

Correction

Correction: Akbay et al. Variable Neighborhood Search for the Two-Echelon Electric Vehicle Routing Problem with Time Windows. *Appl. Sci.* 2022, 12, 1014

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Due to a minor programming mistake, the authors had to fix the bug and repeat all computational experiments reported in [1]. The bug, however, did not have much influence on the results. In particular, the results changed only slightly, that is, no qualitative change in the results was observed. In the following, the changes applied to the paper are listed.

First, due to fixing the bug, the parameters of the algorithm had to be tuned again. The following two tables are the updated Tables 3 and 4 of the paper. The values in blue are those that have changed in comparison to the original paper version.

Table 3. Parameter values determined by irace for the C&W savings heuristic.

Parameters	Small Instances	Large Instances
λ	1.3	1.1
μ	0.3	0.1
γ	0.9	0.6

Table 4. Parameter values determined by irace for VNS.

Parameters	Small Instances	Large Instances
$rr1_{Lb}$	0.1	0.3
$rr1_{Ub}$	0.7	0.4
$rr2_{Lb}$	0.1	0.4
$rr2_{Ub}$	0.6	0.4
p_{init}	15	20
p_{min}	5	0.5
p_{max}	40	35
p_{iter}	1	2
p^+	9	5
p^-	1.6	1.4
t_{init}	200	100
t^-	1.3	2
$iter_{n_{i_{max}}}$	1000	100
ζ	2	4
θ_{max}	4	2

Second, the algorithm was executed with the updated parameter values, and, as a consequence, the results in Tables 5–10 and in Figure 8 of the original paper were updated as follows. Note that, in the first three tables, the changes are marked again in a blue color. In contrast, in the last three tables, the changes are not marked, because all results of VNS_{red} VNS_{full} have changed.



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Finally, note that these slight changes in the results led to very minor changes in the text on pages 22 and 23 of the original paper. In particular, on page 22, the original sentence was replaced with the following one: “For two of the remaining three cases, CPLEX was able to provide feasible solutions of the same quality as VNS_{full} and VNS_{red}, without being able to prove optimality.” Moreover, the following minor changes were made in two sentences of the last paragraph of page 22: “While VNS_{full} provides results at least as good as CPLEX for all instances except for C106_C15, VNS_{red} only does so in seven out of 12 cases. Considering those instances for which CPLEX was able to obtain a solution, both VNS variants improved the solution quality of CPLEX, on average, by 0.55% (VNS_{red}) and 6.86% (VNS_{full}). In fact, VNS_{full} outperforms VNS_{red} both in terms of best-performance (column ‘dist’) and in terms of average-performance (column ‘avg’).”

Furthermore, the last paragraph on page 23 was replaced with the following one: “The following observations can be made. For the large clustered instances (Table 8) and large random instances (Table 9), VNS_{full} significantly outperforms VNS_{red}, both in terms of best-performance and average-performance. This is also shown in Figure 8b,c. However, the opposite is generally the case in the context of random-clustered instances, as shown in Figure 8d. This means that the removal/destroy operators have a rather negative impact on the performance of VNS in these cases. This is most probably due to their elevated computation time requirements. Nevertheless, Figure 8d also shows that this difference is not statistically significant. Moreover, the superiority of VNS_{full} over VNS_{red} is much more significant in the context of instances with a long scheduling horizon (R2* C2* and RC2*) compared to the instances with a short scheduling horizon (R1* C1* and RC1*); see Figure 8e,f. Finally, when considering all large instances together, VNS_{full} significantly outperforms VNS_{red} (see also Figure 8a).”

Table 5. Computational results for small-sized instances with 5 customers.

Instances			CPLEX					C&W Savings Heuristic					VNS _{red}					VNS _{full}				
Name	nv ₁	nv ₂	m	n	Dist	Gap(%)	$\overline{t(s)}$	m	n	Dist	$\overline{t(s)}$		m	n	Dist	Avg	$\overline{t(s)}$	m	n	Dist	Avg	$\overline{t(s)}$
C101_C5	1	2	1	2	385.49	0	1.67	1	3	442.19	0.00021		1	2	385.49	385.49	0.989	1	3	385.49	385.49	12.509
C103_C5	1	1	1	1	341.33	0	0.09	1	2	360.94	0.00011		1	1	341.33	341.33	0.006	1	1	341.33	341.33	0.502
C206_C5	1	1	1	1	417.31	0	5.97	1	3	480.9	0.00017		1	1	417.31	417.31	0.001	1	1	417.31	417.31	0.001
C208_C5	1	1	1	1	381.91	0	0.31	1	1	383.07	0.00011		1	1	381.91	381.91	0.001	1	1	381.91	381.91	0.001
R104_C5	1	2	1	2	317.02	0	1.61	1	1	317.78	0.00012		1	1	317.02	317.02	0.001	1	1	317.02	317.02	0.001
R105_C5	1	3	1	2	453.74	0	9.57	1	1	677.61	0.00014		1	2	453.74	495.16	0.000	1	2	453.74	453.74	29.693
R202_C5	1	1	1	1	347.82	0	0.21	1	1	348.29	0.00010		1	1	347.82	347.82	0.001	1	1	347.82	347.82	0.001
R203_C5	1	1	1	1	371.31	0	0.21	1	1	387.92	0.00016		1	1	386.48	386.48	0.001	1	1	371.31	371.31	7.203
RC105_C5	1	3	1	3	432.64	0	28.84	1	3	496.72	0.00015		1	2	432.64	435.77	0.404	1	2	432.64	437.34	21.488
RC108_C5	1	2	1	2	460.89	0	24.24	1	2	702.23	0.00016		1	2	460.89	460.89	0.008	1	2	460.89	460.89	3.281
RC204_C5	1	1	1	1	332.86	0	0.64	1	1	649.44	0.00015		1	1	332.86	332.86	0.018	1	1	332.86	332.86	0.015
RC208_C5	1	1	1	1	327.30	0	0.37	1	1	331.77	0.00010		1	1	331.77	331.77	0.000	1	1	327.30	327.30	15.193
average	-	-	-	-	380.80	-	6.15	-	-	464.905	0.00014		-	-	382.44	386.15	0.119	-	-	380.80	381.19	7.491

Table 6. Computational results for small-sized instances with 10 customers.

Instances			CPLEX					C&W Savings Heuristic					VNS _{red}					VNS _{full}				
Name	nv ₁	nv ₂	m	n	Dist	Gap(%)	$\overline{t(s)}$	m	n	Dist	$\overline{t(s)}$		m	n	Dist	Avg	$\overline{t(s)}$	m	n	Dist	Avg	$\overline{t(s)}$
C101_C10	1	4	1	4	538.31	0	3021.74	1	5	568.85	0.00017		1	3	538.31	538.74	0.568	1	4	538.31	538.31	13.233
C104_C10	1	3	1	2	484.32	0	5309.78	1	4	663.74	0.00024		1	2	484.32	484.32	0.979	1	2	484.32	484.32	7.119
C202_C10	1	3	1	2	425.53	0	152.011	1	5	625.02	0.00021		1	2	425.53	425.53	0.030	1	2	425.53	425.53	2.018
C205_C10	1	3	1	3	415.48	0	157.97	1	3	435.37	0.00024		1	2	415.48	419.64	0.005	1	3	415.48	415.48	1.006
R102_C10	1	4	1	3	505.50	0	6150.84	1	4	648.65	0.00019		1	3	505.50	505.50	2.477	1	3	505.50	524.59	22.556

Table 6. Cont.

Instances			CPLEX					C&W Savings Heuristic					VNS _{red}					VNS _{full}				
Name	nv_1	nv_2	m	n	Dist	Gap(%)	$\overline{t(s)}$	m	n	Dist	$\overline{t(s)}$		m	n	Dist	Avg	$\overline{t(s)}$	m	n	Dist	Avg	$\overline{t(s)}$
R103_C10	1	3	1	2	436.08	9.27	6318.99	1	3	613.76	0.00024		1	2	436.08	436.08	2.396	1	2	436.08	437.51	3.600
R201_C10	1	2	1	2	460.71	0	2686.75	1	4	730.95	0.00017		1	2	460.71	460.71	2.838	1	2	460.71	460.71	16.455
R203_C10	1	2	1	1	436.51	0	2192.71	1	1	437.75	0.00021		1	1	436.51	436.51	0.002	1	1	436.51	436.51	0.002
RC102_C10	1	5	1	4	618.75	16.85	7079.09	1	5	684.93	0.00026		1	4	618.75	618.75	41.620	1	4	618.75	618.75	11.025
RC108_C10	1	4	1	4	637.23	24.28	6739.84	1	4	721.2	0.00020		1	3	559.88	559.88	0.097	1	3	559.88	559.88	0.016
RC201_C10	1	4	1	3	495.54	0	969.86	1	4	634.13	0.00021		1	2	495.54	497.04	0.004	1	3	495.54	495.54	2.528
RC205_C10	1	3	1	3	576.17	0	462.62	1	3	702.34	0.00025		1	2	576.17	577.76	0.130	1	3	576.17	576.17	15.366
average			-	-	502.51	-	3436.85	-	-	622.22	0.00022		-	-	496.06	496.70	4.262	-	-	496.06	497.77	7.910

Table 7. Computational results for small-sized instances with 15 customers.

Instances			CPLEX					C&W Savings Heuristic					VNS _{red}					VNS _{full}				
Name	nv_1	nv_2	m	n	Dist	Gap(%)	$\overline{t(s)}$	m	n	Dist	$\overline{t(s)}$		m	n	Dist	Avg	$\overline{t(s)}$	m	n	Dist	Avg	$\overline{t(s)}$
C103_C15	1	5	-	-	-	-	-	1	6	690.99	0.00036		1	3	575.18	582.02	4.925	1	4	575.18	575.18	0.623
C106_C15	1	4	1	3	500.32	13.37	7182.91	1	6	681.31	0.00022		1	3	516.60	524.10	2.100	1	3	516.60	516.60	1.027
C202_C15	1	5	1	4	714.81	32.23	7183.04	1	6	729.87	0.00034		1	4	617.24	618.66	29.966	1	3	550.32	550.32	12.454
C208_C15	1	3	1	2	550.02	15.56	7182.95	1	4	737.61	0.00023		1	2	619.73	619.73	6.976	1	2	550.02	550.02	22.000
R102_C15	1	7	-	-	-	-	-	1	9	950.25	0.00026		1	5	716.56	716.56	9.523	1	5	716.56	716.56	12.056
R105_C15	1	5	-	-	-	-	-	1	8	777.77	0.00038		1	4	607.96	607.96	30.850	1	4	607.96	607.96	25.605
R202_C15	1	3	1	3	719.61	35.36	7198.17	1	6	990.37	0.00043		1	2	593.69	597.79	8.033	1	3	593.69	593.69	60.988
R209_C15	1	3	1	2	475.10	10.09	7182.43	1	5	711.09	0.00024		1	2	475.10	519.46	0.712	1	1	475.10	482.30	77.386
RC103_C15	1	5	-	-	-	-	-	1	7	745.82	0.00035		1	4	616.32	622.10	1.565	1	5	616.32	616.32	1.803
RC108_C15	1	5	-	-	-	-	-	1	7	716.22	0.00026		1	5	603.87	603.87	0.214	1	5	603.87	615.11	0.033
RC202_C15	1	3	1	3	552.70	16.06	7182.65	1	5	697.24	0.00033		1	3	601.86	601.86	2.395	1	2	552.70	587.11	11.600
RC204_C15	1	3	1	2	485.34	13.93	7183.03	1	3	604.05	0.00035		1	2	551.56	551.56	0.670	1	2	485.34	485.34	15.566
average			-	-	-	-	-	-	-	752.72	0.00031		-	-	591.31	597.14	8.161	-	-	570.30	574.71	20.095

Table 8. Computational results for large-sized clustered instances.

Instances			C&W Savings Heuristic				VNS _{red}						VNS _{full}					
Name	n_k	n_v	m	n	Dist	$\overline{t(s)}$	m	n	Dist	Avg	Imp(%)	$\overline{t(s)}$	m	n	Dist	Avg	Imp(%)	$\overline{t(s)}$
C101_C21	3	25	3	39	1941.16	0.005	3	20	1513.91	1562.77	19.49	499.70	3	20	1494.18	1538.74	20.73	579.98
C102_C21	3	28	3	33	1822.02	0.005	3	21	1501.66	1506.95	17.29	537.57	3	19	1447.86	1487.11	18.38	572.03
C103_C21	3	26	3	29	1702.89	0.005	3	20	1447.98	1463.34	14.07	509.37	3	19	1399.25	1425.80	16.27	656.63
C104_C21	3	31	3	24	1580.07	0.005	3	20	1435.04	1446.17	8.47	405.19	3	19	1400.52	1439.76	8.88	540.97
C105_C21	4	43	3	36	1877.85	0.005	3	20	1522.97	1541.60	17.91	359.00	3	20	1493.69	1521.13	19.00	466.13
C106_C21	4	37	3	35	1791.74	0.004	3	20	1474.74	1491.70	16.75	361.26	3	20	1429.75	1476.85	17.57	536.93
C107_C21	4	41	3	34	1838.83	0.005	3	20	1499.81	1513.36	17.70	400.85	3	20	1485.7	1513.18	17.71	582.44
C108_C21	3	33	3	29	1687.15	0.005	3	20	1461.25	1476.72	12.47	483.00	3	20	1450.96	1489.63	11.71	523.87
C109_C21	4	31	3	26	1619.19	0.005	3	20	1447.36	1456.90	10.02	326.59	3	20	1409.97	1455.93	10.08	673.76
C201_C21	3	20	2	35	1794.83	0.004	2	11	1251.62	1276.42	28.88	422.74	2	12	1208.76	1233.87	31.25	545.02
C202_C21	4	20	2	31	1672.52	0.005	2	12	1228.61	1260.08	24.66	532.72	2	12	1187.87	1232.74	26.29	703.08
C203_C21	3	19	2	27	1554.96	0.005	2	12	1197.45	1223.16	21.34	356.27	2	11	1201.4	1216.36	21.78	767.58
C204_C21	4	18	2	22	1411.07	0.005	2	12	1178.14	1191.92	15.53	464.31	2	11	1161.07	1181.40	16.28	577.96

Table 8. Cont.

Instances			C&W Savings Heuristic				VNS _{red}						VNS _{full}					
Name	n_k	n_v	m	n	Dist	$\overline{t(s)}$	m	n	Dist	Avg	Imp(%)	$\overline{t(s)}$	m	n	Dist	Avg	Imp(%)	$\overline{t(s)}$
C205_C21	4	20	2	21	1470.73	0.005	2	12	1226.48	1249.59	15.04	460.15	2	12	1205.23	1223.94	16.78	664.39
C206_C21	3	19	2	19	1399.11	0.005	2	12	1202.52	1222.94	12.59	519.78	2	11	1182.63	1198.54	14.34	556.03
C207_C21	3	19	2	20	1406.55	0.005	2	12	1195.1	1211.55	13.86	262.84	2	11	1173.7	1188.92	15.47	562.88
C208_C21	3	17	2	19	1393.28	0.005	2	12	1193.01	1221.40	12.34	429.15	2	11	1169.69	1188.85	14.67	652.98
average					1644.94	0.005			1351.63	1371.56	16.38	431.21			1323.66	1353.69	17.48	597.80

Table 9. Computational results for large-sized random instances.

Instances			C&W Savings Heuristic				VNS _{red}						VNS _{full}					
Name	n_k	n_v	m	n	Dist	$\overline{t(s)}$	m	n	Dist	avg	Imp(%)	$\overline{t(s)}$	m	n	Dist	Avg	Imp(%)	$\overline{t(s)}$
R101_C21	4	34	4	46	2546.45	0.006	4	25	2164.26	2187.39	14.10	573.91	4	26	2179.75	2306.91	9.41	589.70
R102_C21	3	32	4	37	2365.85	0.006	3	21	1840.45	1894.10	19.94	583.85	3	24	1843.45	2025.31	14.39	300.08
R103_C21	3	23	3	32	1974.87	0.006	3	19	1696.36	1754.36	11.17	657.28	3	19	1729.91	1829.33	7.37	350.64
R104_C21	2	20	3	23	1784.94	0.006	2	17	1473.50	1641.42	8.04	770.40	2	17	1470.20	1628.00	8.79	535.30
R105_C21	3	25	3	39	2216.4	0.005	3	23	1842.34	1898.80	14.33	539.41	3	22	1909.13	1975.78	10.86	463.62
R106_C21	3	28	3	32	2055.43	0.006	3	20	1737.88	1870.36	9.00	345.95	3	21	1723.88	1887.34	8.18	153.16
R107_C21	2	23	2	30	1725.89	0.007	2	18	1518.95	1671.82	3.13	287.01	2	18	1490.01	1670.00	3.24	323.49
R108_C21	2	21	2	23	1603.11	0.006	2	18	1454.99	1553.47	3.10	322.44	2	18	1449.13	1569.62	2.09	184.32
R109_C21	2	24	3	29	1947.31	0.006	2	18	1547.52	1694.54	12.98	356.45	2	19	1529.71	1683.81	13.53	386.16
R110_C21	2	23	2	26	1650.24	0.006	2	17	1451.04	1486.15	9.94	597.54	2	17	1470.57	1513.50	8.29	660.80
R111_C21	2	24	3	26	1805.69	0.006	2	18	1487.83	1572.49	12.91	579.21	2	17	1522.49	1593.35	11.76	483.22
R112_C21	2	23	2	20	1460.99	0.006	2	20	1457.06	1457.06	0.27	0.00	2	17	1413.86	1452.74	0.56	64.47
R201_C21	1	14	2	34	1912.59	0.006	1	12	1238.92	1265.99	33.81	486.39	1	9	1218.88	1252.17	34.53	639.80
R202_C21	1	12	2	29	1760.69	0.006	1	9	1158.64	1170.28	33.53	626.39	1	9	1135.84	1166.67	33.74	564.04
R203_C21	1	14	2	22	1587.76	0.007	1	8	1064.16	1093.38	31.14	513.09	1	7	1067.89	1096.69	30.93	542.58
R204_C21	1	9	2	17	1408.95	0.006	1	7	962.16	994.44	29.42	534.08	1	6	965.62	977.19	30.64	591.03
R205_C21	1	14	1	27	1522.45	0.006	1	9	1136.47	1167.99	23.28	711.65	1	7	1134.35	1155.14	24.13	452.03
R206_C21	1	12	1	23	1445.78	0.006	1	8	1106.23	1137.05	21.35	789.19	1	7	1092.55	1117.88	22.68	512.81
R207_C21	1	13	1	17	1334.95	0.006	1	7	1034.45	1072.21	19.68	588.03	1	7	1025.08	1055.93	20.90	512.99
R208_C21	1	12	1	16	1232.96	0.006	1	7	991.25	1018.02	17.43	484.88	1	7	970.31	996.20	19.20	519.00
R209_C21	1	15	1	23	1400.02	0.006	1	8	1078.55	1106.82	20.94	597.86	1	7	1078.00	1089.28	22.20	597.67
R210_C21	1	12	1	19	1350.21	0.006	1	8	1059.31	1090.53	19.23	515.34	1	7	1045.64	1068.65	20.85	480.40
R211_C21	1	9	1	18	1291.64	0.006	1	7	1030.77	1053.79	18.41	524.60	1	6	999.26	1034.15	19.93	421.96
average					1712.40	0.006			1371.00	1428.37	16.83	521.08			1368.07	1441.11	16.44	449.10

Table 10. Computational results for large-sized random-clustered instances.

Instances			C&W Savings Heuristic				VNS _{red}						VNS _{full}					
Name	n_k	n_v	m	n	Dist	$\overline{t(s)}$	m	n	Dist	Avg	Imp(%)	$\overline{t(s)}$	m	n	Dist	Avg	Imp(%)	$\overline{t(s)}$
RC101_C21	3	28	4	38	2467.62	0.004	4	23	2044.99	2274.23	7.84	294.29	3	22	1907.52	2106.42	14.64	605.26
RC102_C21	3	29	4	36	2385.73	0.005	4	22	2004.78	2035.60	14.68	516.43	3	21	1834.97	2047.79	14.16	397.12
RC103_C21	3	28	4	29	2189.24	0.004	3	20	1747.98	1933.49	11.68	393.23	3	20	1728.17	1846.23	15.67	470.22
RC104_C21	2	26	2	26	1710.42	0.004	2	19	1644.36	1686.88	1.38	322.00	2	19	1645.35	1688.65	1.27	372.96
RC105_C21	3	23	5	33	2482.3	0.005	3	20	1789.64	1821.53	26.62	471.32	3	20	1802.85	1936.87	21.97	506.77
RC106_C21	3	23	3	33	2142.63	0.005	3	20	1760.23	1797.62	16.10	584.16	3	19	1750.61	1807.42	15.64	450.61

Table 10. Cont.

Instances			C&W Savings Heuristic				VNS _{red}						VNS _{full}					
Name	n_k	n_v	m	n	Dist	$\bar{t}(s)$	m	n	Dist	Avg	Imp(%)	$\bar{t}(s)$	m	n	Dist	Avg	Imp(%)	$\bar{t}(s)$
RC107_C21	3	24	3	28	1901.16	0.004	3	19	1687.90	1713.75	9.86	493.35	3	19	1686.76	1719.83	9.54	681.21
RC108_C21	3	25	2	26	1737.71	0.005	3	19	1672.75	1676.55	3.52	440.79	3	18	1622.76	1655.21	4.75	760.71
RC201_C21	1	15	1	35	1809.28	0.004	1	14	1313.01	1341.92	25.83	682.08	1	11	1318.73	1358.75	24.90	282.60
RC202_C21	1	13	1	30	1636.91	0.005	1	12	1218.40	1246.29	23.86	691.50	1	10	1200.59	1230.97	24.80	531.87
RC203_C21	1	11	1	22	1401.03	0.005	1	10	1119.62	1140.74	18.58	589.31	1	8	1103.43	1138.82	18.72	624.78
RC204_C21	1	14	1	16	1267.87	0.004	1	9	1045.72	1077.93	14.98	462.65	1	8	1040.09	1054.96	16.79	470.14
RC205_C21	1	17	1	25	1553.79	0.004	1	11	1223.37	1253.27	19.34	368.42	1	9	1217.43	1245.16	19.86	356.82
RC206_C21	1	16	1	25	1536.28	0.004	1	10	1216.70	1235.36	19.59	495.64	1	9	1193.11	1216.17	20.84	610.81
RC207_C21	1	12	1	21	1424.02	0.004	1	9	1116.30	1133.88	20.38	532.73	1	8	1106.60	1146.08	19.52	442.03
RC208_C21	1	14	1	14	1253.98	0.005	1	9	1038.25	1081.38	13.76	535.70	1	8	1049.42	1067.86	14.84	516.79
average					1806.25	0.004			1477.75	1528.15	15.50	492.10			1450.52	1516.70	16.12	505.04

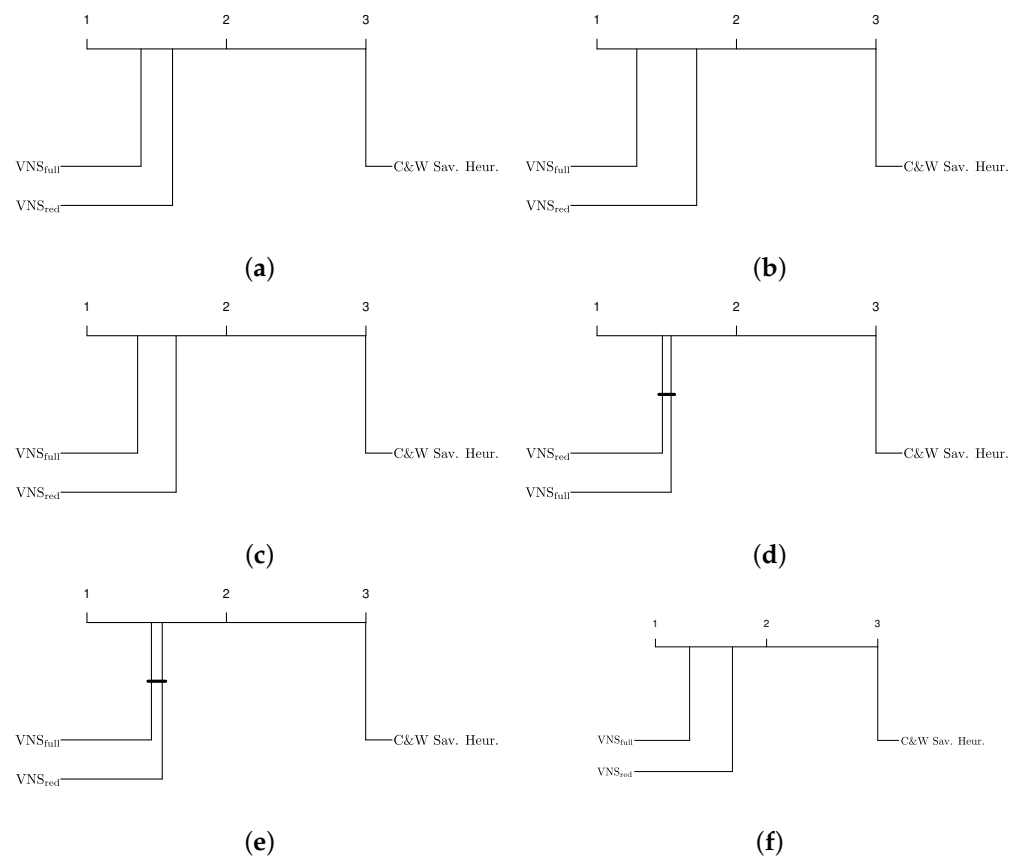


Figure 8. Critical difference plots concerning the results for large instances. The graphic in (a) considers all large instances, while the other graphics consider subsets of the set of large instances. (a) All large instances; (b) clustered instances; (c) random instances; (d) random-clustered instances; (e) instances R1*, C1* and RC1*; and (f) instances R2*, C2*, and RC2*.

The authors apologize for any inconvenience caused and state that the scientific conclusions are unaffected. This correction was approved by the Academic Editor. The original publication has also been updated.

Reference

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