

Supplementary Files for "A Competitive and Cooperative Evolutionary Framework for Ensemble of Constraint Handling Techniques"

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S-I. EXPERIMENTAL RESULTS

The results of the proposed CCMT with eight advanced constrained optimization evolutionary algorithms [1]–[8] on five constrained optimization problem (COP) benchmark suites [9]–[11] are presented in Table S-I to Table S-V. The results of CCMT component validation experiments on the 50-dimensional CEC2017 benchmark suite are presented in Table S-VI. The experimental results of parameter sensitivity analysis for CCMT on the 50-dimensional CEC2017 benchmark suite are shown in Table S-VII to Table S-XI. The results of CCMT on 33 real-world COPs are shown in Table S-XIII.

We describe the structure of these tables. For Table S-I to Table S-VI and Table S-XIII, the first line showed the name of each algorithm. The first column in the table showed the name of each problem in the benchmark suite. The data of each cell in the row with "Obj" in the second column showed the average objective value and standard deviation, and the data in the row with "CV" in the second column showed the average constraint violation and standard deviation. Note that when the results obtained by all algorithms for a problem are infeasible, the objective value were replaced with the constraint violation. If only partial algorithms on a problem failed to obtain a feasible solution, then its data was replaced with "NaN". In each data cell, the objective value or constraint violation and the standard deviation are followed by a symbol "+", "-", or "=", representing that the result of the algorithm for the column corresponding to this cell is significantly better, worse, or equal to the result of the "Base" algorithm in the Wilcoxon rank-sum test on the problem in this cell's corresponding row. The last row in the table showed the total number of significantly better, worse, and equal to the "Base" algorithm for each comparison algorithm on all problems. Different from the previous tables, Table S-VII to Table S-XI did not have the markers and summary statistics obtained by the Wilcoxon rank-sum test.

S-II. REAL-WORLD COPs

We used 33 real-world COPs [12] to test the performance of the proposed CCMT in real-world problems. The details of each problem are shown in Table S-XII. The first column of the table indicates the label of the problem. The second column shows the name of each problem. The last three columns indicate the dimensionality (D), the number of inequality constraints (g), and the number of equality constraints (h), respectively. These 33 problems are divided into three categories according to different types of real-world applications, which are industrial chemical processes [13] (RC01-RC07), process synthesis and design problems [14] (RC08-RC14), and mechanical engineering problems [15] (RC15-RC33).

TABLE S-I
AVERAGE OBJECTIVE VALUES (Obj) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE SELECTED ADVANCED COEAs AND THE PROPOSED CCMT ON THE CEC2006 BENCHMARK SUITE.

		ECHT	VMCH	FROFI	C ^o dE	CORCO	DeCODE	CAL-SHADE	LSHADE44	CCMT
g01	Obj	-1.5000e+01 (0.00e+00) =	-1.4400e+01 (1.50e+00) -	-6.0293e+00 (1.02e+00) -	-1.3061e+01 (4.77e-01) -	-6.3101e+00 (1.82e+00) -	-1.5000e+01 (0.00e+00) =	-9.1249e+00 (6.58e-01) -	-1.0620e+01 (1.29e+00) -	-1.5000e+01 (0.00e+00)
g02	Obj	-8.0145e+01 (4.49e-03) =	-7.9717e-01 (7.07e-03) -	-7.9469e-01 (7.41e-03) -	-8.0324e-01 (1.79e-03) =	-4.4118e-01 (2.89e-02) -	-8.0280e-01 (2.77e-03) =	-8.0364e-01 (2.27e-16) +	-7.9855e-01 (7.08e-03) =	-8.0045e-01 (6.39e-03)
g03	Obj	-1.0005e+00 (2.27e-16) =	-1.0002e+00 (1.62e-03) =	-9.1530e-01 (3.12e-02) -	-6.9047e-01 (1.06e-01) -	0.0000e+00 (0.00e+00) =	-1.0005e+00 (2.27e-16) =	-1.0005e+00 (2.27e-16) =	-1.0005e+00 (2.27e-16) =	-1.0005e+00 (2.27e-16)
g04	Obj	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00)
g05	Obj	5.1749e+03 (8.51e+01) -	5.1265e+03 (0.00e+00) =	NaN -	5.1265e+03 (0.00e+00) =	NaN -	5.1265e+03 (0.00e+00) =	5.2593e+03 (2.15e+02) -	5.3123e+03 (1.61e+02) -	5.1270e+03 (1.66e+00)
g06	Obj	-6.9618e+03 (9.28e-13) =	-5.2443e+03 (1.90e+03) -	-6.8926e+03 (1.07e+02) -	-6.9618e+03 (9.28e-13) =	-5.2993e+03 (1.55e+03) -	-6.9618e+03 (9.28e-13) =	-6.9429e+03 (3.21e+01) -	-6.8926e+03 (1.36e+02) -	-6.9618e+03 (9.28e-13)
g07	Obj	2.4306e+01 (3.63e-15) =	2.4306e+01 (3.63e-15) =	2.5272e+01 (2.45e-01) -	2.4373e+01 (7.24e-02) -	2.4306e+01 (3.63e-15) =	2.4306e+01 (3.63e-15) =	8.9809e+01 (1.93e+01) -	9.0928e+01 (3.40e+01) -	2.4306e+01 (3.63e-15)
g08	Obj	-9.5800e-02 (5.67e-17) =	-9.5800e-02 (5.67e-17) =	-9.5796e-02 (2.00e-05) =	-9.5800e-02 (5.67e-17) =	-8.8344e-02 (1.16e-02) -	-9.5800e-02 (5.67e-17) =	-9.3712e-02 (2.15e-03) -	-9.5728e-02 (1.46e-04) -	-9.5800e-02 (5.67e-17)
g09	Obj	6.8063e+02 (3.48e-13) =	6.8063e+02 (3.48e-13) =	6.8334e+02 (1.05e+00) -	6.8063e+02 (3.48e-13) =	6.8063e+02 (3.48e-13) =	6.8063e+02 (3.48e-13) =	8.1478e+02 (7.16e+01) -	7.3366e+02 (5.39e+01) -	6.8063e+02 (3.48e-13)
g10	Obj	7.0492e+03 (9.28e-13) =	7.0492e+03 (2.00e-02) =	1.2865e+04 (3.87e+03) -	5.9199e+03 (2.71e+02) -	7.5363e+03 (0.00e+00) =	7.0492e+03 (9.28e-13) =	1.0427e+04 (8.30e+02) -	9.9794e+03 (1.20e+03) -	7.0492e+03 (9.28e-13)
g11	Obj	7.4990e-01 (1.13e-16) =	8.4991e-01 (1.25e-01) -	7.5015e-01 (3.42e-04) -	7.4990e-01 (1.13e-16) =	1.0000e+00 (0.00e+00) =	7.4990e-01 (1.13e-16) =	7.6013e-01 (1.71e-02) -	7.7749e-01 (3.74e-02) -	7.4990e-01 (1.13e-16)
g12	Obj	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00) =	-1.0000e+00 (0.00e+00)
g13	Obj	3.0728e-01 (4.17e-01) =	1.7708e-01 (1.83e-01) =	NaN -	5.3970e-02 (9.49e-05) +	2.6137e-01 (1.91e-01) =	5.3900e-02 (2.83e-17) +	8.8004e-01 (1.20e-01) -	9.6317e-01 (8.99e-02) -	4.1304e-01 (4.05e-01)
g14	Obj	-4.7765e+01 (7.25e-15) =	-4.7765e+01 (7.25e-15) =	NaN -	-4.7443e+01 (1.18e-01) -	NaN -	-4.7765e+01 (7.25e-15) =	-4.3168e+01 (2.38e+00) -	-4.5082e+01 (8.65e-01) -	-4.7765e+01 (7.25e-15)
g15	Obj	9.6184e+02 (4.39e-01) =	9.6172e+02 (1.16e-13) =	NaN -	9.6172e+02 (1.16e-13) =	NaN -	9.6172e+02 (1.16e-13) =	9.6477e+02 (2.91e+00) -	9.6272e+02 (1.34e+00) -	9.6172e+02 (1.16e-13)
g16	Obj	-1.9052e+00 (4.53e-16) =	-1.9052e+00 (4.53e-16) =	-1.8879e+00 (7.22e-03) -	-1.8803e+00 (1.50e-02) -	-1.9052e+00 (4.53e-16) =	-1.9052e+00 (4.53e-16) =	-1.6103e+00 (1.45e-01) -	-1.6365e+00 (7.57e-02) -	-1.9052e+00 (4.53e-16)
g17	Obj	8.9318e+03 (3.07e+01) -	8.9465e+03 (1.29e+02) -	NaN -	8.8716e+03 (3.51e+01) =	9.2815e+03 (0.00e+00) =	8.8814e+03 (3.65e+01) =	8.9386e+03 (5.18e+01) -	8.9438e+03 (2.68e+01) -	8.9324e+03 (3.79e+01)
g18	Obj	-8.6600e-01 (2.27e-16) =	-8.6600e-01 (2.27e-16) =	-1.8052e-01 (1.15e-01) -	-7.0067e-01 (2.11e-02) -	-8.6600e-01 (1.14e-16) +	-8.6600e-01 (2.27e-16) =	-5.1477e-01 (6.20e-02) -	-6.1002e-01 (6.39e-02) -	-8.6600e-01 (2.27e-16)
g19	Obj	3.2656e+01 (2.18e-14) =	3.2656e+01 (2.18e-14) =	3.5577e+01 (8.86e-01) -	3.2656e+01 (2.18e-14) =	3.2656e+01 (2.18e-14) =	3.2656e+01 (2.18e-14) =	3.2681e+01 (6.35e-02) -	3.7799e+01 (8.41e+00) -	3.2656e+01 (2.18e-14)
g20	CV	1.4379e-01 (7.97e-05) +	1.4371e-01 (2.67e-11) +	6.9846e-01 (1.28e-02) -	2.0403e-01 (1.07e-02) -	1.1702e+00 (1.15e-01) -	1.4465e-01 (2.02e-03) +	3.1156e-01 (1.98e-01) -	1.4371e-01 (8.45e-13) +	1.4664e-01 (1.77e-03)
g21	Obj	2.5610e+02 (6.70e+01) -	NaN -	NaN -	1.9439e+02 (3.87e-01) +	NaN -	2.0944e+02 (4.34e+01) =	2.8389e+02 (8.18e+01) -	3.0511e+02 (1.42e+02) -	2.0944e+02 (4.34e+01)
g22	CV	3.0801e+06 (2.61e+06) -	1.8832e+06 (3.05e+06) -	1.2030e+05 (6.00e+05) =	4.2423e+05 (6.13e+05) +	2.4196e+05 (8.30e+05) +	6.4904e+01 (4.31e+01) =	7.5967e+03 (6.95e+03) =	1.0810e+06 (1.91e+06) =	1.6006e+06 (1.89e+06)
g23	Obj	-2.1947e+02 (2.08e+02) -	-3.5005e+02 (1.30e+02) =	0.0000e+00 (0.00e+00) =	-3.1605e+02 (1.46e+02) -	-3.5605e+02 (1.23e+02) -	6.0301e+01 (1.46e+02) -	-3.7006e+01 (1.18e+02) -	-4.0006e+02 (3.32e-03) -	-4.0006e+02 (3.32e-03)
g24	Obj	-5.5080e+00 (9.06e-16) =	-5.5080e+00 (9.06e-16) =	-5.5055e+00 (1.42e-03) -	-5.5080e+00 (9.06e-16) =	-5.2971e+00 (8.84e-02) -	-5.5080e+00 (9.06e-16) =	-5.5080e+00 (9.06e-16) =	-5.5080e+00 (9.06e-16) =	-5.5080e+00 (9.06e-16)
+/-/=		1/5/18	1/7/16	0/21/3	3/9/12	2/16/6	2/0/22	1/19/4	1/18/5	Base

TABLE S-II

AVERAGE OBJECTIVE VALUES (O_{Obj}) AND AVERAGE STANDARD DEVIATIONS OBTAINED BY THE SELECTED ADVANCED COEAs AND THE PROPOSED CCMT ON THE 10-DIMENSIONAL CEC2010 BENCHMARK SUITE.

	ECHT	VMCH	FROFI	C ^o dE	CORCO	DeCODE	CAL-SHADE	LSHADE44	CCMT
C01	Obj -7.4596e-01 (2.74e-03) =	-7.4472e-01 (4.81e-03) =	-7.2559e-01 (4.81e-03) =	-7.4730e-01 (3.40e-16) +	-5.1910e-01 (8.22e-02) -	-7.4730e-01 (3.40e-16) +	-7.4730e-01 (3.40e-16) +	-7.4492e-01 (4.19e-03) =	-7.4596e-01 (2.74e-03)
C02	Obj -1.6514e-01 (1.63e+00) -	7.8019e-01 (8.44e-01) -	-1.4380e+00 (4.78e-01) -	8.6009e-01 (1.75e+00) -	-1.7239e+00 (1.55e-01) -	-1.9637e+00 (2.21e-01) -	5.8893e-01 (6.00e-01) -	1.4977e+00 (5.95e-01) -	-2.0177e+00 (3.97e-01)
C03	Obj 0.0000e+00 (0.00e+00) =	4.6153e+00 (4.52e+00) =	8.5237e+00 (1.78e+00) -	8.5262e+00 (1.78e+00) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	3.3071e+06 (1.39e+07) -	3.0463e+13 (7.75e-13) -	0.0000e+00 (0.00e+00)
C04	Obj 0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	NaN -	1.8440e-03 (3.04e-04) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.3031e+01 (4.74e-00) -	1.3625e-01 (3.19e-01) -	0.0000e+00 (0.00e+00)
C05	Obj NaN -	3.8514e+02 (1.78e+02) -	-4.8357e+02 (2.45e-02) +	NaN -	-3.9630e+02 (5.30e+01) -	-4.8361e+02 (1.16e-13) +	2.1625e+02 (1.38e-02) -	4.8845e+02 (1.10e-02) -	-4.8354e+02 (0.00e+00)
C06	Obj -5.7767e+02 (6.68e-01) -	2.3587e+02 (2.21e+02) -	NaN -	NaN -	-5.7302e+02 (2.16e+00) -	-5.7866e+02 (0.00e+00) +	1.7703e+02 (3.19e-02) -	5.3281e+02 (8.08e-01) -	-5.7809e+02 (4.14e-01)
C07	Obj 2.5732e+00 (1.28e+00) -	0.0000e+00 (0.00e+00) =	5.7672e+02 (4.29e+02) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C08	Obj 7.4521e+00 (4.93e+00) -	1.5490e+01 (2.93e+01) -	1.0916e+01 (1.35e-01) -	7.5971e+00 (4.75e+00) -	8.4574e+00 (4.10e+00) -	8.7062e+00 (4.02e+00) -	5.9959e+00 (1.05e-01) -	3.8389e+00 (6.65e+00) -	0.0000e+00 (0.00e+00)
C09	Obj 2.0407e+08 (8.90e+08) -	3.7850e+12 (4.05e+12) -	7.0531e-01 (1.65e+00) -	2.5085e+12 (0.00e+00) -	0.0000e+00 (0.00e+00) =	5.2898e-01 (1.46e+00) -	3.7728e+11 (9.43e+11) -	1.6000e+13 (8.87e+12) -	0.0000e+00 (0.00e+00)
C10	Obj 9.1711e+08 (4.20e+09) -	5.8951e+12 (7.76e+12) -	4.2007e+01 (1.07e-01) -	NaN -	0.0000e+00 (0.00e+00) =	4.0057e+01 (8.35e+00) -	1.3793e+12 (3.12e+12) -	1.0864e+13 (8.73e+12) -	0.0000e+00 (0.00e+00)
C11	Obj -1.5000e-03 (2.29e-19) -	-1.5000e-03 (4.43e-19) =	NaN -	-9.5556e-04 (4.36e-04) -	-1.5000e-03 (4.43e-19) =	-1.5000e-03 (4.43e-19) =	-5.1905e-04 (5.40e-04) -	-1.0640e-03 (1.82e-04) -	-1.5000e-03 (4.43e-19)
C12	Obj -4.4848e+00 (2.33e+01) =	-2.3332e+01 (6.63e+01) =	NaN -	-1.9670e-01 (4.36e-04) -	-1.9920e-01 (0.00e+00) =	-6.3015e-01 (2.15e+00) =	-1.7152e+01 (1.31e+02) +	-8.8385e+00 (5.47e-01) +	-1.1289e+00 (3.23e+00)
C13	Obj -6.3737e+01 (4.87e+00) -	-6.8429e+01 (2.90e-14) =	-6.4084e+01 (3.61e+00) -	-5.1043e+01 (4.72e+00) -	-6.8315e+01 (4.69e-01) -	-6.8429e+01 (2.90e-14) =	-4.3331e+01 (3.03e+00) -	-4.7945e+01 (2.57e+00) -	-6.8429e+01 (2.90e-14)
C14	Obj 2.7166e+00 (1.04e+00) -	6.8777e+05 (3.34e+06) -	7.8268e+00 (1.84e+00) -	7.1112e+10 (8.28e+10) -	3.1893e-01 (1.10e+00) -	0.0000e+00 (0.00e+00) =	7.9420e+06 (3.91e+07) -	4.3955e+12 (3.46e+12) -	0.0000e+00 (0.00e+00)
C15	Obj 1.7730e+08 (8.87e+08) -	1.4608e+12 (2.35e+12) -	3.9010e+00 (2.54e-01) -	3.9265e+12 (3.31e+12) -	5.2600e-01 (2.63e+00) -	3.3793e+00 (1.02e+00) -	1.0448e+10 (3.84e+10) -	3.6017e+13 (3.09e+13) -	0.0000e+00 (0.00e+00)
C16	Obj 1.0096e+00 (4.59e-02) -	8.4090e-01 (2.81e-01) -	2.1800e-03 (8.41e-03) =	8.0695e-11 (2.80e-01) -	0.0000e+00 (0.00e+00) =	1.5860e-02 (2.13e-02) -	4.2181e-01 (4.07e-01) -	9.5644e-01 (7.78e-02) -	3.2520e-03 (7.95e-03)
C17	Obj 4.5512e+01 (1.49e+02) -	8.3391e+01 (5.94e+01) -	0.0000e+00 (0.00e+00) =	2.1193e+02 (1.58e+02) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	2.4636e+01 (2.28e+01) -	2.2577e+02 (8.87e+01) -	0.0000e+00 (0.00e+00)
C18	Obj 9.5070e+03 (5.38e+03) -	2.0105e+03 (1.33e+03) -	0.0000e+00 (0.00e+00) =	5.7870e+03 (3.29e+03) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	7.4215e+02 (2.76e+02) -	5.4208e+03 (1.85e+03) -	0.0000e+00 (0.00e+00)
+/-/=	0/13/5	0/12/6	1/14/3	1/16/1	1/6/11	3/5/10	2/15/1	1/15/2	Base

TABLE S-III

AVERAGE OBJECTIVE VALUES (O_{Obj}) AND AVERAGE STANDARD DEVIATIONS OBTAINED BY THE SELECTED ADVANCED COEAs AND THE PROPOSED CCMT ON THE 30-DIMENSIONAL CEC2010 BENCHMARK SUITE.

	ECHT	VMCH	FROFI	C ^o dE	CORCO	DeCODE	CAL-SHADE	LSHADE44	CCMT
C01	Obj -8.1082e-01 (1.21e-02) -	-7.9745e-01 (1.55e-02) -	-8.0747e-01 (6.72e-03) -	-8.2096e-01 (2.04e-03) +	-4.0324e-01 (3.09e-02) -	-8.1960e-01 (2.92e-03) +	-8.2168e-01 (7.98e-04) +	-7.9640e-01 (1.61e-02) -	-8.1320e-01 (1.05e-02)
C02	Obj 8.4569e-01 (1.40e+00) -	2.1677e+00 (7.26e-01) -	-2.1458e+00 (4.91e-02) -	3.7899e-01 (6.57e-01) -	-1.9040e+00 (8.53e-01) -	-2.1774e+00 (4.09e-02) =	1.9708e+00 (7.84e-01) -	3.0176e+00 (4.90e-01) -	-2.1693e+00 (3.13e-02)
C03	Obj 9.1377e+12 (4.29e+13) -	2.3193e+05 (5.99e+05) -	2.8707e+01 (1.34e-02) -	2.8681e+01 (2.92e-03) -	0.0000e+00 (0.00e+00) =	2.4086e+01 (1.07e+01) -	2.2540e+05 (1.09e+06) -	1.8035e+13 (1.42e+13) -	0.0000e+00 (0.00e+00)
C04	Obj 9.8333e-03 (6.61e-03) +	9.1812e-02 (2.60e-01) =	NaN -	9.7760e-03 (1.40e-02) +	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.9380e+01 (3.13e-01) -	2.4419e-01 (3.13e-01) -	2.5964e-02 (1.30e-01)
C05	Obj NaN -	4.7182e+02 (7.90e+01) -	-4.8341e+02 (7.55e-02) +	1.2146e+02 (2.06e+02) =	-4.5922e+02 (3.12e+01) -	-4.8347e+02 (1.25e-01) +	3.9435e+02 (9.66e+01) -	5.2035e+02 (6.31e+01) -	-4.7990e+02 (3.76e+00)
C06	Obj NaN -	5.3430e+02 (9.02e+01) -	-5.3052e+02 (1.08e-01) +	-3.7199e+01 (5.24e+01) -	-5.1659e+02 (5.17e+00) -	-5.2815e+02 (9.18e-01) -	3.0300e+02 (1.86e+02) =	5.5773e+02 (6.03e-01) -	-5.2991e+02 (3.28e-01)
C07	Obj 9.4895e-01 (1.26e+00) -	0.0000e+00 (0.00e+00) =	1.3859e+04 (1.12e+04) -	0.0000e+00 (0.00e+00) =	1.5946e-01 (7.97e-01) -	0.0000e+00 (0.00e+00) =	6.3786e-01 (1.49e+00) =	1.5946e-01 (7.97e-01) =	1.5946e-01 (7.97e-01)
C08	Obj 1.7024e+01 (6.34e+01) -	2.5625e+02 (6.34e+02) -	3.7660e+01 (2.37e+01) -	3.9600e-04 (1.59e-03) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	2.0290e+02 (3.82e+02) =	6.5738e+00 (1.66e+01) -	0.0000e+00 (0.00e+00)
C09	Obj 4.3107e+13 (0.00e+00) -	2.4375e+13 (1.53e+13) -	1.7602e-01 (8.80e-01) -	1.9914e+12 (1.33e+12) -	0.0000e+00 (0.00e+00) =	2.7284e+01 (3.22e+01) -	1.5337e+12 (2.80e+12) -	3.6548e+13 (1.45e+13) -	0.0000e+00 (0.00e+00)
C10	Obj 4.7679e+12 (0.00e+00) -	2.1139e+13 (1.11e+13) -	3.1347e+01 (1.24e-02) -	2.3982e+12 (1.02e+12) -	0.0000e+00 (0.00e+00) =	3.1309e+01 (3.63e-15) -	1.1510e+11 (3.00e+11) -	4.2069e+13 (1.96e+13) -	7.6579e+00 (9.30e+00)
C11	Obj NaN -	-4.0000e-04 (0.00e+00) =	NaN -	NaN -	-4.0000e-04 (5.53e-20) -	-4.0000e-04 (5.53e-20) -	5.2632e-05 (2.20e-04) -	-8.5714e-05 (7.93e-05) -	-4.0000e-04 (5.53e-20)
C12	Obj -1.9929e-01 (3.59e-05) -	-1.9930e-01 (0.00e+00) =	NaN -	-1.9554e-01 (9.90e-04) -	-1.9930e-01 (0.00e+00) =	-1.9930e-01 (0.00e+00) =	1.4015e+00 (1.87e+00) -	-2.2509e+00 (1.30e+01) -	-1.9930e-01 (0.00e+00)
C13	Obj -5.7857e+01 (5.65e+00) -	6.6899e+01 (1.36e+00) -	-6.4088e+01 (1.94e+00) -	-3.3491e+01 (2.09e+00) -	-6.8429e+01 (0.00e+00) =	-6.8088e+01 (8.40e-01) -	-2.8147e+01 (1.51e+00) -	-3.2190e+01 (1.35e+00) -	-6.8240e+01 (3.47e-01)
C14	Obj 1.4281e+01 (6.99e+00) -	2.2407e+03 (1.12e+04) -	6.8518e+02 (9.90e+02) -	6.5987e+09 (1.80e+10) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.0522e+06 (5.26e+06) -	8.0346e+13 (7.21e+13) -	0.0000e+00 (0.00e+00)
C15	Obj 1.2144e+13 (1.80e+13) -	1.9423e+13 (1.40e+13) -	2.7827e+01 (8.97e-01) -	3.5253e+13 (2.04e+13) -	1.7234e-01 (8.62e-01) -	2.1603e+01 (0.00e+00) -	8.8007e+08 (4.40e+09) -	2.5839e+14 (8.05e+13) -	0.0000e+00 (0.00e+00)
C16	Obj 0.0000e+00 (0.00e+00) =	8.0042e-01 (3.46e-01) -	5.1200e-04 (2.56e-03) -	8.1507e-01 (1.40e-01) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.1009e+00 (0.00e+00) =	1.1009e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C17	Obj 3.9997e+02 (8.42e+02) -	6.3242e+02 (2.55e+02) -	1.3468e-01 (1.75e-01) -	3.7835e+02 (3.98e+02) -	4.1912e-01 (4.37e-01) +	1.6492e-02 (7.79e-02) +	1.0751e+02 (9.72e+01) -	1.1367e+03 (1.50e+02) -	1.2266e+00 (2.28e+00)
C18	Obj 2.4259e+04 (1.07e+04) -	9.7742e+03 (6.91e+03) -	1.6000e-05 (6.24e-05) =	8.6039e+03 (4.98e+03) -	3.7221e+02 (7.20e+02) -	0.0000e+00 (0.00e+00) =	4.2591e+02 (6.79e+02) -	2.3313e+04 (3.58e+03) -	0.0000e+00 (0.00e+00)
+/-/=	1/14/3	0/14/4	2/12/4	2/14/2	4/5/9	4/5/9	1/15/2	1/16/1	Base

TABLE S-IV

AVERAGE OBJECTIVE VALUES (O_{Obj}) OR CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE SELECTED ADVANCED COEAs AND THE PROPOSED CCMT ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		ECHT	VMCH	FROFI	C ^o dE	CORCO	DeCODE	CAL-SHADE	LSHADE44	CCMT
C01	Obj	2.9600e-04 (2.65e-04)	0.0000e+00 (0.00e+00)	1.7668e+02 (3.35e+02)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C02	Obj	1.1200e-04 (1.01e-04)	0.0000e+00 (0.00e+00)	8.9941e+03 (1.52e+03)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	2.2625e+01 (6.04e-01)	4.0816e+04 (5.81e+03)	0.0000e+00 (0.00e+00)
C03	Obj	5.5152e+06 (8.27e+06)	1.0590e+06 (4.86e+05)	6.6147e+03 (1.13e+04)	1.2162e+05 (1.53e+05)	0.0000e+00 (0.00e+00)	1.5041e+03 (5.87e+02)	9.1595e+05 (1.03e+06)	2.5318e+06 (3.54e+06)	0.0000e+00 (0.00e+00)
C04	Obj	4.8453e+02 (6.62e+01)	1.3855e+01 (7.78e-01)	8.1502e+01 (2.89e+01)	7.7668e+01 (2.58e+01)	1.5379e+01 (1.68e+00)	1.5189e+01 (1.79e+00)	1.3573e+01 (0.00e+00)	1.3577e+01 (0.00e+00)	4.0190e+01 (2.18e+01)
C05	Obj	1.0596e+01 (2.65e+00)	7.9732e-01 (1.63e+00)	3.7946e+02 (2.18e+02)	1.5320e-03 (4.08e-03)	0.0000e+00 (0.00e+00)	3.1893e-01 (1.10e+00)	2.5149e+01 (2.06e+01)	1.1956e+05 (3.34e+04)	0.0000e+00 (0.00e+00)
C06	Obj	NaN	8.0056e+03 (1.04e+03)	5.5767e+01 (0.00e+00)	NaN	0.0000e+00 (0.00e+00)	9.6980e+02 (1.36e+03)	2.3695e+03 (1.17e+03)	8.4232e+03 (1.61e+03)	1.3042e+02 (2.51e+02)
C07	Obj	NaN	-4.0221e+02 (1.73e+02)	-2.2515e+03 (1.87e+01)	-4.6255e+02 (1.77e+02)	-7.0528e+01 (2.02e+02)	3.7890e+01 (1.98e+02)	-2.0121e+02 (1.25e+02)	-2.9675e+02 (1.11e+02)	-1.9298e+03 (5.84e+02)
C08	Obj	1.9800e-03 (9.92e-04)	-1.0000e-04 (1.38e-20)	-3.6000e-05 (6.38e-05)	3.9560e-03 (4.05e-04)	-1.0000e-04 (1.38e-20)	-1.0000e-04 (1.38e-20)	7.6200e-03 (1.58e-03)	5.6880e-03 (9.92e-04)	1.6000e-05 (2.79e-04)
C09	Obj	1.1120e-03 (1.48e-02)	-2.0000e-03 (1.33e-18)	-2.0000e-03 (1.33e-18)	3.2978e+00 (8.16e-01)	NaN	-1.8786e-03 (2.75e-04)	1.8560e+01 (1.27e+00)	1.2562e+01 (2.60e+00)	-2.0000e-03 (1.33e-18)
C10	Obj	2.1600e-04 (9.43e-05)	0.0000e+00 (0.00e+00)	8.0000e-06 (4.00e-05)	1.1520e-03 (9.18e-05)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	3.1760e-03 (1.40e-03)	1.7760e-03 (3.50e-04)	0.0000e+00 (0.00e+00)
C11	CV	1.7836e+02 (1.65e+01)	9.8460e-16 (4.92e-15)	3.3285e+03 (1.16e+03)	1.6165e+02 (5.76e+01)	1.7750e+04 (3.31e+03)	9.2574e+03 (2.69e+03)	9.2056e+01 (6.11e+01)	5.0936e-16 (1.49e-15)	4.2867e+00 (6.45e+00)
C12	Obj	1.4884e+01 (8.23e+00)	2.5527e-01 (9.09e+00)	7.7082e+00 (8.18e+00)	1.8265e+02 (1.74e+01)	9.0499e+00 (4.43e-01)	1.1367e+01 (6.05e+00)	6.2950e+00 (6.31e+01)	2.3362e+02 (2.20e+01)	7.8789e+00 (3.96e+00)
C13	Obj	6.4603e+02 (1.33e+03)	3.7652e+01 (4.73e+01)	4.5070e+01 (7.76e+00)	2.4135e+03 (5.74e+02)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	9.3933e+02 (4.62e+02)	3.4429e+03 (6.64e+02)	0.0000e+00 (0.00e+00)
C14	Obj	1.5984e+02 (4.23e-02)	1.1336e+00 (8.59e-02)	1.1019e+00 (5.21e+03)	1.6191e+00 (6.76e-02)	1.6118e+00 (1.28e-01)	1.1000e+00 (4.53e-16)	1.7621e+00 (2.04e-02)	1.5820e+00 (4.39e-02)	1.1156e+00 (2.63e-02)
C15	Obj	1.1257e+01 (4.96e+00)	1.5928e+01 (1.97e+00)	5.7491e+00 (8.70e-01)	1.3917e+01 (1.97e+00)	4.8432e+00 (5.71e+00)	6.1260e+00 (1.28e+00)	7.7597e+00 (7.34e+00)	1.6876e+01 (2.45e+00)	2.3561e+00 (9.06e-06)
C16	Obj	2.2117e+01 (9.20e+00)	2.5057e+02 (1.82e+01)	6.2830e+00 (5.10e-05)	1.7254e+02 (2.49e-01)	0.0000e+00 (0.00e+00)	6.0321e+00 (5.07e-05)	0.0000e+00 (0.00e+00)	2.6546e+02 (2.26e+01)	0.0000e+00 (0.00e+00)
C17	CV	5.1000e+01 (2.91e-04)	5.1000e+01 (0.00e+00)	5.9250e+01 (4.00e-01)	5.1000e+01 (1.17e-05)	4.9503e+01 (3.95e-01)	5.0920e+01 (4.00e-01)	4.9015e+01 (1.93e-02)	5.1000e+01 (0.00e+00)	5.0520e+01 (8.72e-01)
C18	Obj	3.6495e+01 (1.73e-03)	3.7308e+01 (1.96e+00)	NaN	3.7313e+01 (0.00e+00)	NaN	3.8040e+01 (3.25e+00)	3.6515e+01 (1.47e-02)	4.2116e+01 (6.96e+00)	3.6491e+01 (3.23e-03)
C19	CV	7.2232e+04 (4.46e-11)	7.2232e+04 (4.46e-11)	7.2232e+04 (2.27e-04)	7.2232e+04 (1.12e-08)	7.2352e+04 (4.54e+00)	7.2232e+04 (6.63e-09)	7.2232e+04 (5.05e-11)	7.2232e+04 (3.60e-11)	7.2232e+04 (4.46e-11)
C20	Obj	1.4633e+01 (1.06e+00)	2.1131e+00 (4.64e-01)	5.3929e+00 (1.07e+00)	4.4400e+00 (5.29e-01)	6.6578e+00 (1.91e+00)	5.1773e+00 (1.25e+00)	2.6505e+00 (7.01e-01)	2.3388e+00 (2.85e-01)	4.9263e+00 (1.17e+00)
C21	Obj	5.9278e+01 (1.79e+01)	1.1820e+01 (1.06e+01)	6.7755e+00 (4.31e+00)	1.9040e+01 (1.47e+01)	NaN	2.6964e+01 (1.28e+01)	1.0855e+02 (1.80e+01)	2.6017e+02 (2.58e+01)	4.3179e+01 (1.93e+01)
C22	Obj	9.6765e+01 (5.52e+01)	4.3264e+04 (1.34e+04)	4.3955e+01 (3.66e-01)	3.3429e+03 (1.60e+03)	7.7154e+00 (2.18e+00)	1.6850e+01 (2.07e+00)	6.7505e+03 (8.69e+03)	6.4290e+04 (1.01e+04)	1.8579e+00 (1.42e+00)
C23	Obj	1.5199e+00 (4.76e-02)	1.1125e+00 (4.33e-02)	1.1028e+00 (1.04e-02)	1.5121e+00 (5.14e-02)	1.7537e+00 (1.167e-01)	1.5479e+00 (2.02e-01)	1.6205e+00 (4.76e-02)	1.6320e+00 (2.69e-02)	1.2398e+00 (7.97e-02)
C24	Obj	1.0147e+01 (2.74e+00)	1.5676e+01 (1.37e+00)	5.4897e+00 (3.74e-05)	1.1907e+01 (1.10e+00)	2.6180e+00 (8.87e-01)	5.3720e+00 (1.43e+00)	1.5048e+01 (2.12e+00)	1.6053e+01 (1.54e+00)	2.3561e+00 (9.06e-16)
C25	Obj	5.5041e+01 (1.96e+01)	2.6496e+02 (1.89e+01)	2.9371e+04 (4.36e-05)	1.8516e+02 (2.91e+01)	0.0000e+00 (0.00e+00)	6.2831e+00 (5.10e-05)	9.2928e+01 (3.34e-01)	7.2891e+02 (1.57e+01)	0.0000e+00 (0.00e+00)
C26	CV	5.1000e+01 (2.77e-04)	5.1000e+01 (0.00e+00)	5.1000e+01 (2.22e-05)	5.1000e+01 (7.31e-06)	5.1006e+01 (5.32e-03)	5.1000e+01 (5.59e-05)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)
C27	Obj	3.7695e+01 (4.23e+00)	3.7329e+01 (3.07e+00)	NaN	5.1144e+01 (7.05e+00)	NaN	3.6487e+01 (4.87e+03)	4.6295e+01 (6.82e+00)	4.0312e+01 (6.52e+00)	3.6767e+01 (1.34e+00)
C28	CV	7.2275e+04 (2.05e+00)	7.2601e+04 (3.11e+01)	7.2325e+04 (2.65e+01)	7.2471e+04 (2.99e+01)	7.2475e+04 (2.23e+01)	7.2531e+04 (2.88e+01)	7.2619e+04 (1.84e+01)	7.2613e+04 (2.77e+01)	7.2313e+04 (2.84e+01)
+/-=		1/25/2	7/13/8	6/16/6	11/20/23/5	4/15/9	5/14/9	4/19/5	4/20/4	Base

TABLE S-V

AVERAGE OBJECTIVE VALUES (Obj) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE SELECTED ADVANCED COEAs AND THE PROPOSED CCMT ON THE 100-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		ECHT	VMCH	FROFI	C ² oDE	CORCO	DeCODE	CAL-SHADE	LSHADE44	CCMT
C01	Obj	6.5210e+01 (3.42e+01) -	0.0000e+00 (0.00e+00) =	5.4907e+03 (3.61e+03) -	8.4000e-05 (8.98e-05) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C02	Obj	2.1056e+01 (7.91e+00) -	0.0000e+00 (0.00e+00) =	2.1430e+04 (8.01e+03) -	6.8000e-05 (6.90e-05) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	2.4416e+04 (4.57e+04) -	1.6848e+05 (3.89e+04) -	0.0000e+00 (0.00e+00)
C03	Obj	9.5406e+06 (2.59e+06) -	2.5217e+06 (1.72e+06) -	3.3028e+03 (3.82e+03) -	1.9746e+05 (8.72e+04) -	0.0000e+00 (0.00e+00) =	5.5250e+03 (1.82e+03) -	2.3229e+06 (2.57e+06) -	3.2003e+06 (2.17e+06) -	1.5470e+02 (9.32e+01)
C04	Obj	2.5423e+02 (7.41e+01) -	2.0825e+01 (1.45e+01) +	2.4213e+02 (4.73e+01) -	1.5048e+02 (2.65e+01) =	7.7401e+01 (1.91e+01) +	8.2387e+01 (2.00e+01) +	1.3573e+01 (0.00e+00) +	1.3573e+01 (0.00e+00) +	1.6192e+02 (5.05e+01)
C05	Obj	8.0179e+01 (2.23e+01) -	1.5946e-01 (7.97e-01) =	3.4016e+03 (1.38e+03) -	4.1871e+01 (1.33e+01) -	1.1804e+02 (2.69e+00) -	1.1151e+00 (1.89e+00) -	1.0106e+02 (2.63e+01) -	5.6065e+05 (1.01e+05) -	1.5946e-01 (7.97e-01)
C06	Obj	NaN -	1.6931e+04 (2.59e+03) -	NaN -	5.5772e+03 (1.16e+03) -	2.9485e+02 (1.15e+02) +	2.2711e+03 (3.00e+03) -	6.0188e+03 (2.27e+03) -	1.7994e+04 (2.35e+03) -	1.1220e+03 (3.96e+02)
C07	Obj	NaN -	-9.8889e-02 (2.54e+02) =	-4.5636e+03 (3.59e+01) +	-8.2383e+02 (1.44e+02) =	-1.0340e+02 (2.18e+02) -	-5.2659e+01 (2.51e+02) -	-2.9562e+02 (1.52e+02) -	-4.0168e+02 (9.74e+01) -	-7.6071e+02 (4.82e+02)
C08	Obj	NaN -	1.2480e-03 (2.86e-04) +	8.9600e-04 (1.06e-04) +	NaN -	3.2000e-03 (1.11e+03) +	1.7680e-03 (2.54e-04) +	1.8920e-03 (1.36e-03) =	7.0480e-03 (1.73e-03) =	3.7643e-03 (1.75e-03)
C09	Obj	6.4723e+00 (2.51e+00) -	0.0000e+00 (0.00e+00) +	0.0000e+00 (0.00e+00) +	1.1808e+00 (1.89e+00) -	NaN -	0.0000e+00 (0.00e+00) +	1.8924e+01 (8.85e-01) -	1.5579e+01 (1.94e+00) -	6.4000e-05 (1.58e-04)
C10	Obj	6.1600e-04 (1.03e-04) -	3.2000e-04 (5.77e-05) -	3.1600e-04 (4.73e-05) -	1.0960e-03 (8.41e-05) -	3.8800e-04 (6.00e-05) -	3.5200e-04 (8.72e-05) -	3.1760e-03 (1.15e-03) -	1.8320e-03 (4.14e-04) -	2.6400e-04 (5.69e-05)
C11	CV	2.0817e+02 (1.97e+02) =	2.3587e-02 (2.79e-02) =	4.4512e+03 (7.18e+02) -	4.5429e+02 (1.96e+02) -	2.1904e-04 (5.20e+03) -	3.0289e+04 (4.44e+03) -	4.7533e+02 (2.46e+02) -	2.5413e+02 (4.36e+02) +	1.2956e+02 (1.33e+01)
C12	Obj	2.7997e+01 (7.28e+00) -	1.2063e+01 (7.06e+00) +	6.4985e+00 (4.20e+00) +	2.5410e+02 (1.79e+01) -	NaN -	2.0294e+01 (9.63e+00) =	6.6052e+00 (3.94e+01) +	4.1459e+02 (3.12e+01) -	2.2137e+01 (7.85e+00)
C13	Obj	7.7077e+02 (8.40e+02) -	1.5405e-03 (6.25e+03) =	1.8068e+02 (1.24e+02) -	5.4161e+03 (1.22e+03) -	2.6994e+01 (2.10e+01) +	4.2224e-01 (1.82e+01) -	1.9201e+03 (3.47e+02) -	1.3510e+04 (1.95e+04) -	3.1672e+01 (1.94e+00)
C14	Obj	1.0691e+00 (3.10e-02) -	7.8960e-01 (1.36e-02) =	7.8831e-01 (9.39e-03) -	1.1227e+00 (2.57e-02) -	1.0844e+00 (9.76e-02) -	7.9734e-01 (6.57e-02) -	1.1678e+00 (3.38e-03) -	1.1128e+00 (1.38e-02) -	7.8569e-01 (4.84e-03)
C15	Obj	1.2409e+01 (2.87e+00) -	2.1834e+01 (2.40e+00) -	8.6393e+00 (9.07e-01) -	1.7436e+01 (1.28e+00) -	9.3933e+00 (1.64e+00) -	1.2284e+01 (1.18e+00) -	4.4924e+00 (3.10e+00) -	2.2462e+01 (2.03e+00) -	2.3561e+00 (9.06e-16)
C16	Obj	1.3697e+01 (1.64e+01) -	6.1871e-02 (2.57e+01) -	8.5449e+00 (3.08e+00) -	4.0244e+02 (3.72e+01) -	0.0000e+00 (0.00e+00) =	6.2831e+00 (5.10e-05) -	0.0000e+00 (0.00e+00) =	6.4114e+02 (2.65e+01) -	0.0000e+00 (0.00e+00)
C17	CV	1.0100e-02 (5.24e-04) -	1.0100e-02 (0.00e+00) =	1.0100e-02 (3.73e-05) =	1.0100e-02 (0.00e+00) =	1.0055e+02 (7.74e-01) =	1.0100e-02 (4.29e-05) -	9.9016e+01 (1.73e-02) =	1.0100e+02 (0.00e+00) =	1.0100e+02 (0.00e+00)
C18	Obj	4.5985e+01 (6.28e+00) -	3.7953e-01 (3.14e+00) =	NaN -	4.6996e+01 (5.92e+00) -	NaN -	3.8659e+01 (5.36e+00) -	3.6467e+01 (4.59e+02) +	5.487e+01 (8.42e+00) -	3.6743e+01 (1.69e+00)
C19	CV	1.4594e+05 (8.91e-11) =	1.4594e+05 (8.91e-11) =	1.4594e+05 (1.09e-04) -	1.4594e+05 (1.37e-08) -	1.4622e+05 (7.45e-00) -	1.4594e+05 (1.04e-08) -	1.4594e+05 (2.80e-09) -	1.4594e+05 (1.32e-09) -	1.4594e+05 (8.91e-11)
C20	Obj	3.3499e+01 (1.44e+00) -	5.1292e+00 (9.41e+01) +	1.2342e+01 (2.16e+00) -	1.1695e+01 (3.03e+00) -	1.5432e+01 (4.71e+00) -	1.0702e+01 (2.43e+00) -	5.6084e+00 (6.93e+01) +	5.1225e+00 (7.57e+01) +	1.0098e+01 (2.02e+00)
C21	Obj	1.2517e+01 (7.10e+00) -	7.2185e+00 (3.97e+00) =	2.1489e+01 (1.34e+01) -	2.9521e+02 (2.30e+01) -	NaN -	6.0046e+00 (4.02e+00) +	2.5655e+02 (4.03e+01) -	4.6953e+02 (3.19e+01) -	9.1587e+00 (6.39e+00)
C22	Obj	2.7793e+03 (1.17e+03) -	NaN -	1.7567e+03 (7.41e+02) -	NaN -	8.4450e+01 (1.16e+01) +	2.5104e+02 (2.04e+02) -	1.1858e+04 (6.11e+03) -	NaN -	1.3371e+02 (2.09e+02)
C23	Obj	1.0411e+00 (1.43e-02) -	7.8420e-01 (1.13e+16) +	7.9930e-01 (1.32e-02) +	1.0618e+00 (1.71e-02) -	1.0154e+00 (9.34e-02) -	9.3212e-01 (1.50e-01) =	1.1191e+00 (2.13e-02) -	1.1327e+00 (1.02e-02) -	8.6092e-01 (6.15e-02)
C24	Obj	1.3540e+01 (2.58e+00) -	2.2337e+01 (1.54e+00) -	7.8853e+00 (1.37e+00) -	1.5299e+01 (1.04e+00) -	2.3561e+00 (9.06e-16) =	6.0004e+00 (1.18e+00) -	1.9195e+01 (2.00e+00) -	2.3091e+01 (2.72e+00) -	2.3561e+00 (9.06e-16)
C25	Obj	1.1228e+02 (2.29e+01) -	7.1195e+02 (2.18e+01) -	3.1667e+01 (1.69e+01) -	5.1937e+02 (2.99e+01) -	4.4485e+01 (2.15e+01) -	3.5437e+01 (1.80e+01) -	5.4915e+02 (8.26e+01) -	7.1396e+02 (2.19e+01) -	1.1184e+01 (6.65e+00)
C26	CV	1.0100e-02 (4.54e-04) -	1.0100e+02 (0.00e+00) =	1.0100e+02 (1.55e-05) =	1.0100e+02 (1.51e-07) =	1.0101e+02 (1.02e-02) -	1.0100e+02 (1.17e-05) =	1.0100e+02 (0.00e+00) =	1.0100e+02 (0.00e+00) =	1.0100e+02 (0.00e+00)
C27	Obj	3.9868e+01 (2.70e-01) =	3.9207e+01 (4.33e+00) =	NaN -	5.1299e+01 (3.05e+00) =	NaN -	4.7974e+01 (9.78e+00) =	4.7062e+01 (5.06e+00) =	3.9581e+01 (6.30e+00) =	4.4664e+01 (3.50e+00)
C28	CV	1.4626e+05 (1.30e+02) +	1.4679e+05 (3.04e+01) -	1.4641e+05 (1.33e+01) -	1.4658e+05 (5.52e+01) -	1.4668e+05 (3.88e+01) -	1.4667e+05 (4.04e+01) -	1.4680e+05 (2.31e+01) -	1.4679e+05 (2.77e+01) -	1.4635e+05 (3.60e+01)
+/-/=		1/24/3	7/10/11	5/21/2	0/22/6	6/17/5	4/16/8	5/18/5	3/20/5	Base

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TABLE S-VI
AVERAGE OBJECTIVE VALUES (Obj) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE PROPOSED CCMT AND ITS COMPONENT VARIANTS ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

	wo-RA	wo-KA	wo-KD	only-FP	only-EC	only-DeMO	only-COR	wo-Heu	wo-His	new-ECHT	new-MCH	CCMT
C01 Obj	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	1.926e-01 (1.56e-01) -	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00)
C02 Obj	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	1.275e-01 (9.47e-02) -	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00)
C03 Obj	6.2830e+01 (3.80e+01) -	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	6.3878e+06 (5.59e+06) -	0.000e+00 (0.00e+00) =	1.6402e+05 (1.22e+05) -	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	1.2142e+02 (2.75e+01) -	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00)
C04 Obj	5.0935e+01 (2.03e+01) -	3.5644e+01 (1.45e+01) -	2.8142e+02 (3.60e+01) -	1.6268e+02 (1.41e+01) -	1.5880e+02 (1.56e+01) -	1.6149e+02 (1.36e+01) -	2.0089e+02 (1.66e+01) -	4.4924e+01 (1.72e+01) -	3.2141e+01 (1.30e+01) =	3.7734e+02 (2.15e+01) -	2.2177e+02 (9.38e+00) -	4.0190e+01 (2.18e+01)
C05 Obj	1.5946e+02 (7.97e-01) -	0.000e+00 (0.00e+00) =	1.1624e+01 (1.30e+00) -	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00) =	1.9494e+01 (7.97e-01) -	3.1893e+01 (1.10e+01) =	2.8793e+01 (6.43e-01) -	0.000e+00 (0.00e+00) =	0.000e+00 (0.00e+00)
C06 Obj	5.2365e+02 (2.83e+02) -	0.000e+00 (0.00e+00) =	NaN -	8.7345e+03 (1.43e+03) =	NaN -	1.0016e+03 (0.00e+00) -	NaN -	2.4975e+02 (3.90e+02) =	5.3470e+02 (3.84e+02) =	NaN -	NaN -	1.3042e+02 (2.51e+02)
C07 Obj	-1.4029e+03 (9.33e+02) -	-2.000e+03 (5.45e+02) =	NaN -	-4.3534e+01 (2.40e+02) =	-5.7845e+02 (8.90e+00) -	-1.5569e+02 (1.86e+02) -	1.1033e+01 (7.12e+01) -	-1.7486e+03 (6.83e+02) =	-2.1674e+03 (3.17e+01) =	-2.0379e+02 (0.00e+00) -	NaN -	-1.9298e+03 (5.84e+02)
C08 Obj	-9.6000e-05 (2.00e-05) +	-5.6000e-05 (8.21e-05) =	NaN -	-1.0000e-04 (1.38e-20) +	-1.0000e-04 (1.38e-20) +	-1.0000e-04 (1.38e-20) +	-1.0000e-04 (1.38e-20) +	-1.6263e-20 (3.29e+04) =	2.0000e-05 (3.62e+04) =	NaN -	-5.2000e-05 (7.77e-05) =	-1.6000e-05 (2.79e+02)
C09 Obj	-2.0000e-03 (1.33e-18) =	-2.0000e-03 (1.33e-18) =	NaN -	-2.0000e-03 (1.33e-18) =	NaN -	NaN -	NaN -	-2.0000e-03 (1.33e-18) =	-2.0000e-03 (1.33e-18) =	NaN -	NaN -	-2.0000e-03 (1.33e-18)
C10 Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	8.9600e-04 (2.68e-04) =	0.0000e+00 (0.00e+00) =	2.2000e-04 (5.00e-05) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	NaN -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C11 CV	5.2915e+00 (7.92e+00) =	1.3444e+01 (1.68e+01) =	8.1895e+01 (5.24e+01) =	2.2153e-11 (7.77e-11) +	8.1280e-01 (1.56e+00) +	1.6815e+04 (2.61e+03) +	1.1591e+01 (4.53e+00) +	2.2777e+00 (3.30e+00) =	2.2981e+00 (2.44e+00) =	1.0485e+04 (7.91e+02) -	1.9063e+04 (2.63e+03) -	4.2867e+00 (6.45e+00)
C12 Obj	1.0416e+01 (5.61e+00) =	1.0377e+01 (6.04e+00) =	1.0665e+01 (1.56e+00) =	4.7846e+00 (1.46e+00) +	5.9579e+00 (1.22e+00) =	3.9816e+00 (2.00e+05) +	0.0000e+00 (0.00e+00) =	9.9812e+00 (6.84e+00) -	1.2848e+01 (5.99e+00) -	NaN -	5.6683e+00 (1.12e+00) +	7.8789e+00 (3.96e+00)
C13 Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	1.8750e+01 (8.83e-01) -	7.1483e+02 (1.54e+02) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	3.7947e+01 (1.13e+01) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C14 Obj	1.1325e+00 (3.37e-02) -	1.3279e+00 (1.71e+01) -	1.1823e+00 (7.76e-02) -	1.5990e+00 (3.69e-02) -	1.1000e+00 (4.53e-16) +	1.1000e+00 (4.53e-16) +	1.1192e+00 (2.16e+02) =	1.1192e+00 (2.16e+02) =	1.1066e+00 (1.04e-02) =	1.5665e+00 (3.32e+02) -	1.1000e+00 (1.80e-04) +	1.1156e+00 (2.63e-02)
C15 Obj	2.3561e+00 (9.06e-16) =	2.3561e+00 (4.36e-05) =	2.3561e+00 (4.08e-05) =	2.0079e+01 (2.38e+00) -	2.8588e+00 (1.18e+00) +	9.2677e+00 (8.70e-01) -	2.6074e+00 (8.70e-01) -	2.3561e+00 (9.06e-16) =	2.3561e+00 (9.06e-16) =	2.3561e+00 (2.77e+05) =	2.3562e+00 (4.64e-05) =	2.3561e+00 (9.06e-16)
C16 Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	3.1906e+02 (1.98e+01) -	0.0000e+00 (0.00e+00) =	1.1309e+01 (2.31e+00) -	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	5.2000e-05 (5.70e-05) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C17 CV	5.0520e+01 (8.72e-01) =	5.0661e+01 (7.12e-01) =	5.1000e+01 (1.78e-04) =	5.1000e+01 (3.79e-05) -	5.0648e+01 (6.74e-01) -	5.0788e+01 (6.32e+01) =	5.1013e+01 (1.24e+02) -	4.9880e+01 (1.01e+00) +	5.0201e+01 (9.99e-01) =	5.1000e+01 (5.07e-04) =	5.0204e+01 (9.71e-01) =	5.0520e+01 (8.72e-01)
C18 Obj	3.6478e+01 (3.80e-03) +	3.6500e+01 (3.61e-03) =	NaN -	3.6486e+01 (1.77e-03) +	3.6510e+01 (3.70e-03) =	3.6498e+01 (1.80e-03) =	NaN -	3.6498e+01 (4.54e+03) =	3.6993e+01 (3.14e-03) =	NaN -	NaN -	3.6491e+01 (3.23e-03)
C19 CV	7.2232e+04 (4.46e-11) =	7.2232e+04 (4.46e-11) =	7.2232e+04 (1.07e-04) =	7.2232e+04 (4.46e-11) =	7.2232e+04 (4.46e-11) =	7.2232e+04 (4.46e-11) =	7.2348e+04 (3.30e+00) -	7.2232e+04 (4.46e-11) =	7.2232e+04 (3.14e-03) =	7.2374e+04 (6.28e+00) -	7.2232e+04 (6.90e-06) -	7.2232e+04 (4.46e-11)
C20 Obj	4.8668e+00 (8.27e-01) =	5.3599e+00 (1.11e+00) =	1.0990e+01 (5.41e+01) =	8.6416e+00 (1.03e+00) -	8.5390e+00 (1.41e+00) -	8.9788e+00 (1.48e+00) -	8.8121e+00 (1.61e+00) -	4.9793e+01 (1.38e+00) =	4.9476e+01 (1.26e+00) =	1.1329e+01 (3.53e-01) =	9.2563e+00 (4.04e-01) -	4.9268e+00 (1.17e+00)
C21 Obj	4.1695e+01 (1.58e+01) =	5.3403e+01 (2.00e+01) =	7.5346e+01 (1.45e+00) =	5.9895e+01 (1.12e+01) =	5.0219e+01 (1.46e+01) =	5.1863e+01 (1.29e+01) =	NaN -	4.6121e+01 (1.76e+01) =	4.1654e+01 (1.76e+01) =	NaN -	6.2654e+01 (1.42e+01) -	4.3179e+01 (1.93e+01)
C22 Obj	2.6852e+00 (1.52e+00) =	1.2518e+00 (7.39e-01) =	3.3377e+01 (9.60e-01) =	1.0542e+04 (1.41e+04) =	4.8699e+00 (2.83e+00) -	2.2546e+01 (1.61e+01) =	NaN -	2.9999e+01 (1.02e+01) =	3.3671e+00 (1.00e+00) =	NaN -	3.5684e+01 (1.09e+02) -	1.8379e+00 (1.42e+00)
C23 Obj	1.1799e+00 (4.30e-02) +	1.5142e+00 (2.00e+05) =	1.2296e+00 (3.66e-02) =	1.3653e+00 (4.54e-02) =	1.6424e+00 (3.07e-02) =	1.5663e+00 (3.37e-02) =	1.3851e+00 (5.38e-02) =	1.2625e+00 (5.85e-02) =	1.2229e+00 (8.39e-02) =	1.5104e+00 (5.02e-02) =	1.5832e+00 (3.11e-02) =	1.2509e+00 (7.97e-02)
C24 Obj	2.3561e+00 (9.06e-16) =	2.3561e+00 (4.76e-05) =	2.3561e+00 (4.76e-05) =	1.9321e+02 (2.22e+00) =	2.6073e+00 (8.70e-01) -	8.8907e+00 (6.70e-01) -	2.7332e+00 (1.38e+00) -	2.3561e+00 (9.06e-16) =	2.3561e+00 (9.06e-16) =	2.4818e+00 (6.28e-01) -	2.3561e+00 (4.90e-05) =	2.3561e+00 (9.06e-16)
C25 Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	3.1774e+02 (1.57e+01) -	0.0000e+00 (0.00e+00) =	1.2189e+01 (1.30e+00) -	0.0000e+00 (0.00e+00) =	6.2826e-02 (3.14e-01) =	0.0000e+00 (0.00e+00) =	1.5707e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
C26 CV	5.1000e+01 (7.93e-04) =	5.1000e+01 (5.73e-05) =	5.1000e+01 (1.82e-04) =	5.1000e+01 (5.73e-05) =	5.1000e+01 (1.78e-05) =	5.1000e+01 (1.78e-05) =	5.1008e+01 (6.73e-03) =	5.1000e+01 (0.00e+00) =	5.1000e+01 (0.00e+00) =	5.1000e+01 (2.99e-04) =	5.1000e+01 (1.73e-04) =	5.1000e+01 (0.00e+00)
C27 Obj	3.6667e+01 (2.38e+00) =	5.7457e+01 (2.71e+00) =	NaN -	3.8397e+01 (6.00e+00) =	4.1890e+01 (5.78e+00) -	3.6666e+01 (2.94e+00) -	NaN -	3.7094e+01 (2.08e+00) =	3.6528e+01 (1.42e+00) =	NaN -	NaN -	3.6767e+01 (1.34e+00)
C28 CV	7.2522e+04 (2.52e+01) =	7.2522e+04 (2.51e+00) =	7.2238e+04 (7.11e+00) +	7.2502e+04 (2.00e+01) -	7.2503e+04 (2.94e+00) -	7.2505e+04 (2.88e+01) -	7.2427e+04 (1.96e+03) -	7.2533e+04 (2.89e+01) -	7.2677e+04 (2.88e+01) =	7.2511e+04 (1.70e+01) -	7.2589e+04 (1.23e+02) +	7.2319e+04 (2.94e+01)
+/-=	3/8/17	0/10/18	1/21/6	5/16/7	2/16/13	3/16/9	1/19/8	2/6/20	0/4/24	0/27/1	3/15/10	Base

TABLE S-VII

AVERAGE OBJECTIVE VALUES (Obj) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE PROPOSED CCMT WITH DIFFERENT pr SETTINGS ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		$pr = 0$	$pr = 0.1$	$pr = 0.2$	$pr = 0.3$	$pr = 0.5$
C01	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C02	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C03	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	3.7443e+00 (1.67e+01)	8.0466e+01 (1.60e+01)	4.9921e+03 (1.35e+04)
C04	Obj	3.9971e+01 (2.42e+01)	4.3886e+01 (2.26e+01)	4.1114e+01 (1.56e+01)	6.9115e+01 (2.79e+01)	7.3452e+01 (1.80e+01)
C05	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	3.9866e-01 (1.23e+00)	1.9933e-01 (8.91e-01)
C06	Obj	3.3333e-05 (5.16e-05)	6.2464e+01 (9.14e+01)	1.5928e+02 (3.19e+02)	4.0916e+02 (3.71e+02)	NaN
C07	Obj	-2.1932e+03 (2.97e+01)	-2.0979e+03 (4.02e+02)	-1.7018e+03 (7.57e+02)	-1.5215e+03 (8.61e+02)	-1.1152e+03 (8.31e+02)
C08	Obj	-6.5000e-05 (8.13e-05)	-3.0000e-05 (8.65e-05)	1.2530e+04 (3.23e+04)	2.6500e-04 (4.17e-04)	5.2500e-04 (3.14e-04)
C09	Obj	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)
C10	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C11	CV	1.5202e+01 (2.99e+01)	4.4576e+00 (6.95e+00)	9.2572e-01 (1.36e+00)	1.0538e+00 (1.59e+00)	7.0225e-01 (2.30e+00)
C12	Obj	9.9762e+00 (5.18e+00)	7.8468e+00 (3.58e+00)	1.0175e+01 (5.26e+00)	7.3032e+00 (2.68e+00)	1.2349e+01 (5.77e+00)
C13	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C14	Obj	1.2525e+00 (1.77e-01)	1.1147e+00 (2.90e-02)	1.1055e+00 (8.62e-03)	1.1064e+00 (8.27e-03)	1.1009e+00 (1.70e-03)
C15	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C16	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C17	CV	5.0500e+01 (8.20e-01)	5.0400e+01 (9.40e-01)	5.0400e+01 (9.40e-01)	5.0400e+01 (9.40e-01)	5.0000e+01 (1.03e+00)
C18	Obj	3.6502e+01 (5.76e-03)	3.6491e+01 (3.44e-03)	3.6480e+01 (7.49e-03)	3.6474e+01 (6.21e-03)	3.6472e+01 (6.04e-03)
C19	CV	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)
C20	Obj	5.3807e+00 (8.31e-01)	4.9062e+00 (1.05e+00)	4.3867e+00 (1.26e+00)	4.4830e+00 (1.41e+00)	4.5217e+00 (1.20e+00)
C21	Obj	5.4462e+01 (1.82e+01)	4.1931e+01 (1.93e+01)	4.6153e+01 (1.58e+01)	3.1923e+01 (1.67e+01)	3.9518e+01 (1.70e+01)
C22	Obj	1.4381e+00 (7.16e-01)	1.5504e+00 (9.02e-01)	2.1210e+00 (1.48e+00)	2.2410e+00 (1.48e+00)	3.3548e+00 (2.05e+00)
C23	Obj	1.3830e+00 (2.12e-01)	1.2549e+00 (8.21e-02)	1.2251e+00 (6.30e-02)	1.2338e+00 (4.54e-02)	1.2201e+00 (2.82e-02)
C24	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C25	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C26	CV	5.1001e+01 (6.41e-04)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)
C27	Obj	3.8820e+01 (5.50e+00)	3.6833e+01 (1.50e+00)	3.8264e+01 (5.53e+00)	3.6470e+01 (5.23e-04)	3.6470e+01 (1.57e-03)
C28	CV	7.2305e+04 (3.38e+01)	7.2309e+04 (2.32e+01)	7.2327e+04 (2.14e+01)	7.2360e+04 (2.51e+01)	7.2385e+04 (3.35e+01)

TABLE S-VIII

AVERAGE OBJECTIVE VALUES (Obj) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE PROPOSED CCMT WITH DIFFERENT α SETTINGS ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		$\alpha = 0$	$\alpha = 0.25$	$\alpha = 0.5$	$\alpha = 0.75$	$\alpha = 1$
C01	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C02	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C03	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	7.1232e+01 (3.37e+01)
C04	Obj	4.1573e+01 (3.05e+01)	3.6564e+01 (2.21e+01)	4.3886e+01 (2.26e+01)	4.9338e+01 (2.64e+01)	5.7337e+01 (2.43e+01)
C05	Obj	1.9933e-01 (8.91e-01)	1.9933e-01 (8.91e-01)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C06	Obj	3.2358e+02 (3.86e+02)	4.0583e+02 (3.63e+02)	6.2464e+01 (9.14e+01)	4.3378e+02 (4.31e+02)	3.5164e+02 (4.97e+02)
C07	Obj	-1.8237e+03 (7.59e+02)	-1.7789e+03 (7.71e+02)	-2.0979e+03 (4.02e+02)	-2.0104e+03 (5.68e+02)	-1.4158e+03 (9.14e+02)
C08	Obj	7.2105e-04 (1.02e-03)	2.8947e-04 (6.07e-04)	-3.0000e-05 (8.65e-05)	-1.0000e-04 (1.29e-20)	-1.0000e-04 (1.39e-20)
C09	Obj	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)
C10	Obj	0.0000e+00 (0.00e+00)	2.0000e-05 (6.16e-05)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C11	CV	7.6843e+01 (4.84e+01)	3.0411e+01 (2.63e+01)	4.4576e+00 (6.95e+00)	1.6500e-01 (5.00e-01)	6.6790e-09 (2.86e-08)
C12	Obj	8.9428e+00 (4.71e+00)	7.4576e+00 (2.56e+00)	7.8468e+00 (3.58e+00)	9.4986e+00 (7.58e+00)	7.8467e+00 (3.58e+00)
C13	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C14	Obj	1.1050e+00 (6.81e-03)	1.1098e+00 (1.22e-02)	1.1147e+00 (2.90e-02)	1.1132e+00 (2.96e-02)	1.1513e+00 (4.29e-02)
C15	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C16	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C17	CV	5.0500e+01 (8.89e-01)	5.0700e+01 (7.33e-01)	5.0400e+01 (9.40e-01)	5.0500e+01 (8.89e-01)	5.0800e+01 (6.16e-01)
C18	Obj	3.6498e+01 (3.08e-03)	3.6495e+01 (3.03e-03)	3.6491e+01 (3.44e-03)	3.6490e+01 (4.19e-03)	3.6471e+01 (2.54e-03)
C19	CV	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)
C20	Obj	4.7009e+00 (1.19e+00)	4.9198e+00 (1.11e+00)	4.9062e+00 (1.05e+00)	5.2838e+00 (6.90e-01)	4.8404e+00 (1.07e+00)
C21	Obj	4.2487e+01 (1.84e+01)	4.1189e+01 (1.79e+01)	4.1931e+01 (1.95e+01)	4.3941e+01 (1.65e+01)	3.9844e+01 (1.93e+01)
C22	Obj	1.5966e+00 (1.01e+00)	1.5740e+00 (8.12e-01)	1.5504e+00 (9.02e-01)	1.9019e+00 (9.71e-01)	7.2524e+00 (3.48e+00)
C23	Obj	1.3436e+00 (1.22e-01)	1.3176e+00 (1.09e-01)	1.2549e+00 (8.21e-02)	1.2080e+00 (8.81e-02)	1.1494e+00 (3.20e-02)
C24	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C25	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C26	CV	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)
C27	Obj	3.6504e+01 (4.05e-03)	3.6502e+01 (3.60e-03)	3.6833e+01 (1.50e+00)	3.7037e+01 (2.42e+00)	3.6507e+01 (1.67e-01)
C28	CV	7.2314e+04 (2.61e+01)	7.2318e+04 (2.52e+01)	7.2309e+04 (2.32e+01)	7.2317e+04 (2.03e+01)	7.2321e+04 (3.21e+01)

TABLE S-IX

AVERAGE OBJECTIVE VALUES (Obj) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE PROPOSED CCMT WITH DIFFERENT β SETTINGS ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		$\beta = 0$	$\beta = 0.1$	$\beta = 0.2$	$\beta = 0.3$	$\beta = 0.5$
C01	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C02	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C03	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	3.7344e+00 (1.67e+01)
C04	Obj	3.6493e+01 (3.30e+01)	4.3886e+01 (2.26e+01)	5.6118e+01 (1.96e+01)	5.4788e+01 (1.55e+01)	4.7581e+01 (1.72e+01)
C05	Obj	1.9933e-01 (8.91e-01)	0.0000e+00 (0.00e+00)	1.9933e-01 (8.91e-01)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C06	Obj	2.0494e+02 (2.84e+02)	6.2464e+01 (9.14e+01)	3.1244e+02 (5.41e+02)	5.4183e+02 (3.57e+02)	2.3722e+02 (2.97e+02)
C07	Obj	-2.0101e+03 (4.46e+02)	-2.0979e+03 (4.02e+02)	-1.9399e+03 (6.74e+02)	-2.2032e+03 (4.11e+01)	-1.8581e+03 (7.37e+02)
C08	Obj	1.7008e-04 (5.05e-04)	-3.0000e-05 (8.65e-05)	-4.0000e-05 (1.67e-04)	-9.0000e-05 (3.08e-05)	-7.0000e-05 (4.70e-05)
C09	Obj	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)
C10	Obj	5.0000e-06 (2.24e-05)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C11	CV	6.3759e+00 (8.21e+00)	4.4576e+00 (6.95e+00)	2.3243e+00 (3.40e+00)	1.5463e+00 (2.16e+00)	2.7415e+00 (5.11e+00)
C12	Obj	9.2425e+00 (4.46e+00)	7.8468e+00 (3.58e+00)	9.7573e+00 (5.21e+00)	1.0256e+01 (5.90e+00)	9.0593e+00 (4.99e+00)
C13	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C14	Obj	1.1081e+00 (9.35e-03)	1.1147e+00 (2.90e-02)	1.1149e+00 (2.08e-02)	1.1117e+00 (1.50e-02)	1.1201e+00 (2.92e-02)
C15	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C16	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C17	CV	5.0100e+01 (1.02e+00)	5.0400e+01 (9.40e-01)	5.0200e+01 (1.01e+00)	5.0300e+01 (9.79e-01)	5.0400e+01 (9.40e-01)
C18	Obj	3.6491e+01 (3.33e-03)	3.6491e+01 (3.44e-03)	3.6492e+01 (3.42e-03)	3.6491e+01 (3.00e-03)	3.6488e+01 (5.96e-03)
C19	CV	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)
C20	Obj	5.1849e+00 (7.59e-01)	4.9062e+00 (1.05e+00)	4.8611e+00 (1.09e+00)	5.0595e+00 (8.61e-01)	4.3822e+00 (9.37e-01)
C21	Obj	4.8729e+01 (1.61e+01)	4.1931e+01 (1.93e+01)	4.8365e+01 (1.47e+01)	4.4500e+01 (1.39e+01)	3.7143e+01 (1.78e+01)
C22	Obj	1.4870e+00 (6.89e-01)	1.5504e+00 (9.02e-01)	2.0295e+00 (8.62e-01)	3.4851e+00 (2.02e+00)	2.5362e+00 (1.25e+00)
C23	Obj	1.2415e+00 (1.07e-01)	1.2549e+00 (8.21e-02)	1.2272e+00 (9.05e-02)	1.2833e+00 (8.23e-02)	1.2659e+00 (1.09e-01)
C24	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C25	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C26	CV	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)
C27	Obj	3.6499e+01 (2.14e-03)	3.6833e+01 (1.50e+00)	3.6500e+01 (1.68e-03)	3.6498e+01 (2.83e-03)	3.6497e+01 (4.91e-03)
C28	CV	7.2284e+04 (1.71e+01)	7.2309e+04 (2.32e+01)	7.2322e+04 (2.99e+01)	7.2324e+04 (1.59e+01)	7.2318e+04 (2.10e+01)

TABLE S-X
AVERAGE OBJECTIVE VALUES (Obj) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE PROPOSED CCMT WITH DIFFERENT p_{min} SETTINGS ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		$p_{min} = 0$	$p_{min} = 0.1$	$p_{min} = 0.2$	$p_{min} = 0.3$	$p_{min} = 0.5$
C01	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C02	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C03	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	3.7770e+00 (1.69e+01)
C04	Obj	4.0320e+01 (2.52e+01)	4.3886e+01 (2.26e+01)	4.3613e+01 (2.42e+01)	3.9726e+01 (1.54e+01)	5.0765e+01 (2.22e+01)
C05	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	1.9933e-01 (8.91e-01)	1.9933e-01 (8.91e-01)
C06	Obj	1.7115e+02 (3.24e+02)	6.2464e+01 (9.14e+01)	2.4531e+02 (2.09e+02)	1.1795e+02 (2.31e+02)	2.5536e+02 (3.00e+02)
C07	Obj	-2.0699e+03 (4.79e+02)	-2.0979e+03 (4.02e+02)	-2.1315e+03 (2.83e+02)	-1.9545e+03 (5.25e+02)	-1.8554e+03 (7.50e+02)
C08	Obj	8.5000e-05 (2.94e-04)	-3.0000e-03 (8.65e-05)	-8.0000e-05 (5.23e-05)	-4.5000e-03 (1.32e-04)	-8.5000e-05 (3.66e-05)
C09	Obj	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)
C10	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C11	CV	5.7501e+00 (7.22e+00)	4.4576e+00 (6.95e+00)	2.2280e+00 (5.02e+00)	1.4265e+00 (2.45e+00)	3.9658e+00 (5.71e+00)
C12	Obj	9.2425e+00 (4.46e+00)	7.8468e+00 (3.58e+00)	9.2640e+00 (5.00e+00)	8.7507e+00 (5.21e+00)	9.4773e+00 (5.10e+00)
C13	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C14	Obj	1.1153e+00 (2.81e-02)	1.1147e+00 (2.90e-02)	1.1160e+00 (1.88e-02)	1.1104e+00 (1.02e-02)	1.1141e+00 (2.26e-02)
C15	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C16	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C17	CV	5.0700e+01 (7.33e-01)	5.0400e+01 (9.40e-01)	5.0100e+01 (1.02e+00)	5.0400e+01 (9.40e-01)	5.0300e+01 (9.79e-01)
C18	Obj	3.6496e+01 (2.63e-03)	3.6491e+01 (3.44e-03)	3.6491e+01 (2.56e-03)	3.6486e+01 (3.74e-03)	3.6483e+01 (3.54e-03)
C19	CV	7.2232e+04 (2.56e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)
C20	Obj	4.8600e+00 (9.09e-01)	4.9062e+00 (1.05e+00)	5.1478e+00 (1.12e+00)	4.3579e+00 (1.19e+00)	4.4094e+00 (1.15e+00)
C21	Obj	4.0442e+01 (1.63e+01)	4.1931e+01 (1.93e+01)	3.8230e+01 (1.62e+01)	4.5229e+01 (1.69e+01)	5.4439e+01 (1.21e+01)
C22	Obj	1.6542e+00 (9.09e-01)	1.5504e+00 (9.02e-01)	1.7719e+00 (9.77e-01)	2.1636e+00 (1.38e+00)	1.9169e+00 (7.84e-01)
C23	Obj	1.2384e+00 (1.00e-01)	1.2549e+00 (8.21e-02)	1.2464e+00 (8.44e-02)	1.2151e+00 (8.48e-02)	1.2133e+00 (5.23e-02)
C24	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C25	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C26	CV	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)
C27	Obj	3.6937e+01 (1.53e+00)	3.6833e+01 (1.50e+00)	3.6495e+01 (4.17e-03)	3.7116e+01 (2.79e+00)	3.6488e+01 (7.63e-03)
C28	CV	7.2300e+04 (1.86e+01)	7.2309e+04 (2.32e+01)	7.2312e+04 (2.83e+01)	7.2324e+04 (2.96e+01)	7.2318e+04 (2.73e+01)

TABLE S-XI
AVERAGE OBJECTIVE VALUES (Obj) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE PROPOSED CCMT WITH DIFFERENT RH SETTINGS ON THE 50-DIMENSIONAL CEC2017 BENCHMARK SUITE.

		$RH = 1$	$RH = 5$	$RH = 10$	$RH = 100$	$RH = 1000$
C01	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C02	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C03	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C04	Obj	3.0894e+01 (2.13e+01)	3.0488e+01 (1.70e+01)	4.3886e+01 (2.26e+01)	4.9861e+01 (2.21e+01)	3.7808e+01 (2.27e+01)
C05	Obj	1.9933e-01 (8.91e-01)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	1.9933e-01 (8.91e-01)	0.0000e+00 (0.00e+00)
C06	Obj	2.0677e+02 (2.69e+02)	4.8283e+02 (3.93e+02)	6.2464e+01 (9.14e+01)	7.0961e+02 (2.48e+02)	2.6158e+02 (3.00e+02)
C07	Obj	-2.1306e+03 (3.38e+02)	-1.9993e+03 (7.27e+02)	-2.0979e+03 (4.02e+02)	-1.8282e+03 (7.63e+02)	-1.2388e+03 (8.60e+02)
C08	Obj	4.8333e-04 (3.67e-04)	7.5000e-05 (1.65e-04)	-3.0000e-05 (8.65e-05)	-5.5000e-05 (8.26e-05)	-2.5000e-05 (1.59e-04)
C09	Obj	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)	-2.0000e-03 (8.90e-19)
C10	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C11	CV	4.6056e+01 (3.76e+01)	6.0103e+00 (6.51e+00)	4.4576e+00 (6.95e+00)	7.9600e-01 (1.18e+00)	4.9408e+00 (7.80e+00)
C12	Obj	8.9721e+00 (4.79e+00)	1.0738e+01 (5.91e+00)	7.8468e+00 (3.58e+00)	9.4773e+00 (5.10e+00)	9.3405e+00 (5.25e+00)
C13	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C14	Obj	1.1120e+00 (1.87e-02)	1.1188e+00 (3.38e-02)	1.1147e+00 (2.90e-02)	1.1094e+00 (1.03e-02)	1.1196e+00 (2.50e-02)
C15	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C16	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C17	CV	4.9900e+01 (1.02e+00)	5.0100e+01 (1.02e+00)	5.0400e+01 (9.40e-01)	5.0100e+01 (1.02e+00)	5.0700e+01 (7.33e-01)
C18	Obj	3.6496e+01 (4.15e-03)	3.6495e+01 (3.07e-03)	3.6491e+01 (3.44e-03)	3.6486e+01 (2.80e-03)	3.6479e+01 (4.54e-03)
C19	CV	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (2.99e-11)	7.2232e+04 (6.03e-03)
C20	Obj	4.9533e+00 (9.80e-01)	4.6367e+00 (1.17e+00)	4.9062e+00 (1.05e+00)	5.0273e+00 (1.33e+00)	5.2825e+00 (8.14e-01)
C21	Obj	4.0952e+01 (1.63e+01)	4.6520e+01 (1.72e+01)	4.1931e+01 (1.93e+01)	3.7508e+01 (1.93e+01)	4.1730e+01 (1.69e+01)
C22	Obj	1.6375e+00 (6.03e-01)	2.2927e+00 (1.97e+00)	1.5504e+00 (9.02e-01)	2.1075e+00 (6.95e-01)	1.9329e+00 (1.44e+00)
C23	Obj	1.3325e+00 (9.18e-02)	1.2510e+00 (8.55e-02)	1.2549e+00 (8.21e-02)	1.2513e+00 (8.03e-02)	1.1999e+00 (5.78e-02)
C24	Obj	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)	2.3561e+00 (4.56e-16)
C25	Obj	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)	0.0000e+00 (0.00e+00)
C26	CV	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)	5.1000e+01 (0.00e+00)
C27	Obj	3.6504e+01 (3.93e-03)	3.6500e+01 (2.49e-03)	3.6833e+01 (1.50e+00)	3.6495e+01 (2.78e-03)	3.6680e+01 (8.94e-01)
C28	CV	7.2304e+04 (3.57e+01)	7.2314e+04 (2.99e+01)	7.2309e+04 (2.32e+01)	7.2316e+04 (2.43e+01)	7.2297e+04 (2.55e+01)

TABLE S-XII
DETAILS OF THE 33 REAL-WORLD COPs.

	Name	D	g	h
Industrial chemical processes				
RC01	Heat exchanger network design (case 1)	9	0	8
RC02	Heat exchanger network design (case 2)	11	0	9
RC03	Optimal operation of Alkylation unit	7	14	0
RC04	Reactor network design (RND)	6	1	4
RC05	Haverly's pooling problem	9	2	4
RC06	Blending-pooling-separation problem	38	0	32
RC07	Propane, isobutane, n-Butane non-sharp separation	48	0	38
Process synthesis and design problems				
RC08	Process synthesis problem	2	2	0
RC09	Process synthesis and design problem	3	1	1
RC10	Process flow sheeting problem	3	3	0
RC11	Two-reactor problem	7	4	4
RC12	Process synthesis problem	7	9	0
RC13	Process design problem	5	3	0
RC14	Multi-product batch plant	10	10	0
Mechanical engineering problem				
RC15	Weight minimization of a speed reducer	7	11	0
RC16	Optimal design of industrial refrigeration system	14	15	0
RC17	Tension/compression spring design (case 1)	3	3	0
RC18	Pressure vessel design	4	4	0
RC19	Welded beam design	4	5	0
RC20	Three-bar truss design problem	2	3	0
RC21	Multiple disk clutch brake design problem	5	7	0
RC22	Planetary gear train design optimization problem	9	10	1
RC23	Step-cone pulley problem	5	8	3
RC24	Robot gripper problem	7	7	0
RC25	Hydro-static thrust bearing design problem	4	7	0
RC26	Four-stage gearbox problem	22	86	0
RC27	10-bar truss design	10	3	0
RC28	Rolling element bearing	10	9	0
RC29	Gas transmission compressor design (GTCD)	4	1	0
RC30	Tension/compression spring design (case 2)	3	8	0
RC31	Gear train design Problem	4	1	1
RC32	Himmelblau's function	5	6	0
RC33	Topology optimization	30	30	0

TABLE S-XIII

AVERAGE OBJECTIVE VALUES (Obj) OR AVERAGE CONSTRAINT VIOLATIONS (CV) AND STANDARD DEVIATIONS OBTAINED BY THE SELECTED ADVANCED COEAs AND THE PROPOSED CCMT ON THREE TYPES OF REAL-WORLD COPs.

	ECMT	VMCH	FROFI	C ^o DE	CORCO	DeCODE	CAL-SHADE	LSHADE#4	CCMT
RC01 Obj	NaN -	3.8663e+02 (1.03e+02) -	NaN -	NaN -	NaN -	4.3213e+02 (1.34e+02) -	2.3861e+02 (9.77e+01) +	4.1064e+02 (1.01e+02) -	2.7506e+02 (6.73e+01)
RC02 Obj	7.0490e+03 (0.00e+00) =	7.0490e+03 (0.00e+00) =	NaN -	7.0490e+03 (0.00e+00) =	7.0490e+03 (0.00e+00) =	NaN -	4.7059e+04 (6.53e+04) -	7.9190e+03 (1.67e+03) -	7.0490e+03 (0.00e+00)
RC03 Obj	-4.5291e+03 (1.86e-12) =	-4.5291e+03 (1.86e-12) =	NaN -	-4.3174e+03 (1.09e+02) -	NaN -	-4.5291e+03 (1.86e-12) =	3.7252e+02 (8.68e+02) -	-4.1715e+03 (2.56e+02) -	-4.5291e+03 (1.86e-12)
RC04 Obj	-2.8829e-01 (9.66e-02) =	-3.0352e-02 (1.05e-01) -	0.0000e+00 (0.00e+00) -	-1.7060e-01 (1.88e-01) -	NaN -	0.0000e+00 (0.00e+00) -	-2.6939e-01 (8.29e-02) -	-1.8080e-03 (4.52e-03) -	-3.1112e-01 (1.18e-01)
RC05 Obj	7.9973e+00 (2.77e+01) =	3.2000e+01 (4.76e+01) -	6.6667e+01 (5.77e+01) -	-4.8680e-03 (1.67e-03) =	NaN -	-2.7634e+02 (1.70e+02) +	8.6850e+01 (2.01e+02) -	1.5991e+01 (3.74e+01) =	-2.2001e+01 (1.49e+02)
RC06 CV	7.8136e+00 (4.42e+00) -	2.3729e+00 (8.45e-01) =	7.5551e+01 (6.27e+00) +	4.0410e+00 (3.79e+00) +	7.7223e+01 (5.50e-01) -	2.0046e+01 (1.80e+01) -	1.0162e+01 (4.48e+00) -	2.2276e+00 (7.05e-01) =	7.6541e+00 (1.56e+01)
RC07 CV	4.2019e+01 (2.31e+01) -	2.3361e+00 (6.04e-01) =	4.5376e+01 (1.87e+01) -	2.1683e+01 (1.87e+01) -	8.2825e+01 (3.49e+01) -	3.3137e+01 (3.34e+01) -	1.5201e+01 (4.28e+00) -	2.7999e+00 (3.17e+00) =	9.6381e+00 (1.47e+01)
RC08 Obj	2.0000e+00 (0.00e+00) =	2.0000e+00 (0.00e+00) =	2.0000e+00 (6.63e-04) -	2.0000e+00 (0.00e+00) =	2.0226e+00 (3.26e-02) -	2.0000e+00 (0.00e+00) =	2.0000e+00 (0.00e+00) =	2.0000e+00 (0.00e+00) =	2.0000e+00 (0.00e+00)
RC09 Obj	2.5577e+00 (1.36e-15) =	2.5577e+00 (1.36e-15) =	2.7990e+00 (1.32e-01) -	2.5579e+00 (1.17e-04) -	NaN -	2.5577e+00 (1.36e-15) =	2.5864e+00 (4.82e-02) -	2.5976e+00 (3.67e-02) -	2.5577e+00 (1.36e-15)
RC10 Obj	1.0765e+00 (4.53e-16) =	1.1009e+00 (5.90e-02) -	1.1036e+00 (1.44e-02) -	1.0768e+00 (2.75e-04) -	1.0765e+00 (4.53e-16) =	1.0765e+00 (4.53e-16) =	1.1765e+00 (6.01e-02) -	1.1185e+00 (6.33e-02) -	1.0765e+00 (4.53e-16)
RC11 Obj	1.1373e+02 (6.59e+00) -	1.0448e+02 (4.09e+00) =	NaN -	NaN -	NaN -	1.1052e+02 (4.34e+00) -	NaN -	1.1257e+02 (7.70e+00) -	1.0525e+02 (4.39e+00)
RC12 Obj	2.9248e+00 (4.53e-16) =	3.0414e+00 (3.22e-01) =	2.9791e+00 (3.44e-02) -	2.9248e+00 (2.77e-05) =	3.5289e+00 (7.46e-01) -	6.7634e+00 (1.92e+00) -	4.1742e+00 (5.07e-01) -	3.8020e+00 (4.64e-01) -	2.9248e+00 (4.53e-16)
RC13 Obj	2.6887e+04 (0.00e+00) =	2.6887e+04 (0.00e+00) =	2.6892e+04 (3.91e+00) -	2.6888e+04 (2.12e+00) -	2.8532e+04 (9.48e+02) -	2.6887e+04 (0.00e+00) =	2.6918e+04 (3.18e+01) -	2.6915e+04 (4.41e+01) -	2.6887e+04 (0.00e+00)
RC14 Obj	5.3639e+04 (0.00e+00) =	5.4498e+04 (2.01e+03) -	6.5640e+04 (4.72e+03) -	5.6884e+04 (1.19e+03) -	1.4935e+05 (2.88e+04) -	6.0126e+04 (4.56e+03) -	7.6855e+04 (5.79e+03) -	7.6347e+04 (1.36e+04) -	5.3639e+04 (0.00e+00)
RC15 Obj	2.9944e+03 (0.00e+00) =	2.9944e+03 (0.00e+00) =	3.0128e+03 (5.28e+00) -	2.9954e+03 (9.48e-01) -	3.5651e+03 (4.68e+02) -	2.9944e+03 (0.00e+00) =	3.0437e+03 (1.90e+01) -	3.0409e+03 (2.57e+01) -	2.9944e+03 (0.00e+00)
RC16 Obj	5.3260e-02 (4.91e-02) +	3.2200e-02 (0.00e+00) +	5.9724e-02 (6.22e-03) +	3.7113e-02 (2.15e-02) -	9.8503e+02 (1.65e+03) -	5.7067e-01 (2.69e+00) =	1.1552e+02 (1.62e+02) -	1.9498e+02 (5.94e+02) -	1.1650e-01 (3.77e-01)
RC17 Obj	1.2700e-02 (5.31e-18) =	1.2700e-02 (5.31e-18) =	1.2960e-02 (1.89e-04) -	1.2728e-02 (4.58e-05) -	3.2750e-02 (2.75e-02) -	1.2700e-02 (5.31e-18) =	1.3480e-02 (6.01e-04) -	1.2828e-02 (1.77e-04) -	1.2700e-02 (5.31e-18)
RC18 Obj	6.0597e+03 (0.00e+00) =	6.0634e+03 (1.02e+01) =	6.3011e+03 (1.66e+02) -	6.0597e+03 (0.00e+00) =	1.5659e+04 (3.91e+03) -	6.0597e+03 (0.00e+00) =	6.0882e+03 (6.09e+01) -	6.1771e+03 (1.86e+02) -	6.0597e+03 (0.00e+00)
RC19 Obj	1.6702e+00 (6.80e-16) =	1.7543e+00 (2.21e-02) -	1.7543e+00 (2.21e-02) -	1.6702e+00 (2.77e-05) =	3.4740e+00 (6.48e-01) -	1.6702e+00 (6.80e-16) =	1.6702e+00 (6.80e-16) =	1.6702e+00 (6.80e-16) =	1.6702e+00 (6.80e-16)
RC20 Obj	2.6390e+02 (1.16e-13) =	2.6390e+02 (1.16e-13) =	2.6407e+02 (1.49e-01) -	2.6390e+02 (1.16e-13) =	2.6863e+02 (4.21e+00) -	2.6390e+02 (1.16e-13) =	2.6391e+02 (3.34e-02) -	2.6390e+02 (1.16e-13) =	2.6390e+02 (1.16e-13)
RC21 Obj	2.3520e-01 (5.67e-17) =	2.3520e-01 (5.67e-17) =	2.3520e-01 (1.80e-04) -	2.3520e-01 (5.67e-17) =	2.4827e-01 (8.95e-03) -	2.3520e-01 (5.67e-17) =	2.3520e-01 (5.67e-17) =	2.3520e-01 (5.67e-17) =	2.3520e-01 (5.67e-17)
RC22 Obj	5.2648e-01 (1.21e-03) =	5.2833e-01 (3.73e-03) -	5.2602e-01 (3.23e-04) =	5.2802e-01 (3.00e-03) -	5.2790e-01 (3.98e-03) -	5.2630e-01 (5.77e-04) =	5.3519e-01 (6.27e-03) -	5.4740e-01 (1.88e-02) -	5.2648e-01 (1.10e-03)
RC23 Obj	1.6070e+01 (5.63e-15) =	1.6070e+01 (2.63e-15) =	NaN -	1.6084e+01 (4.50e-03) -	1.6070e+01 (3.70e-15) =	1.6070e+01 (2.63e-15) =	1.6423e+01 (3.84e-01) -	1.6412e+01 (2.86e-01) -	1.6070e+01 (3.63e-15)
RC24 Obj	2.5447e+00 (6.87e-04) =	2.5438e+00 (9.06e-16) =	2.5486e+00 (2.04e-03) -	2.6423e+00 (1.26e-01) -	3.2954e+01 (1.16e+02) -	2.5438e+00 (9.06e-16) =	3.4616e+00 (4.79e-01) -	4.9222e+00 (6.20e-01) -	2.5438e+00 (9.06e-16)
RC25 Obj	1.6163e+03 (4.50e-01) -	1.6161e+03 (4.64e-01) -	4.8244e+03 (1.52e+03) -	2.4411e+03 (1.96e+02) -	4.3375e+03 (1.53e+03) -	1.9855e+03 (6.13e+02) -	2.8212e+03 (5.14e+02) -	4.0013e+03 (6.59e+02) -	1.6161e+03 (4.64e-01)
RC26 Obj	NaN -	4.9540e+01 (1.66e+01) -	NaN -	6.5327e+01 (4.45e-02) -	4.5324e+01 (1.44e+01) -	3.8712e+01 (1.97e+00) -	4.3750e+01 (5.66e+00) -	5.1671e+01 (7.99e+00) -	3.6893e+01 (6.82e-01)
RC27 Obj	5.2478e+02 (7.51e-02) -	5.2445e+02 (2.32e-13) =	5.4606e+02 (4.42e+00) -	5.2749e+02 (1.42e+00) -	7.1846e+02 (5.38e+01) -	5.2445e+02 (2.32e-13) =	5.5424e+02 (1.08e+01) -	5.2615e+02 (2.54e+02) -	5.2445e+02 (2.32e-13)
RC28 Obj	1.6958e+04 (0.00e+00) =	1.6958e+04 (0.00e+00) =	1.7100e+04 (5.38e+01) -	1.6970e+04 (6.14e+00) -	2.6236e+04 (6.70e+03) -	1.6958e+04 (0.00e+00) =	1.7374e+04 (3.65e+02) -	1.7192e+04 (2.08e+02) -	1.6958e+04 (0.00e+00)
RC29 Obj	2.9649e+06 (0.00e+00) =	2.9649e+06 (0.00e+00) =	3.1097e+06 (6.53e+04) -	2.9649e+06 (0.00e+00) =	3.8812e+06 (4.54e+05) -	2.9649e+06 (0.00e+00) =	2.9649e+06 (0.00e+00) =	2.9649e+06 (0.00e+00) =	2.9649e+06 (0.00e+00)
RC30 Obj	2.6586e+00 (4.53e-16) =	2.6602e+00 (8.18e-03) =	3.1734e+00 (2.46e-01) -	2.6617e+00 (3.22e-03) -	7.7079e+00 (5.83e+00) -	2.6586e+00 (4.53e-16) =	2.9478e+00 (2.73e-01) -	2.6766e+00 (2.03e-02) -	2.6586e+00 (4.53e-16)
RC31 Obj	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00) =	0.0000e+00 (0.00e+00)
RC32 Obj	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0628e+04 (1.49e+01) -	-3.0666e+04 (0.00e+00) =	-2.9916e+04 (2.74e+02) -	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00) =	-3.0666e+04 (0.00e+00)
RC33 Obj	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16) =	2.6393e+00 (4.53e-16)
+/-/=	1/8/24	1/7/25	1/29/3	1/17/15	0/28/5	1/10/22	1/25/7	0/22/11	Base