An Iterated Local Search Algorithm for the Vehicle Routing Problem with Convex Time Penalty Functions: Detailed Computational Results

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We proposed an iterated local search algorithm for the vehicle routing problem with capacity and time window constraints in [1]. We conducted some computational experiments to evaluate the proposed algorithm. The algorithm was coded in C language and run on an IBM-compatible PC (Intel Pentium 4, 2.8 GHz, 1 GB memory). We used the following benchmark instances: (1) Solomon's benchmark instances [2], and (2) Gehring and Homberger's benchmark instances [3]. The time limit of our iterated local search algorithm for instances with 100, 200, 400, 600, 800 and 1000 customers are 1000, 2000, 4000, 6000, 8000 and 10000 seconds, respectively. As initial values of κ^{p} and κ^{q} (parameters), we conducted two types of experiments: (1) $\kappa^{\mathrm{p}} = 1/100000$ and $\kappa^{\mathrm{q}} = 1/100000$ (called ILS-1), and (2) $\kappa^{\mathrm{p}} = 1$ and $\kappa^{\mathrm{q}} = 1$ (called ILS-2).

The detailed results for these instances are shown in Tables 1, 2, 3, 4, 5 and 6. We compare our computational results with the previous best known values as of June 7, 2006, presented in the web site (`http://www.sintef.no/static/am/opti/projects/top/vrp/benchmarks.html`).

Each row of these tables represents a problem instance. "m" represents the number of vehicles, "distance" represents the total travel distance value, and "#LS in total" represents the total number of local search procedure called in our iterated local search algorithm.

An asterisk "$*$" in the row "m" means that our algorithm uses a smaller number of vehicles than the previous best known solution. An asterisk "$*$" in the row "distance" means that our algorithm uses the same number of vehicles as the previous best known solution, and the total travel distance value is smaller than the best known value. A dagger "†" in the row "distance" means that our algorithm uses the same number of vehicles as the previous best known solution, and the total travel distance is also same as the best known value.

References

[1] T. Ibaraki, S. Imahori, K. Nonobe, K. Sobue, T. Uno, M. Yagiura, "An iterated local search algorithm for the vehicle routing problem with convex time penalty functions," Technical Report METR2006-36, Department of Mathematical Informatics, Graduate School of Information Science and Technology, The University of Tokyo, 2006.

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

[3] H. Gehring and J. Homberger, "A parallel hybrid evolutionary metaheuristic for the vehicle routing problem with time windows," *Proceedings of EUROGEN99.Jyväskylä* University of Jyväskylä, 57–64, 1999.

Table 1: The detailed results for 100-customer benchmark instances

	ILS-1			ILS-2			best known	
instance	m	distance	#LS in total	m	distance	#LS in total	m	distance
C101	10	828.94†	15420	10	828.94†	15943	10	828.94
C102	10	828.94†	15506	10	828.94†	15842	10	828.94
C103	10	828.06†	15108	10	828.06†	15336	10	828.06
C104	10	824.78†	14811	10	824.78†	15117	10	824.78
C105	10	828.94†	14770	10	828.94†	15399	10	828.94
C106	10	828.94†	13404	10	828.94†	13867	10	828.94
C107	10	828.94†	17418	10	828.94†	17745	10	828.94
C108	10	828.94†	15957	10	828.94†	16248	10	828.94
C109	10	828.94†	16842	10	828.94†	17139	10	828.94
C201	3	591.56†	3481	3	591.56†	3830	3	591.56
C202	3	591.56†	3279	3	591.56†	3547	3	591.56
C203	3	591.17†	3054	3	591.17†	3266	3	591.17
C204	3	590.60†	3354	3	590.60†	3592	3	590.60
C205	3	588.88†	4648	3	588.88†	4955	3	588.88
C206	3	588.49†	5143	3	588.49†	5329	3	588.49
C207	3	588.29†	5171	3	588.29†	5414	3	588.29
C208	3	588.32†	5176	3	588.32†	5485	3	588.32
R101	19	1650.80	11956	19	1650.80	12187	19	1645.79
R102	17	1486.12†	10249	17	1486.12†	10396	17	1486.12
R103	13	1292.68†	8183	13	1292.68†	8350	13	1292.68
R104	9	1007.31	2909	10	983.73	6719	9	1007.24
R105	14	1377.11†	9591	14	1377.11†	10084	14	1377.11
R106	12	1257.96	7594	12	1258.90	7820	12	1251.98
R107	10	1110.88	5633	10	1131.55	5189	10	1104.66
R108	9	967.51	3573	9	963.99	3693	9	960.88
R109	11	1210.71	5702	11	1197.42	6203	11	1194.73
R110	10	1118.84	4670	10	1130.36	4866	10	1118.59
R111	10	1177.31	4672	10	1116.67	5089	10	1096.72
R112	10	958.70	7755	10	955.75	7709	9	982.14
R201	4	1252.37†	3562	4	1253.02	3838	4	1252.37
R202	3	1197.59	2003	3	1191.70†	2142	3	1191.70
R203	3	943.50	2911	3	941.41	3152	3	939.54
R204	2	838.97	972	2	837.40	1325	2	825.52
R205	3	1043.32	2471	3	994.43	2468	3	994.42
R206	3	906.70	2780	3	906.14†	3157	3	906.14
R207	2	971.93	568	2	913.49	745	2	890.61
R208	2	728.86	1929	2	727.69	2447	2	726.75
R209	3	914.00	2435	3	914.13	2620	3	909.16
R210	3	939.37	2611	3	946.24	2690	3	939.34
R211	2	911.09	434	2	944.80	550	2	892.71
RC101	14	1696.95	9669	14	1696.95	9470	14	1696.94
RC102	12	1593.06	7208	12	1554.75†	7039	12	1554.75
RC103	11	1266.97	7994	11	1271.00	7527	11	1261.67
RC104	10	1135.52	7719	10	1141.37	7121	10	1135.48
RC105	13	1629.44†	8587	13	1629.44†	8140	13	1629.44
RC106	12	1377.16	9444	11	1460.97	6508	11	1424.73
RC107	11	1232.26	8520	11	1230.54	8342	11	1230.48
RC108	10	1145.98	7318	10	1146.66	7098	10	1139.82
RC201	4	1413.52	3438	4	1413.52	3374	4	1406.91
RC202	3	1406.13	1725	3	1399.38	1583	3	1365.65
RC203	3	1071.36	2229	3	1065.63	2535	3	1049.62
RC204	3	798.46	4122	3	798.46	4076	3	798.41
RC205	4	1297.65	3707	4	1297.65	3516	4	1297.19
RC206	3	1153.03	1918	3	1146.32†	1779	3	1146.32
RC207	3	1061.84	2023	3	1066.86	1819	3	1061.14
RC208	3	828.14†	2280	3	828.14†	2198	3	828.14

Table 2: The detailed results for 200-customer benchmark instances

	ILS-1			ILS-2			best known	
instance	m	distance	#LS in total	m	distance	#LS in total	m	distance
C1_2_1	20	2704.57†	14043	20	2704.57†	14332	20	2704.57
C1_2_2	18	2965.86	8080	18	2998.38	8133	18	2917.89
C1_2_3	18	2735.22	8918	18	2741.88	9124	18	2708.08
C1_2_4	18	2655.78	9471	18	2656.30	9553	18	2644.61
C1_2_5	20	2702.05†	11519	20	2702.05†	11778	20	2702.05
C1_2_6	20	2701.04†	13340	20	2701.04†	13524	20	2701.04
C1_2_7	20	2701.04†	11561	20	2701.04†	11844	20	2701.04
C1_2_8	19	2809.06	8851	19	2790.01	8754	18	2769.19
C1_2_9	18	2690.23	8664	18	2692.53	8850	18	2642.82
C1_210	18	2655.43	8532	18	2656.35	9051	18	2643.51
C2_2_1	6	1931.44†	2617	6	1931.44†	2955	6	1931.44
C2_2_2	6	1863.16†	2529	6	1863.16†	2829	6	1863.16
C2_2_3	6	1776.96	2627	6	1777.56	2834	6	1775.11
C2_2_4	6	1733.39	3124	6	1717.11	3483	6	1705.05
C2_2_5	6	1878.85†	3130	6	1878.85†	3514	6	1878.85
C2_2_6	6	1857.35†	3049	6	1857.35†	3306	6	1857.35
C2_2_7	6	1849.46†	2197	6	1849.46†	2427	6	1849.46
C2_2_8	6	1820.53†	3834	6	1820.53†	4080	6	1820.53
C2_2_9	6	1830.05†	2850	6	1830.05†	3041	6	1830.05
C2_210	6	1807.11	3560	6	1808.21	3885	6	1806.60
R1_2_1	20	4796.84	6242	20	4784.90	6201	19	5024.65
R1_2_2	18	4118.01	6079	18	4121.54	6202	18	4049.69
R1_2_3	18	3428.04	7235	18	3417.41	7288	18	3382.65
R1_2_4	18	3090.86	8445	18	3112.19	8484	18	3067.93
R1_2_5	18	4131.86	6686	18	4136.63	6661	18	4112.88
R1_2_6	18	3658.16	7109	18	3658.04	7158	18	3586.80
R1_2_7	18	3236.59	8285	18	3162.71	8470	18	3151.42
R1_2_8	18	2971.57	9344	18	3004.93	9238	18	2963.90
R1_2_9	18	3877.90	6794	18	3812.11	7064	18	3784.33
R1_210	18	3347.90	8215	18	3341.92	8396	18	3307.78
R2_2_1	4	4559.43	1544	4	4559.43	1494	4	4501.80
R2_2_2	4	3695.06	1671	4	3711.86	1822	4	3645.38
R2_2_3	4	2913.53	2476	4	2885.86	2568	4	2883.16
R2_2_4	4	2031.39	3266	4	2037.56	3562	4	1981.29
R2_2_5	4	3379.45	2468	4	3369.58	2722	4	3367.55
R2_2_6	4	2913.85*	2997	4	2919.10	2816	4	2914.56
R2_2_7	4	2469.63	3517	4	2459.46	3704	4	2453.62
R2_2_8	4	1861.31	4174	4	1852.51	4587	4	1849.87
R2_2_9	4	3149.30	2506	4	3133.26	2897	4	3111.41
R2_210	4	2683.45	3143	4	2656.98*	3014	4	2657.00
RC1_2_1	18	3878.59	5772	18	3807.62	5726	18	3637.80
RC1_2_2	18	3394.90	7571	18	3313.76	7082	18	3269.30
RC1_2_3	18	3052.12	8474	18	3060.83	7828	18	3025.90
RC1_2_4	18	2873.37	9248	18	2875.74	8882	18	2852.62
RC1_2_5	18	3524.60	6730	18	3540.24	6444	18	3419.81
RC1_2_6	18	3436.06	6729	18	3449.13	6644	18	3338.84
RC1_2_7	18	3314.86	7033	18	3302.34	6848	18	3219.86
RC1_2_8	18	3189.58	7475	18	3172.17	7310	18	3109.44
RC1_2_9	18	3160.99	7404	18	3135.35	7337	18	3083.41
RC1_210	18	3051.01	7977	18	3096.59	7468	18	3012.52
RC2_2_1	6	3113.98	3254	6	3120.60	2915	6	3103.48
RC2_2_2	5	2827.43*	2618	5	2825.54*	2531	5	2827.45
RC2_2_3	4	2624.09	2038	4	2627.38	1932	4	2613.12
RC2_2_4	4	2067.60	2698	4	2075.08	2603	4	2043.05
RC2_2_5	4	2919.54	1278	4	2929.16	1161	4	2912.13
RC2_2_6	4	2885.49*	1265	4	2974.30*	1129	4	2975.13
RC2_2_7	4	2591.53	1537	4	2608.60	1563	4	2529.30
RC2_2_8	4	2342.08	2117	4	2354.45	1736	4	2298.12
RC2_2_9	4	2182.55	2165	4	2212.47	2303	4	2175.61
RC2_210	4	2071.32	2498	4	2033.57	2690	4	2015.60

Table 3: The detailed results for 400-customer benchmark instances

	ILS-1			ILS-2			best known	
instance	m	distance	#LS in total	m	distance	#LS in total	m	distance
C1_4_1	40	7152.06	10753	40	7152.06	10919	40	7152.02
C1_4_2	36	7879.28	5868	36	7794.44	5756	36	7733.55
C1_4_3	36	7211.43	7131	36	7180.45	7396	36	7082.13
C1_4_4	36	6851.24	8165	36	6840.61	8319	36	6816.17
C1_4_5	40	7152.06	10812	40	7152.06	10971	40	7152.02
C1_4_6	40	7153.45	10857	40	7153.45	10978	40	7153.41
C1_4_7	40	7149.43	9217	39	7550.69	6578	39	7546.78
C1_4_8	37	7704.26	5336	37	7632.76	5467	37	7546.32
C1_4_9	36	7686.14	5565	36	7494.40*	5175	36	7524.32
C1_410	36	6882.14*	7665	36	7074.09	7143	36	6907.26
C2_4_1	12	4116.14	3084	12	4116.14	3259	12	4116.05
C2_4_2	12	3930.05	3879	12	3930.45	4177	12	3929.89
C2_4_3	12	3795.90	3554	12	3808.95	4059	12	3739.72
C2_4_4	12	3589.36	3773	11*	4327.10	745	12	3535.99
C2_4_5	12	3938.69*	4086	12	3938.69*	4196	12	3939.42
C2_4_6	12	3875.94†	4310	12	3875.94†	4417	12	3875.94
C2_4_7	12	3903.06	3045	12	3894.98	3149	12	3894.13
C2_4_8	12	3804.57	3884	12	3801.53	4072	12	3787.08
C2_4_9	12	3881.03	3442	12	3878.96	3492	12	3876.10
C2_410	12	3684.90	3823	11*	4279.40	1154	12	3684.89
R1_4_1	40	10434.69	5616	40	10489.37	5713	38	11084.00
R1_4_2	36	9604.80	4833	36	9474.79	4997	36	9053.18
R1_4_3	36	8110.99	5419	36	8126.90	5606	36	7941.53
R1_4_4	36	7447.68	6657	36	7491.93	6296	36	7332.93
R1_4_5	36	10048.04	5166	36	10110.68	5091	36	9437.28
R1_4_6	36	8874.22	5439	36	8879.73	5564	36	8534.05
R1_4_7	36	7835.52	6214	36	8010.09	5685	36	7710.41
R1_4_8	36	7412.83	6731	36	7438.50	6517	36	7385.29
R1_4_9	36	9164.47	5407	36	9239.29	5398	36	8878.19
R1_410	36	8536.19	5604	36	8624.14	5520	36	8227.49
R2_4_1	8	9341.52	2394	8	9301.85	2645	8	9257.92
R2_4_2	8	7831.76	2444	8	7662.53	2734	8	7649.87
R2_4_3	8	5977.79*	2670	8	6098.31	3055	8	5988.02
R2_4_4	8	4350.65	3907	8	4351.95	4282	8	4300.95
R2_4_5	8	7287.40	3196	8	7215.74	3217	8	7143.55
R2_4_6	8	6214.03	3037	8	6188.33	3516	8	6163.81
R2_4_7	8	5156.67	3782	8	5199.63	3522	8	5082.10
R2_4_8	8	4140.42	4268	8	4109.64	4811	8	4051.98
R2_4_9	8	6451.18*	3101	8	6469.45*	3340	8	6493.13
R2_410	8	5947.60	3850	8	5917.95	3837	8	5844.77
RC1_4_1	36	9630.58	4570	36	9688.05	4148	36	8813.43
RC1_4_2	36	8451.01	5432	36	8552.80	5276	36	7985.50
RC1_4_3	36	7952.02	5615	36	7890.49	5685	36	7627.30
RC1_4_4	36	7413.59	6930	36	7470.42	6343	36	7355.29
RC1_4_5	36	8694.50	5246	36	8883.35	4699	36	8321.91
RC1_4_6	36	9060.71	4993	36	8876.58	4747	36	8304.99
RC1_4_7	36	8342.88	5210	36	8478.87	5164	36	8051.71
RC1_4_8	36	8267.11	5278	36	8275.51	4943	36	7917.68
RC1_4_9	36	8167.58	5251	36	8443.99	4512	36	7890.45
RC1_410	36	8073.26	5020	36	8158.42	4820	36	7716.32
RC2_4_1	11	6796.06*	2988	11	6915.64	2812	11	6834.02
RC2_4_2	9	6249.18*	2059	10	5927.44	3005	9	6355.59
RC2_4_3	8	5079.49	2574	8	5109.24	2598	8	5055.02
RC2_4_4	8	3647.60	4262	8	3661.68	4043	8	3635.04
RC2_4_5	10	5753.09	2803	9	6152.79	1970	9	6063.46
RC2_4_6	8	6170.95	1445	8	5944.69*	1415	8	5997.24
RC2_4_7	8	5693.32	1697	8	5589.73	1707	8	5476.57
RC2_4_8	8	4927.27	2380	8	4924.41	2360	8	4854.16
RC2_4_9	8	4676.31	2740	8	4664.72	2600	8	4599.57
RC2_410	8	4381.68	3048	8	4398.03	3047	8	4316.36

Table 4: The detailed results for 600-customer benchmark instances

	ILS-1			ILS-2			best known	
instance	m	distance	#LS in total	m	distance	#LS in total	m	distance
C1_6_1	60	14095.64†	8033	60	14095.64†	8168	60	14095.64
C1_6_2	56	14394.90	5819	56	14218.85	6376	56	14172.33
C1_6_3	56	13897.54	6201	56	13865.19	6217	56	13803.50
C1_6_4	56	13658.55	6358	56	13649.47	6424	56	13571.88
C1_6_5	60	14085.72	8366	60	14085.72	8474	60	14085.70
C1_6_6	60	14089.66	7783	60	14089.66	7938	60	14089.56
C1_6_7	58	15280.26	5319	58	15328.87	5262	58	15017.03
C1_6_8	57	14180.39*	6104	57	14376.10	5627	57	14343.05
C1_6_9	56	13796.50	6594	56	13774.21	6884	56	13733.56
C1_610	56	13690.49	6799	56	13804.96	6606	56	13677.81
C2_6_1	18	7776.10	3648	18	7774.16	3783	18	7774.10
C2_6_2	17	9014.04	2114	17	8530.88*	2320	17	8799.38
C2_6_3	17	7948.53	2530	17	8191.92	2363	17	7604.00
C2_6_4	17	7380.16	2578	17	7568.31	2579	17	6993.77
C2_6_5	18	7575.20*	4038	18	7575.20*	4236	18	7576.35
C2_6_6	18	7474.45*	4099	18	7489.51	4019	18	7478.63
C2_6_7	18	7523.35	3019	18	7542.94	3125	18	7520.34
C2_6_8	17	7847.83*	2345	17	8201.34*	2161	17	8579.89
C2_6_9	17*	9446.40	1220	17*	9666.28	1199	18	7350.94
C2_610	17	7469.51*	2871	17	7376.47*	3090	17	7523.34
R1_6_1	59	21701.10	4224	59	21892.68	4220	59	21131.09
R1_6_2	54	21434.46	3517	54	21964.72	3498	54	19603.70
R1_6_3	54	18811.50	3772	54	18805.67	3714	54	17400.60
R1_6_4	54	16727.37	4693	54	16773.27	4489	54	15993.80
R1_6_5	54	23811.49	3562	54	22980.95	3704	54	20395.00
R1_6_6	54	20307.72	4066	54	20520.91	3923	54	18620.26
R1_6_7	54	17989.03	4281	54	18219.96	4147	54	17107.91
R1_6_8	54	16477.82	4848	54	16493.00	4842	54	15725.86
R1_6_9	54	21517.25	3777	54	21879.39	3828	54	19372.96
R1_610	54	19666.15	4013	54	20105.02	3967	54	18235.57
R2_6_1	11	18473.06	2347	11	18389.17	2412	11	18325.60
R2_6_2	11	14943.38*	2169	11	14915.96*	2241	11	14995.76
R2_6_3	11	11441.21	2518	11	11344.04	2713	11	11255.49
R2_6_4	11	8107.37*	3627	11	8148.20	3190	11	8126.87
R2_6_5	11	15230.94*	2931	11	15294.94*	3030	11	15357.25
R2_6_6	11	12685.19*	2617	11	12749.17*	2705	11	12903.83
R2_6_7	11	10261.75	2549	11	10243.67	2895	11	10172.17
R2_6_8	11	7859.42	3553	11	7729.25*	3697	11	7752.78
R2_6_9	11	13837.33	2966	11	13642.37	3103	11	13567.84
R2_610	11	12558.18	3285	11	12508.59*	3552	11	12513.45
RC1_6_1	55	18731.20	4185	55	18959.65	4061	55	17454.39
RC1_6_2	55	17517.62	4321	55	17490.46	4243	55	16208.24
RC1_6_3	55	15973.43	4835	55	16256.38	4326	55	15424.19
RC1_6_4	55	15158.06	5364	55	15363.04	4820	55	14872.79
RC1_6_5	55	18476.97	3824	55	18585.76	3843	55	17344.12
RC1_6_6	55	18599.85	3806	55	18265.81	3802	55	17248.87
RC1_6_7	55	17286.29	4241	55	17941.68	3672	55	16454.79
RC1_6_8	55	17103.19	3957	55	17202.70	3835	55	16462.49
RC1_6_9	55	17184.90	3704	55	17219.60	3589	55	16153.00
RC1_610	55	16756.59	3848	55	16669.97	3775	55	16030.86
RC2_6_1	15	12995.14*	3447	14*	13595.69	2572	15	13163.03
RC2_6_2	12	11673.33*	2403	12	11632.72*	2149	12	11853.72
RC2_6_3	11	9694.59*	2423	11	9789.80*	2110	11	9816.47
RC2_6_4	11	7526.90	3509	11	7268.62	3231	11	7191.11
RC2_6_5	12	12302.84*	2200	13	11924.25	2708	12	12560.43
RC2_6_6	11	12811.47	1447	11	12550.01	1475	11	12282.52
RC2_6_7	11	11088.72	1925	11	11021.28	1850	11	10929.56
RC2_6_8	11	10488.33	2146	11	10419.89*	2263	11	10474.95
RC2_6_9	11	10086.59	2462	11	9913.24	2480	11	9821.39
RC2_610	11	9249.08*	2904	11	9314.83*	2642	11	9339.41

Table 5: The detailed results for 800-customer benchmark instances

	ILS-1			ILS-2			best known	
instance	m	distance	#LS in total	m	distance	#LS in total	m	distance
C1_8_1	80	25184.38	6733	80	25184.38	6777	80	25030.36
C1_8_2	75	25562.96	5148	75	25366.86	5457	74	25536.76
C1_8_3	72	24778.93	5129	72	25001.87	4834	72	24629.86
C1_8_4	72	23966.39	5491	72	24062.85	5366	72	23917.70
C1_8_5	80	25166.49	6750	80	25166.49	6740	80	25166.28
C1_8_6	80	25160.85	6451	80	25160.85	6470	80	25160.83
C1_8_7	79	25432.43	5722	79	25607.99	5756	79	25425.92
C1_8_8	75	25863.83	4470	75	25627.70	4442	75	25450.99
C1_8_9	72	27546.77	3763	73	24534.45	4906	72	25737.46
C1_810	72	26212.50	3872	72	27665.86	3616	72	25697.68
C2_8_1	24	11662.08	5033	24	11664.00	5257	24	11654.81
C2_8_2	23*	13001.90	2377	23*	13103.93	2254	24	11422.34
C2_8_3	23	12454.50	2158	23	12772.80	1839	23	11554.18
C2_8_4	23	11568.77	2450	23	11615.83	2235	23	10963.49
C2_8_5	24	11426.05*	4972	24	11434.65	5120	24	11432.92
C2_8_6	24	11348.43*	4132	24	11364.05	4213	24	11357.86
C2_8_7	24	11441.74	2697	24	11405.99	2854	24	11397.54
C2_8_8	23	11428.95*	3380	23	11461.17*	2880	23	12927.45
C2_8_9	23*	12991.54	1436	24	11199.26*	3679	24	11249.00
C2_810	23	11285.05	2607	23	11240.85*	2865	23	11284.46
R1_8_1	80	37752.98	3306	80	37754.97	3222	79	39612.20
R1_8_2	72	35486.36	2964	72	35227.70	3098	72	33548.54
R1_8_3	72	31795.32	3218	72	31930.65	3118	72	30151.90
R1_8_4	72	28921.77	4042	72	28998.98	3817	72	26838.04
R1_8_5	72	37611.23	3120	72	37760.03	3246	72	34741.53
R1_8_6	72	33499.94	3497	72	34030.50	3235	72	31737.47
R1_8_7	72	30581.95	3728	72	30808.86	3361	72	29538.40
R1_8_8	72	28886.61	4054	72	28985.83	3963	72	28341.21
R1_8_9	72	34567.48	3370	72	35380.73	3259	72	34218.41
R1_810	72	33653.56	3359	72	33255.82	3354	72	31730.45
R2_8_1	15	28394.16*	2572	15	28478.06	2613	15	28440.28
R2_8_2	15	22977.11*	2303	15	22978.58*	2283	15	23274.22
R2_8_3	15	18017.33	2415	15	18016.62	2511	15	17992.25
R2_8_4	15	13403.71*	3191	15	13301.17*	3310	15	13413.79
R2_8_5	15	24798.51	3036	15	24599.08*	3093	15	24611.39
R2_8_6	15	20904.14	2516	15	20799.02	2479	15	20697.06
R2_8_7	15	16890.75*	2455	15	17057.19	2604	15	16977.49
R2_8_8	15	13052.09	3205	15	12912.56*	3524	15	12945.52
R2_8_9	15	22770.83	3025	15	22675.78	3196	15	22588.02
R2_810	15	20890.54*	3361	15	20925.16*	3471	15	21092.27
RC1_8_1	73	32846.34	3480	73	32978.62	3303	73	31275.38
RC1_8_2	73	30202.88	3434	72	38867.70*	2209	72	39696.20
RC1_8_3	72	34373.59*	2694	72	34834.81*	2259	72	35577.87
RC1_8_4	72	29656.71*	3207	72	30053.94*	2922	72	32654.10
RC1_8_5	73	31411.96	3543	73	31488.86	3309	73	30454.15
RC1_8_6	73	31526.57	3442	73	31711.64	3196	73	29674.68
RC1_8_7	72	41633.18*	2274	73	30937.78	3092	72	43829.43
RC1_8_8	72	38108.52*	2238	72	41710.36*	1780	72	43694.60
RC1_8_9	72	40915.63*	2001	72	42966.35	1747	72	41816.70
RC1_810	72	35540.90*	2084	72	37412.86*	1730	72	41182.44
RC2_8_1	19	20867.05*	3162	20	20230.46	3634	19	20954.95
RC2_8_2	16*	18551.80	2268	16*	18613.65	2095	17	18032.89
RC2_8_3	16	14466.40	2404	15	14734.94*	2275	15	14800.78
RC2_8_4	15	11242.65*	3539	15	11393.18	3519	15	11312.68
RC2_8_5	16	19164.98	2460	17	18705.13	2774	16	19105.75
RC2_8_6	15	18628.52*	2393	15	18675.83*	2269	15	18882.30
RC2_8_7	15	17188.79*	2429	15	17511.67	2422	15	17327.53
RC2_8_8	15	16028.77	2605	15	16242.54	2555	15	16203.18
RC2_8_9	15	15729.03	2739	15	15831.57	2802	15	15622.52
RC2_810	15	14799.61*	3035	15	14711.83*	2990	15	14892.29

Table 6: The detailed results for 1000-customer benchmark instances

	ILS-1			ILS-2			best known	
instance	m	distance	#LS in total	m	distance	#LS in total	m	distance
C110_1	100	42478.95†	6006	100	42478.95†	5995	100	42478.95
C110_2	91	42607.30	4070	91	42626.53	4050	91	42242.95
C110_3	90	41566.82	4079	90	40934.59	4057	90	40376.43
C110_4	90	40376.03	4277	90	40094.57	4388	90	39735.30
C110_5	100	42469.18†	5731	100	42469.18†	5714	100	42469.18
C110_6	100	42471.29	5504	100	42471.28	5568	100	42470.04
C110_7	99	42827.82	5006	100	42464.87	5099	99	42624.60
C110_8	94*	43386.31	3653	94*	42711.37	4046	95	42274.98
C110_9	91	41592.79*	3804	91	42270.47*	3369	91	45363.78
C11010	90	44816.98	3299	90	44771.50	3043	90	40894.38
C210_1	30	16879.24†	4871	30	16879.24†	4822	30	16879.24
C210_2	29	17986.81	3021	29	17435.89	3514	29	17144.29
C210_3	29	17321.71	2798	29	17567.33	2482	29	16367.59
C210_4	29	17534.09	2408	29	16546.91	2860	29	15919.46
C210_5	30	16563.00	4575	30	16569.23	4687	30	16561.70
C210_6	30	16354.53	4049	30	16342.34	3825	30	16341.67
C210_7	30	16451.75	3217	30	16689.69	2067	30	16435.10
C210_8	29	17103.14	3083	29	16382.51	3363	29	16315.89
C210_9	29*	17617.91	2202	30	16238.87	3354	30	16161.74
C21010	29	16052.41	3574	29	16145.59	3521	29	15885.41
R110_1	100	54720.88	3128	100	55307.78	3005	100	54145.31
R110_2	91	57838.88	2440	91	57726.40	2346	91	55428.79
R110_3	91	50845.43	2728	91	51081.61	2732	91	46621.19
R110_4	91	45257.73	3388	91	45859.09	3040	91	43461.84
R110_5	91	63808.26*	2518	91	65568.19*	2465	91	70838.01
R110_6	91	53616.27	2931	91	56210.42	2657	91	49059.80
R110_7	91	49202.10	3089	91	50506.49	2681	91	45847.84
R110_8	91	45424.18	3398	91	46065.57	2975	91	42767.77
R110_9	91	57253.04	2995	91	62647.58	2468	91	51391.80
R11010	91	55694.21	2571	91	58123.14	2319	91	49348.36
R210_1	19	42842.26	2680	19	42632.60	2735	19	42467.87
R210_2	19	34214.13	2177	19	33917.01	2220	19	33589.08
R210_3	19	25400.99	2377	19	25536.64	2348	19	25321.00
R210_4	19	18520.46	3432	19	18762.81	2984	19	18222.30
R210_5	19	36939.28	3116	19	37000.66	3069	19	36735.20
R210_6	19	30521.21	2399	19	30670.95	2404	19	30261.75
R210_7	19	24018.98	2485	19	23909.23	2652	19	23463.80
R210_8	19	18027.09	3714	19	18239.22	3598	19	17705.20
R210_9	19	33860.33	3244	19	33972.02	3139	19	33519.84
R21010	19	31117.21	3463	19	31255.95	3298	19	30706.00
RC110_1	90	52918.15	2551	90	52069.69	2771	90	47143.90
RC110_2	90	47809.13	2958	90	48850.18	2779	90	44906.58
RC110_3	90	45602.88	2894	90	46133.80	2871	90	43782.57
RC110_4	90	43242.09	3309	90	43221.42	3228	90	41917.14
RC110_5	90	51482.62	2703	90	51785.68	2585	90	47632.31
RC110_6	90	49270.77	2942	90	51497.66	2611	90	46391.60
RC110_7	90	49653.78	2592	90	49899.00	2423	90	46157.71
RC110_8	90	47881.55	2673	90	48427.42	2478	90	45585.08
RC110_9	90	47448.67	2616	90	48288.47	2526	90	45405.54
RC11010	90	47442.31	2389	90	47515.39	2494	90	45041.64
RC210_1	20*	31078.25	2592	21	30270.16	2831	21	29754.06
RC210_2	19	26304.19	2063	19	25804.87	2083	18	27552.05
RC210_3	18	21068.14	2173	18	20612.41	2153	18	20276.16
RC210_4	18	16469.89	3176	18	16621.82	2903	18	15954.60
RC210_5	18	29057.24	1734	18	28181.66	1969	18	27766.56
RC210_6	18	27954.99	2044	18	27911.01	2087	18	27003.30
RC210_7	18	26254.82	2049	18	25987.99	2015	18	25526.73
RC210_8	18	24436.00	2285	18	24673.61	2405	18	24335.40
RC210_9	18	23867.91	2390	18	23888.77	2406	18	23465.51
RC21010	18	22549.40	2587	18	22726.87	2472	18	22481.03