582.2	35.2	585.8	35.6	5.8	-0.2	120.2	19,441	8723.3	582.2	35.2	582.9	35.2	1.2	-0.2	0.0	135.4
C3	396.4	548.8	27.8	559.1	29.1	6.8	43.3	548.8	27.8	556.1	28.7	5.7	0.0	119.1	20,378	4610.9	548.8	27.8	551.4	28.1	1.5	0.0	0.0	130.2
C4	367.4	519.9	29.3	530.6	30.8	7.0	41.9	519.9	29.3	525.8	30.1	4.0	0.0	117.8	20,637	6730.3	519.8	29.3	523.2	29.8	2.5	0.0	0.0	127.6
C5	496.9	678.6	26.8	702.9	29.3	20.7	36.4	670.6	25.9	689.8	28.0	19.2	-1.2	114.6	23,978	7658.3	670.6	25.9	675.3	26.4	4.4	-1.2	0.0	130.1
C6	366.1	840.7	56.4	845.5	56.7	5.0	43.1	840.7	56.4	843.5	56.6	3.2	0.0	119.3	20,032	3166.6	840.7	56.4	842.4	56.5	1.4	0.0	0.0	128.2
C7	365.2	534.9	31.7	540.4	32.4	5.4	48.9	528.5	30.9	536.8	32.0	5.4	-1.2	124.0	18,097	4447.8	528.5	30.9	532.5	31.4	3.4	-1.2	0.0	133.5
C8	377.1	474.6	20.5	480.1	21.5	4.0	42.3	473.3	20.3	477.4	21.0	3.5	-0.3	118.1	20,720	6047.9	472.0	20.1	475.1	20.6	1.5	-0.5	-0.3	133.5
C9	361.5	534.3	32.3	551.1	34.4	8.8	49.6	533.9	32.3	545.1	33.7	7.0	-0.1	123.3	18,149	4990.6	531.2	31.9	538.7	32.9	4.5	-0.6	-0.5	130.7
C10	449.8	611.3	26.4	618.3	27.2	4.7	40.9	611.3	26.4	615.3	26.9	3.3	0.0	126.2	23,021	8315.3	610.9	26.4	612.3	26.5	2.0	-0.1	-0.1	130.2
	403.5	629.1	35.9	639.4	34.9	8.0	43.5	627.4	35.7	635.0	34.4	6.5	-0.3	120.4	20,485	5916.8	627.0	35.6	630.0	33.8	2.4	-0.4	-0.1	130.7
D1	514.4	1186.2	56.6	1209.6	57.5	15.8	108.6	1186.2	56.6	1207.4	57.4	13.7	0.0	164.8	11,318	4618.9	1179.9	56.4	1195.9	57.0	7.1	-0.5	-0.5	169.3

Table D4: Continued.

Inst.	LB ⁺	K2020						BRKGA-TL								BRKGA-MP-IPR								
		Best	Gap (best)	Mean	Gap (mean)	SD	Time	Best	Gap (best)	Mean	Gap (mean)	SD	Diff. K2020	Time	Gens.	LI gen.	Best	Gap	Mean	Gap (mean)	SD	Diff. K2020	Diff. BRKGA-TL	Time
D2	386.0	693.3	44.3	718.0	46.2	17.3	96.1	685.9	43.7	709.2	45.6	16.2	-1.1	156.5	13,018	4916.3	684.3	43.6	694.8	44.4	7.3	-1.3	-0.2	155.5
D3	379.5	635.7	40.3	651.4	41.7	8.2	118.5	635.7	40.3	647.6	41.4	6.3	0.0	170.9	10,945	4311.0	633.4	40.1	640.6	40.8	4.0	-0.4	-0.4	170.2
D4	408.5	814.3	49.8	841.6	51.5	11.6	95.4	804.5	49.2	838.7	51.3	13.6	-1.2	156.3	12,974	4484.1	804.4	49.2	829.6	50.8	14.2	-1.2	0.0	159.8
D5	404.3	691.5	41.5	703.1	42.5	13.5	107.1	689.4	41.4	701.3	42.4	13.8	-0.3	164.1	11,514	3885.3	682.8	40.8	691.8	41.6	4.6	-1.3	-1.0	165.5
D6	391.8	733.7	46.6	744.7	47.4	7.1	122.7	731.3	46.4	742.0	47.2	7.4	-0.3	174.3	10,430	3473.4	712.1	45.0	727.6	46.1	6.5	-2.9	-2.6	170.7
D7	359.0	590.6	39.2	604.7	40.6	6.9	130.8	590.6	39.2	604.0	40.6	6.5	0.0	177.6	10,333	3031.7	585.6	38.7	592.4	39.4	5.0	-0.9	-0.9	177.8
D8	406.8	661.8	38.5	680.3	40.2	11.4	119.0	657.8	38.2	676.9	39.9	11.9	-0.6	171.0	10,824	3695.6	658.4	38.2	663.3	38.7	3.0	-0.5	0.1	171.2
D9	387.6	706.1	45.1	723.4	46.4	10.2	107.3	704.5	45.0	721.6	46.3	10.6	-0.2	164.0	11,619	4810.7	696.2	44.3	713.7	45.7	12.1	-1.4	-1.2	162.4
D10	479.3	1208.7	60.3	1290.6	62.9	72.5	90.1	1205.8	60.2	1276.0	62.4	71.6	-0.2	153.2	13,543	6668.4	1201.7	60.1	1223.5	60.8	21.1	-0.6	-0.3	156.8
	411.7	792.2	48.0	816.8	47.7	17.4	109.6	789.2	47.8	812.5	47.4	17.2	-0.4	165.3	11,652	4389.5	783.9	47.5	797.3	46.5	8.5	-1.1	-0.7	165.9
E1	421.8	1331.5	68.3	1352.3	68.8	11.2	224.4	1329.0	68.3	1348.2	68.7	11.5	-0.2	234.6	8,087	4368.5	1318.9	68.0	1335.1	68.4	10.6	-0.9	-0.8	219.0
E2	423.7	848.1	50.0	871.2	51.4	16.6	222.6	842.3	49.7	867.5	51.2	15.1	-0.7	231.8	8,358	3291.6	824.2	48.6	846.1	49.9	16.6	-2.8	-2.2	218.1
E3	445.2	788.0	43.5	814.2	45.3	16.8	212.0	785.8	43.3	809.8	45.0	15.4	-0.3	227.2	8,358	3901.9	785.1	43.3	794.4	44.0	7.4	-0.4	-0.1	216.9
E4	398.5	711.2	44.0	729.9	45.4	12.7	227.8	709.0	43.8	726.8	45.2	12.6	-0.3	234.2	7,945	4666.2	703.1	43.3	720.3	44.7	8.9	-1.1	-0.8	222.2
E5	403.6	781.5	48.4	803.9	49.8	13.8	211.3	772.9	47.8	793.8	49.2	12.5	-1.1	226.8	8,525	5031.1	760.5	46.9	777.2	48.1	11.0	-2.7	-1.6	217.2
E6	404.5	790.5	48.8	804.2	49.7	8.0	205.9	785.4	48.5	801.0	49.5	8.7	-0.6	233.7	7,958	4135.4	772.1	47.6	788.4	48.7	8.6	-2.3	-1.7	223.3
E7	384.7	711.1	45.9	733.9	47.6	8.9	222.4	707.3	45.6	730.8	47.4	9.8	-0.5	246.6	7,705	4444.1	708.8	45.7	720.7	46.6	5.8	-0.3	0.2	231.2
E8	425.9	752.4	43.4	762.0	44.1	7.2	195.7	749.3	43.2	758.9	43.9	7.3	-0.4	226.4	8,325	3789.7	725.6	41.3	743.6	42.7	8.9	-3.6	-3.2	217.1
E9	431.2	921.8	53.2	951.9	54.7	13.9	189.1	910.7	52.6	944.1	54.3	14.2	-1.2	224.1	8,691	4906.3	877.1	50.8	913.8	52.8	16.2	-4.8	-3.7	213.4
E10	441.8	825.2	46.5	845.1	47.7	14.7	202.3	819.3	46.1	842.3	47.5	15.7	-0.7	233.0	8,351	4819.1	815.0	45.8	828.2	46.7	9.8	-1.2	-0.5	219.6
	418.1	846.1	50.6	866.9	50.5	12.4	211.3	841.1	50.3	862.3	50.2	12.3	-0.6	231.9	8,230	4335.4	829.0	49.6	846.8	49.3	10.4	-2.0	-1.4	219.8
F1	546.7	1402.0	61.0	1426.0	61.7	14.4	864.3	1396.5	60.8	1416.2	61.4	12.2	-0.4	618.1	5,379	4317.5	1342.1	59.3	1373.7	60.2	19.0	-4.3	-3.9	535.8
F2	535.0	1336.3	60.0	1383.6	61.3	26.1	941.5	1322.3	59.5	1367.5	60.9	25.2	-1.0	651.6	5,234	4223.3	1296.0	58.7	1322.8	59.6	16.7	-3.0	-2.0	564.1
F3	541.6	1263.4	57.1	1285.8	57.9	12.6	904.7	1258.0	56.9	1281.1	57.7	13.3	-0.4	628.0	5,302	3665.1	1201.1	54.9	1228.5	55.9	11.9	-4.9	-4.5	549.0
F4	524.0	1124.2	53.4	1146.2	54.3	11.9	1045.7	1123.4	53.4	1141.6	54.1	10.3	-0.1	733.8	5,135	3702.7	1093.9	52.1	1107.6	52.7	14.4	-2.7	-2.6	640.9
F5	529.0	1329.3	60.2	1365.2	61.2	20.0	957.8	1322.1	60.0	1355.2	61.0	21.0	-0.5	682.0	5,103	4068.9	1286.8	58.9	1317.0	59.8	16.2	-3.2	-2.7	592.3
F6	498.6	1332.1	62.6	1373.3	63.7	24.3	753.3	1330.8	62.5	1366.1	63.5	22.5	-0.1	597.1	5,525	3814.8	1295.6	61.5	1315.5	62.1	10.8	-2.7	-2.6	522.5
F7	502.5	1131.3	55.6	1157.4	56.6	14.2	947.2	1125.0	55.3	1149.4	56.3	15.0	-0.6	719.0	5,093	4266.5	1088.2	53.8	1119.1	55.1	18.5	-3.8	-3.3	624.7
F8	532.9	1132.8	53.0	1165.1	54.3	18.1	830.5	1125.4	52.6	1160.1	54.1	17.4	-0.7	654.5	5,230	3942.7	1098.7	51.5	1131.1	52.9	12.4	-3.0	-2.4	566.3
F9	535.9	1311.4	59.1	1345.0	60.2	18.0	893.2	1304.2	58.9	1336.5	59.9	19.1	-0.5	686.2	5,145	3599.5	1262.1	57.5	1291.4	58.5	19.1	-3.8	-3.2	594.0
F10	540.2	1418.5	61.9	1446.3	62.6	17.1	858.3	1405.1	61.6	1438.1	62.4	17.0	-0.9	670.9	5,132	4069.4	1358.0	60.2	1392.6	61.2	14.2	-4.3	-3.4	582.4
	528.6	1278.1	58.6	1309.4	59.4	17.7	899.6	1271.3	58.4	1301.2	59.1	17.3	-0.5	664.1	5,228	3967.0	1232.3	57.1	1259.9	57.8	15.3	-3.6	-3.1	577.2
G1	584.6	1778.5	67.1	1855.2	68.5	35.4	2260.5	1762.6	66.8	1837.0	68.2	32.5	-0.9	1370.6	4,636	4020.3	1728.3	66.2	1749.3	66.6	20.4	-2.8	-1.9	1198.9
G2	600.6	1824.7	67.1	1898.0	68.4	37.6	2452.1	1811.6	66.8	1874.1	68.0	34.7	-0.7	1524.4	4,570	4288.9	1714.0	65.0	1771.0	66.1	21.7	-6.1	-5.4	1297.8
G3	584.8	1514.2	61.4	1546.5	62.2	15.7	2243.5	1501.1	61.0	1533.4	61.9	18.3	-0.9	1347.2	4,678	4209.4	1441.9	59.4	1474.4	60.3	15.7	-4.8	-3.9	1180.6
G4	591.9	1564.4	62.2	1599.4	63.0	23.9	2478.3	1551.3	61.8	1586.4	62.7	23.8	-0.8	1562.6	4,668	4240.3	1490.1	60.3	1523.1	61.1	19.0	-4.8	-3.9	1345.7
G5	616.5	1698.3	63.7	1749.1	64.8	26.5	2134.3	1680.5	63.3	1729.2	64.3	24.1	-1.0	1335.8	4,712	4313.9	1623.4	62.0	1650.9	62.7	23.2	-4.4	-3.4	1137.4
G6	583.5	1714.4	66.0	1777.4	67.2	24.4	2335.5	1701.2	65.7	1764.1	66.9	25.0	-0.8	1629.8	4,559	4114.8	1657.5	64.8	1682.8	65.3	18.0	-3.3	-2.6	1408.2
G7	604.8	1640.1	63.1	1677.9	64.0	24.4	2138.3	1625.0	62.8	1663.0	63.6	26.7	-0.9	1402.6	4,706	4212.8	1569.0	61.5	1590.6	62.0	14.4	-4.3	-3.4	1210.5
G8	618.3	1547.6	60.0	1583.9	61.0	20.5	2085.8	1532.9	59.7	1567.4	60.6	17.5	-1.0	1390.4	4,789	4403.4	1477.6	58.2	1503.0	58.9	17.0	-4.5	-3.6	1185.1

Table D4: Continued.

Inst.	LB ⁺	K2020						BRKGA-TL								BRKGA-MP-IPR								
		Best	Gap (best)	Mean	Gap (mean)	SD	Time	Best	Gap (best)	Mean	Gap (mean)	SD	Diff. K2020	Time	Gens.	LI gen.	Best	Gap	Mean	Gap (mean)	SD	Diff. K2020	Diff. BRKGA-TL	Time
G9	637.4	1942.2	67.2	1972.5	67.7	21.1	2099.3	1932.6	67.0	1954.7	67.4	18.3	-0.5	1429.9	4,731	4123.4	1827.7	65.1	1880.3	66.1	38.1	-5.9	-5.4	1210.9
G10	621.0	1872.1	66.8	1932.3	67.9	28.2	1912.5	1855.9	66.5	1907.1	67.4	27.2	-0.9	1277.3	4,747	4189.3	1797.1	65.4	1822.4	65.9	16.6	-4.0	-3.2	1110.0
	604.3	1709.7	64.7	1759.2	65.4	25.8	2214.0	1695.5	64.4	1741.6	65.1	24.8	-0.8	1427.1	4,680	4211.6	1632.7	63.0	1664.8	63.5	20.4	-4.5	-3.7	1228.5