An Iterated Local Search Algorithm for the Time-Dependent Vehicle Routing Problem with Time Windows — Detailed Computational Results —

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We proposed an iterated local search (ILS) algorithm for the time-dependent vehicle routing problem with time windows in [1], and below are the detailed computational results of our ILS.

We use Solomon's benchmark instances [4] and Gehring and Homberger's benchmark instances [2], which have been widely used in the literature. We compare our computational results with the previous best known values as of June 2, 2004, presented in the web site (http://www.sintef.no/static/am/opti/projects/top/vrp/benchmarks.html). The algorithm was coded in C language and run on a PC (Intel Pentium 4, 2.8 GHz, 1 GB memory). We used $L^{\mathrm{cross}} = 3$, $L^{\mathrm{intra}}_{\mathrm{path}} = 3$, $L^{\mathrm{intra}}_{\mathrm{ins}} = 15$ and $D_{\mathrm{cross}} = 1.5$ in the experiments. We first set the number of vehicles to the number that is used by Ibaraki et al. [3]. To determine parameter value α in each instance, we first try to run with some αs from $\{1, 5, 10, 50, 100, 500, \ldots\}$ within 10% of the time limit for each α. Then, we choose the best α of them and the both adjacent αs. We use the three αs and report the best one below. If we cannot find a feasible solution, which satisfies the time window and capacity constraints as hard, even with $\alpha = 1000000$, we increase the number of vehicles by one. As for the Solomon's instances, the time limit of our algorithm for each instance is 1000 seconds. The results are shown in Table 1. As for the Gehring and Homberger's instances, the time limit of our algorithm for 200, 400, 600, 800 and 1000-customer instances are 2000, 4000, 6000, 8000 and 10000 seconds, respectively. The results are shown in Tables 2, 3, 4, 5 and 6. Each row of these tables represents a problem instance. "m" represents the number of vehicles, "d_{sum}" represents the total travel distance value, and "LS" represents the total number of local search procedure called in our iterated local search algorithm.

References

[1] H. Hashimoto, M. Yagiura, and T. Ibaraki. An iterated local search algorithm for the time-dependent vehicle routing problem with time windows. *Discrete Optimization*, to appear.

[2] J. Homberger and H. Gehring. A two-phase hybrid metaheuristic for the vehicle routing problem with time windows. *European Journal of Operational Research*, 162:220–238, 2005.

[3] T. Ibaraki, S. Imahori, K. Nonobe, K. Sobue, T. Uno, and M. Yagiura. An iterated local search algorithm for vehicle routing problem with convex time penalty functions. *Discrete Applied Mathematics*, to appear.

[4] M. M. Solomon. The vehicle routing and scheduling problems with time window constraints. *Operations Research*, 35:254–265, 1987.

Table 1: Detailed results for 100-customer benchmark instances

					bknown								bknown	
Inst	m	α	d_{sum}	LS	m	d_{sum}	Inst	m	α	d_{sum}	LS	m	d_{sum}
c101	10	5	828.94	26577	10	828.94	c201	3	5	591.56	5715	3	591.56
c102	10	5	828.94	30171	10	828.94	c202	3	5	591.56	5046	3	591.56
c103	10	5	828.06	33544	10	828.06	c203	3	5	591.17	5244	3	591.17
c104	10	5	824.78	36223	10	824.78	c204	3	5	590.60	7976	3	590.60
c105	10	5	828.94	24613	10	828.94	c205	3	5	588.88	7101	3	588.88
c106	10	5	828.94	27728	10	828.94	c206	3	5	588.49	7098	3	588.49
c107	10	5	828.94	28134	10	828.94	c207	3	5	588.29	7554	3	588.29
c108	10	5	828.94	31400	10	828.94	c208	3	5	588.32	8937	3	588.32
c109	10	5	828.94	36113	10	828.94							
r101	19	100	1650.80	35156	19	1645.79	r201	4	5	1253.23	6720	4	1252.37
r102	17	100	1486.12	30962	17	1486.12	r202	3	10	1191.80	3401	3	1191.70
r103	13	50	1292.68	28086	13	1292.68	r203	3	1	943.27	5566	3	939.54
r104	9	50000	1007.31	24758	9	1007.24	r204	2	1	832.76	2579	2	825.52
r105	14	5	1377.11	29396	14	1377.11	r205	3	10	994.43	5965	3	994.42
r106	12	5	1252.03	25695	12	1251.98	r206	3	1	906.14	6214	3	906.14
r107	10	50	1104.66	22944	10	1104.66	r207	2	5	898.16	2509	2	893.33
r108	9	10	963.99	25944	9	960.88	r208	2	1	730.54	5620	2	726.75
r109	11	10	1205.36	25423	11	1194.73	r209	3	1	915.06	5279	3	909.16
r110	10	10	1129.47	23971	10	1118.59	r210	3	5	939.37	5818	3	939.34
r111	10	50	1096.73	23646	10	1096.72	r211	2	5	906.96	2538	2	892.71
r112	9	100	991.85	28919	9	982.14							
rc101	14	100	1696.95	32400	14	1696.94	rc201	4	5	1406.94	7387	4	1406.91
rc102	12	100	1554.75	28893	12	1554.75	rc202	3	500	1367.00	3604	3	1365.64
rc103	11	10	1262.02	31070	11	1261.67	rc203	3	10	1058.33	6260	3	1049.62
rc104	10	5	1135.83	27181	10	1135.48	rc204	3	5	798.46	11137	3	798.41
rc105	13	100	1629.44	31288	13	1629.44	rc205	4	1	1297.65	6838	4	1297.19
rc106	11	100	1424.73	31523	11	1424.73	rc206	3	5	1146.32	5099	3	1146.32
rc107	11	50	1230.48	36141	11	1230.48	rc207	3	1	1061.14	4658	3	1061.14
rc108	10	50	1139.82	34620	10	1139.82	rc208	3	1	828.14	7816	3	828.14

Table 2: Detailed results for 200-customer benchmark instances

					bknown								bknown	
Inst	m	α	d_{sum}	LS	m	d_{sum}	Inst	m	α	d_{sum}	LS	m	d_{sum}
c101	20	5	2704.57	22870	20	2704.57	c201	6	5	1931.44	4168	6	1931.44
c102	18	10	2917.89	11949	18	2917.89	c202	6	5	1863.16	5011	6	1863.16
c103	18	1	2707.35	14031	18	2708.08	c203	6	1	1786.39	5869	6	1775.11
c104	18	1	2649.99	14891	18	2644.61	c204	6	5	1733.40	7505	6	1720.09
c105	20	5	2702.05	18817	20	2702.05	c205	6	1	1878.85	6071	6	1878.85
c106	20	5	2701.04	20996	20	2701.04	c206	6	1	1857.35	7177	6	1857.35
c107	20	5	2701.04	20453	20	2701.04	c207	6	1	1849.46	6975	6	1849.46
c108	19	50	2793.58	17304	18	2769.19	c208	6	1	1820.53	8309	6	1820.59
c109	18	10	2693.99	14666	18	2642.82	c209	6	1	1832.43	7834	6	1830.18
c110	18	5	2647.92	16678	18	2649.26	c210	6	1	1806.58	9139	6	1806.60
r101	20	1000	4795.04	17905	19	5024.65	r201	4	1000000	4520.81	1389	4	4501.80
r102	18	1000	4157.01	13533	18	4054.44	r202	4	100	3667.70	1949	4	3645.38
r103	18	50	3458.01	12306	18	3382.65	r203	4	1000	2891.23	3010	4	2932.44
r104	18	50	3088.56	12037	18	3067.93	r204	4	1	1988.23	4373	4	1981.29
r105	18	100	4190.21	11595	18	4112.88	r205	4	5	3367.53	2354	4	3367.55
r106	18	50	3719.57	12072	18	3599.84	r206	4	10	2914.76	2754	4	2914.56
r107	18	50	3195.05	13352	18	3151.42	r207	4	50	2456.05	4100	4	2453.62
r108	18	1	2982.37	9881	18	2963.90	r208	4	5	1849.98	6700	4	1849.87
r109	18	50	3909.27	12480	18	3784.33	r209	4	10	3115.72	2722	4	3111.41
r110	18	50	3408.31	13821	18	3307.78	r210	4	50	2666.82	3506	4	2657.00
rc101	18	100	3769.86	11424	18	3691.99	rc201	6	100	3125.75	5693	6	3103.48
rc102	18	50	3379.01	12974	18	3298.68	rc202	5	500	2829.45	4029	5	2827.45
rc103	18	50	3110.69	14202	18	3025.90	rc203	4	500	2618.23	3056	4	2617.90
rc104	18	5	2917.42	12541	18	2879.40	rc204	4	1	2103.47	3528	4	2055.97
rc105	18	100	3685.57	13026	18	3419.81	rc205	4	5	2933.33	2103	4	2912.57
rc106	18	50	3474.90	13496	18	3393.09	rc206	4	100	2889.42	2315	4	3138.02
rc107	18	10	3471.25	12592	18	3266.48	rc207	4	5	2557.40	3247	4	2550.56
rc108	18	10	3259.56	13221	18	3115.82	rc208	4	1	2361.34	3348	4	2317.80
rc109	18	10	3251.53	13826	18	3083.41	rc209	4	5	2198.52	4182	4	2175.61
rc110	18	5	3130.30	12097	18	3038.85	rc210	4	5	2029.88	4841	4	2015.60

Table 3: Detailed results for 400-customer benchmark instances

					bknown								bknown	
Inst	m	α	d_{sum}	LS	m	d_{sum}	Inst	m	α	d_{sum}	LS	m	d_{sum}
c101	40	1	7152.06	11893	40	7152.02	c201	12	5	4116.14	3296	12	4116.05
c102	36	5000	7856.66	6817	37	7357.45	c202	12	1	3930.45	4605	12	3930.29
c103	36	5	7363.31	6264	36	7151.17	c203	12	1	3779.77	4978	12	3739.72
c104	36	1	6869.50	6508	36	6822.18	c204	11	1000000	4350.20	3120	12	3535.99
c105	40	5	7152.06	9751	40	7152.02	c205	12	1	3938.69	5564	12	3939.42
c106	40	1	7153.45	10622	40	7153.41	c206	12	1	3875.94	6480	12	3875.94
c107	39	5000	7505.24	8914	39	8043.18	c207	12	10	3897.70	6325	12	3894.13
c108	37	10000	7882.36	8587	38	7113.40	c208	12	1	3798.66	6732	12	3787.08
c109	36	1000	8086.45	7491	36	7524.32	c209	12	10	3879.83	6728	12	3876.10
c110	36	5	7419.52	6683	36	6907.26	c210	11	5000	4257.64	4662	12	3684.89
r101	40	5000	10547.11	9961	38	11084.00	r201	8	50	9319.21	1860	8	9257.92
r102	36	500	9610.16	5937	36	9161.26	r202	8	1000	7662.25	2408	8	7674.90
r103	36	500	8513.14	5744	36	7941.53	r203	8	1000	6044.85	2811	8	5988.02
r104	36	10	7649.41	4952	36	7332.93	r204	8	5	4348.34	4269	8	4331.07
r105	36	50	10270.00	5412	36	9512.25	r205	8	10	7191.03	2733	8	7143.55
r106	36	100	9197.03	5940	36	8534.05	r206	8	10	6246.39	2917	8	6163.81
r107	36	50	8089.12	5630	36	7710.41	r207	8	5	5140.19	3631	8	5082.10
r108	36	5	7701.29	4659	36	7398.68	r208	8	5	4124.64	5357	8	4068.97
r109	36	10	9660.98	5075	36	8878.19	r209	8	5	6486.50	2795	8	6493.13
r110	36	50	8748.10	5799	36	8227.49	r210	8	10	6016.55	3598	8	5895.93
rc101	36	1000	9769.63	6505	36	8960.82	rc201	11	50	6770.44	3784	11	7019.89
rc102	36	50	8820.22	6916	36	8174.27	rc202	9	10000	6419.16	1990	10	5924.84
rc103	36	50	7973.35	7037	36	7737.99	rc203	8	5	5048.38	2590	8	5114.76
rc104	36	10	7551.31	5666	36	7411.02	rc204	8	10	3700.01	5338	8	3648.64
rc105	36	100	8948.55	7427	36	8499.15	rc205	9	50	6047.21	2712	9	6063.46
rc106	36	10	8873.07	6521	36	8304.99	rc206	8	50	5998.19	2102	8	6054.21
rc107	36	10	8898.66	6386	36	8051.71	rc207	8	100	5570.20	3172	8	5519.25
rc108	36	5	8493.26	5002	36	7917.68	rc208	8	1	4916.86	2885	8	4854.16
rc109	36	5	8282.77	5030	36	7890.45	rc209	8	50	4657.48	4810	8	4628.26
rc110	36	50	8110.30	7046	36	7716.32	rc210	8	5	4427.98	4326	8	4316.36

Table 4: Detailed results for 600-customer benchmark instances

					bknown							bknown	
Inst	m	α	d_{sum}	LS	m	d_{sum}	Inst	m	α	d_{sum}	LS	m	d_{sum}
c101	60	5	14095.64	7222	60	14095.64	c201	18	1	7774.16	3407	18	7774.16
c102	56	500	14209.47	4840	56	14325.96	c202	17	1000	8784.11	2208	18	7486.88
c103	56	5	13934.96	4264	56	13898.99	c203	17	50	7977.15	2401	17	8371.07
c104	56	10	13864.79	4479	56	13610.66	c204	17	5	7474.75	3129	17	7216.45
c105	60	10	14085.72	6278	60	14085.70	c205	18	5	7576.44	4415	18	7576.35
c106	60	50	14089.66	6616	60	14089.70	c206	18	1	7479.48	5428	18	7478.63
c107	59	10000	14580.31	6403	59	14659.74	c207	18	10	7535.05	4797	18	7560.53
c108	56	10000	15437.77	6056	57	14976.88	c208	17	100	8169.53	4031	18	7352.42
c109	56	100	14543.28	4332	56	13733.56	c209	17	1000	9168.68	3193	18	7350.94
c110	56	1	14127.95	4164	56	13758.19	c210	17	1	7662.03	3967	17	7523.34
r101	59	1000	21857.78	6509	59	21131.09	r201	11	50	19060.46	1242	11	18325.60
r102	54	1000	21734.84	5076	54	19603.70	r202	11	500	15473.66	1465	11	15346.42
r103	54	50	19475.54	3600	54	17400.60	r203	11	100	12045.89	1728	11	11663.06
r104	54	50	17391.78	2954	54	15993.80	r204	11	10	8503.38	2299	11	8386.64
r105	54	1000	22962.20	4538	54	20395.00	r205	11	100	15871.96	1791	11	15640.60
r106	54	100	21178.18	3578	54	18620.26	r206	11	50	13565.21	1775	11	12937.47
r107	54	50	18857.78	3460	54	17107.91	r207	11	50	10565.35	2120	11	10536.84
r108	54	50	17033.88	2912	54	15725.86	r208	11	10	8254.00	2700	11	8023.64
r109	54	1000	22315.90	4404	54	19372.96	r209	11	50	14245.68	1839	11	13567.84
r110	54	50	20823.64	3557	54	18235.57	r210	11	100	12886.16	2303	11	12607.09
rc101	55	1000	19365.42	4426	55	17454.39	rc201	14	100	13753.35	2216	15	13275.93
rc102	55	500	17752.43	4475	55	16208.24	rc202	12	100	11756.29	1789	12	12071.40
rc103	55	10	16461.69	4178	55	15524.33	rc203	11	50	10248.58	1409	11	9978.25
rc104	55	10	15546.46	3652	55	15180.72	rc204	11	10	7894.73	2070	11	7349.88
rc105	55	500	18828.10	4433	55	17468.57	rc205	12	10000	12757.40	2071	13	11919.72
rc106	55	100	18583.52	4331	55	17248.87	rc206	11	1000	13396.83	1202	12	11411.08
rc107	55	100	18167.54	4495	55	16454.79	rc207	11	100	11808.20	1709	11	11687.04
rc108	55	50	17863.08	4216	55	16462.49	rc208	11	10	10978.22	1784	11	10474.95
rc109	55	50	17653.90	4004	55	16153.00	rc209	11	10	10593.09	2094	11	10113.82
rc110	55	10	17421.19	3584	55	16030.86	rc210	11	5	9966.14	1987	11	9339.41

Table 5: Detailed results for 800-customer benchmark instances

					bknown								bknown	
Inst	m	α	d_{sum}	LS	m	d_{sum}	Inst	m	α	d_{sum}	LS	m	d_{sum}
c101	80	5	25184.38	5074	80	25030.36	c201	24	1	11662.08	3248	24	11654.72
c102	74	1000000	26114.66	4387	75	25518.17	c202	23	10000	12773.63	2326	24	11422.34
c103	72	5	26213.54	2472	72	25438.60	c203	23	100	12503.37	2195	23	11554.18
c104	72	1	24719.93	2225	72	24040.47	c204	23	1	11342.56	2615	23	10963.49
c105	80	100	25166.28	4669	80	25166.30	c205	24	1	11434.03	4187	24	11432.92
c106	80	100	25160.85	4728	80	25160.90	c206	24	1	11348.43	4624	24	11357.86
c107	79	500	25538.54	3758	79	25518.85	c207	24	50	11468.03	4474	24	11397.54
c108	75	10000	26243.46	4762	76	25379.85	c208	23	10000	12195.91	4542	24	11206.32
c109	72	1000	27827.13	3729	73	24713.38	c209	23	10000	13069.53	3364	24	11249.00
c110	72	10	26987.10	2845	72	29536.81	c210	23	5	11627.82	3785	23	11284.46
r101	80	1000000	38056.29	4884	79	39612.20	r201	15	100	29206.74	1784	15	28440.28
r102	72	5000	35999.87	3367	72	33548.54	r202	15	10	24088.01	1517	15	23335.67
r103	72	100	32529.49	2361	72	30151.90	r203	15	10	18286.82	1935	15	17992.25
r104	72	10	30303.52	1990	72	26838.04	r204	15	5	13929.80	2422	15	13625.25
r105	72	50	38055.58	2496	72	34741.53	r205	15	50	25349.89	2135	15	24611.39
r106	72	10	34546.53	2321	72	31737.47	r206	15	10	21397.18	1868	15	20697.06
r107	72	10	31537.02	2196	72	29538.40	r207	15	10	17249.67	2134	15	17058.30
r108	72	5	29662.64	1892	72	28342.64	r208	15	10	13396.06	2769	15	13053.31
r109	72	100	35986.98	2505	72	34231.38	r209	15	10	23252.47	2147	15	22588.02
r110	72	10	34272.51	2299	72	31730.45	r210	15	5	21948.49	2080	15	21551.26
rc101	73	100	33711.89	3387	73	31590.23	rc201	19	10000	20716.21	3238	20	19989.12
rc102	72	50	35112.82	3455	72	39696.20	rc202	16	10000	19129.08	1660	17	18099.68
rc103	72	100	33015.08	3261	72	35577.87	rc203	15	100	15346.72	1823	15	15116.26
rc104	72	10	30085.34	2717	72	32654.10	rc204	15	5	11604.53	2374	15	11392.25
rc105	73	100	32344.49	3481	73	30454.15	rc205	16	100	19321.34	2195	16	19105.75
rc106	73	50	32782.06	3286	73	29674.68	rc206	15	10	19945.66	1617	15	18882.30
rc107	72	500	39643.15	3244	72	43829.43	rc207	15	5	17547.91	1713	15	17461.44
rc108	72	100	36512.04	3059	72	43694.60	rc208	15	5	16752.84	1998	15	16529.24
rc109	72	50	35660.83	3038	72	41816.70	rc209	15	5	16329.70	2180	15	15823.50
rc110	72	10	34716.75	2504	72	41182.44	rc210	15	10	15041.86	2804	15	14892.29

Table 6: Detailed results for 1000-customer benchmark instances

					bknown							bknown	
Inst	m	α	d_{sum}	LS	m	d_{sum}	Inst	m	α	d_{sum}	LS	m	d_{sum}
c101	100	5	42478.95	5050	100	42478.95	c201	30	5	16879.24	2797	30	16879.24
c102	90	1000	45854.82	2666	92	42920.70	c202	29	50	17473.93	2307	29	17228.82
c103	90	5	42218.92	2401	90	40934.87	c203	29	50	17043.13	2626	29	16367.59
c104	90	1	41575.26	2112	90	40410.58	c204	29	5	16896.99	2624	29	17153.19
c105	100	100	42469.18	4984	100	42469.20	c205	30	5	16568.73	3692	30	16586.46
c106	100	100	42471.28	5135	100	42471.30	c206	30	5	16348.20	4508	30	16371.65
c107	99	1000	42821.17	3984	99	42711.39	c207	30	10000	16827.81	4416	31	16578.42
c108	94	10000	43555.1	4238	96	42170.31	c208	29	1	16532.88	3500	29	18662.10
c109	91	1000	42755.59	3254	91	45386.93	c209	29	10000	17462.68	4022	30	16651.96
c110	90	100	44468.65	3344	90	40894.38	c210	29	1	16194.56	3545	29	16178.26
r101	100	1000	55922.77	3756	100	54145.31	r201	19	500	43554.40	1779	19	42922.56
r102	91	1000	56975.89	2929	91	56367.45	r202	19	50	35416.79	1562	19	34918.49
r103	91	100	51259.61	2645	91	46621.19	r203	19	50	26396.47	1787	19	25689.62
r104	91	50	47116.49	2306	91	43461.84	r204	19	5	19026.43	2214	19	18858.24
r105	91	50	61437.30	2672	91	70838.01	r205	19	100	38162.84	2040	19	37265.32
r106	91	50	55707.67	2783	91	49059.80	r206	19	100	31990.34	1745	19	30725.20
r107	91	100	50834.66	2640	91	45847.84	r207	19	50	24603.46	1942	19	24363.83
r108	91	50	46612.45	2290	91	42767.77	r208	19	5	18950.37	2220	19	18185.38
r109	91	500	59344.93	2652	91	51391.80	r209	19	10	35737.18	1939	19	33777.76
r110	91	50	56283.20	2731	91	49348.36	r210	19	5	32422.07	2046	19	31599.84
rc101	90	100	52084.03	2572	90	47143.90	rc201	21	100	30585.71	2440	22	30320.41
rc102	90	500	49503.47	2435	90	44906.58	rc202	18	1000000	29525.90	746	19	26592.40
rc103	90	100	46038.46	2488	90	43782.57	rc203	18	500	22185.99	1217	18	20588.38
rc104	90	5	43998.71	1883	90	41917.14	rc204	18	10	17645.94	1478	18	16480.17
rc105	90	50	51822.47	2569	90	47632.31	rc205	18	100	30231.94	1116	18	29383.27
rc106	90	500	51377.57	2518	90	46391.60	rc206	18	50	29668.22	1225	18	27003.30
rc107	90	500	50657.17	2489	90	46391.60	rc207	18	50	27928.74	1341	18	26161.91
rc108	90	10	50099.58	2175	90	45585.08	rc208	18	5	26631.77	1113	18	24995.00
rc109	90	5	50320.45	2004	90	45405.54	rc209	18	50	25381.34	1716	18	23582.89
rc110	90	10	47885.23	2208	90	45041.64	rc210	18	5	24502.58	1319	18	22481.03