Metaheuristics for the Online Printing Shop Scheduling Problem — Supplementary Material

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This document presents further numerical results of the experiments with the proposed method TS+DE and the classical instances of the flexible job shop scheduling problem, performed in (Lunardi et al., Metaheuristics for the Online Printing Shop Scheduling Problem, *submitted*). Additionally, this document gathers the lower bounds used in the experiments, and the best and mean makespan values found by state-of-the-art algorithms.

Lower bounds for instances in sets BR, BC, DP, and HK were taken from (Mastrolilli and Gambardella, 2000). Lower bounds for instances in sets YFJS and DAFJS were computed with the constraint programming models proposed in (Lunardi et al., 2020a; Lunardi, 2020b) and the IBM ILOG CP Optimizer (CPO) version 12.9 with a CPU time limit of 2 hours. TS+DE was compared against ten different methods from the literature that reported results in at least one of the considered sets, namely: scatter search with path relinking (SSPR) proposed in (González et al., 2015); improved greedy randomized adaptive search procedure (GRASP) proposed in (Kemmoé-Tchomté et al., 2017); priority-based genetic algorithm (PBGA) introduced in (Cinar et al., 2016); hybrid genetic algorithm and tabu search (HA) proposed in (Li and Gao, 2016); hybrid differential evolution with local search (HDE) introduced in (Yuan and Xu, 2013); hybrid genetic algorithm and tabu search (HGTS) proposed in (Palacios et al., 2015); hybrid genetic algorithm and variable neighborhood descent algorithm (HGVN) proposed in (Gao et al., 2008); beam search algorithm (BS) introduced in (Birgin et al., 2015); knowledge-based cuckoo search algorithm (KCSA) proposed in Cao et al. (2019); and methods genetic algorithm (GA), grey wolf optimizer (GWO), imperialist competitive algorithm (ICA), and hybrid imperialist competitive algorithm and tabu search (ICA+TS) introduced in (Lunardi et al., 2019). The makespan values obtained with the proposed method TS+DE are shown in the tables where $\underline{\text{TSDE}}$ is the best makespan and $\overline{\text{TSDE}}$ is the mean makespan.

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Table 1: The lower bound considered for each instance proposed in (Brandimarte, 1993). The best makespan and the mean makespan obtained with the TSDE over the Brandimarte (1993) instances are presented.

Instance	LB	GRASP	HA	HDE	HGTS	HGVN	PBGA	SSPR	$\underline{\text{TSDE}}$	$\overline{\text{TSDE}}$
Mk01	36	40	40	40	40	40	40	40	40	40
Mk02	24	26	26	26	26	26	27	26	26	26
Mk03	204	204	204	204	204	204	204	204	204	204
Mk04	48	60	60	60	60	60	60	60	60	60
Mk05	168	172	172	172	172	172	173	172	172	172.12
Mk06	33	58	57	57	57	58	63	57	57	57.75
Mk07	133	139	139	139	139	139	142	139	139	139
Mk08	523	523	523	523	523	523	523	523	523	523
Mk09	299	307	307	307	307	307	307	307	307	307
Mk010	165	197	197	198	198	197	211	196	197	198.38

Table 2: The lower bound considered for each instance proposed in (Barnes and Chambers, 1996). The best makespan and the mean makespan obtained with the TSDE over the Barnes and Chambers (1996) instances are presented.

Instance	LB	GRASP	HA	HDE	HGTS	HGVN	PBGA	SSPR	$\underline{\text{TSDE}}$	$\overline{\text{TSDE}}$
mt10c1	655	927	927	927	927	927	927	927	927	927
mt10cc	655	908	908	908	908	910	910	908	908	908
mt10x	655	918	918	918	918	918	918	918	918	918
mt10xx	655	918	918	918	918	918	918	918	918	918
mt10xxx	655	918	918	918	918	918	918	918	918	918
mt10xy	655	905	905	905	905	905	905	905	905	905
mt10xyz	655	847	847	847	847	849	849	847	847	847
setb4c9	857	914	914	914	914	914	914	914	914	914
setb4cc	857	907	907	907	907	914	909	907	907	907
setb4x	846	925	925	925	925	925	925	925	925	925
setb4xx	846	925	925	925	925	925	925	925	925	925
setb4xxx	846	925	925	925	925	925	925	925	925	925
setb4xy	845	910	910	910	910	916	912	910	910	910
setb4xyz	838	902	905	903	905	905	905	905	902	902
seti5c12	1027	1169	1170	1171	1170	1175	1172	1170	1169	1169
seti5cc	955	1135	1136	1136	1136	1138	1136	1135	1135	1135
seti5x	955	1198	1198	1200	1199	1204	1204	1198	1198	1198
seti5xx	955	1194	1197	1197	1197	1202	1199	1197	1194	1194
seti5xxx	955	1194	1197	1197	1197	1204	1199	1194	1194	1194
seti5xy	955	1135	1136	1136	1136	1136	1136	1135	1135	1135
seti5xyz	955	1125	1125	1125	1125	1126	1128	1125	1125	1125

Table 3: The lower bound considered for each instance proposed in (Dauzère-Pérès and Paulli, 1997). The best makespan and the mean makespan obtained with the TSDE over the Dauzère-Pérès and Paulli (1997) instances are presented.

Instance	LB	GRASP	HA	HGTS	HGVN	SSPR	$\underline{\text{TSDE}}$	$\overline{\text{TSDE}}$
01a	2505	2505	2505	2505	2518	2505	2505	2505
02a	2228	2229	2230	2230	2231	2229	2228	2232.44
03a	2228	2228	2229	2228	2229	2228	2228	2229.25
04a	2503	2503	2503	2503	2515	2503	2506	2519.5
05a	2189	2212	2212	2214	2217	2211	2212	2218.78
06a	2162	2195	2197	2193	2196	2183	2187	2193.12
07a	2187	2276	2279	2270	2307	2274	2276	2301
08a	2061	2069	2067	2070	2073	2064	2071	2074
09a	2061	2069	2065	2067	2066	2062	2063	2064.75
10a	2178	2263	2287	2247	2315	2269	2287	2306.67
11a	2017	2065	2060	2064	2071	2051	2061	2065
12a	1969	2039	2027	2027	2030	2018	2008	2012.5
13a	2161	2252	2248	2250	2257	2248	2245	2254
14a	2161	2170	2167	2170	2167	2163	2166	2167.62
15a	2161	2172	2163	2168	2165	2162	2163	2163.62
16a	2148	2243	2249	2246	2256	2244	2240	2257.44
17a	2088	2145	2140	2142	2140	2130	2132	2134.12
18a	2057	2146	2132	2129	2127	2119	2097	2101.75

Table 4: The lower bound considered for each EData instance proposed in (Hurink et al., 1994). The best makespan and the mean makespan obtained with the TSDE over the Hurink et al. (1994) EData instances are presented.

Instance	LB	GRASP	HA	SSPR	$\underline{\text{TSDE}}$	$\overline{\text{TSDE}}$
mt06	55	55	55	55	55	55
mt10	871	871	871	871	871	871
mt20	1088	1088	1088	1088	1088	1088
la1	609	609	609	609	609	609
la2	655	655	655	655	655	655
la3	550	550	550	550	550	550
la4	568	568	568	568	568	568
la5	503	503	503	503	503	503
la6	833	833	833	833	833	833
la7	762	762	762	762	762	762
la8	845	845	845	845	845	845
la9	878	878	878	878	878	878
la10	866	866	866	866	866	866
la11	1087	1103	1103	1103	1103	1103
la12	960	960	960	960	960	960
la13	1053	1053	1053	1053	1053	1053
la14	1123	1123	1123	1123	1123	1123
la15	1111	1111	1111	1111	1111	1111
la16	892	892	892	892	892	892
la17	707	707	707	707	707	707
la18	842	842	842	842	842	842
la19	796	796	796	796	796	796
la20	857	857	857	857	857	857
la21	895	1009	1014	1010	1009	1009
la22	832	880	880	880	880	880
la23	950	950	950	950	950	950
la24	881	908	909	908	908	908
la25	894	936	941	939	936	936
la26	1089	1107	1123	1109	1106	1111.25
la27	1181	1181	1184	1181	1181	1181
la28	1116	1144	1147	1144	1142	1142
la29	1058	1113	1115	1111	1107	1107
la30	1147	1198	1204	1204	1194	1197
la31	1523	1536	1541	1533	1532	1538.75
la32	1698	1698	1698	1698	1698	1698
la33	1547	1547	1547	1547	1547	1547
la34	1592	1599	1599	1599	1599	1599
la35	1736	1736	1736	1736	1736	1736
la36	1006	1160	1160	1160	1160	1160
la37	1355	1397	1397	1397	1397	1397
la38	1019	1141	1143	1141	1141	1141
la39	1151	1184	1184	1184	1184	1184
la40	1034	1144	1146	1144	1144	1144

Table 5: The lower bound considered for each RData instance proposed in (Hurink et al., 1994). The best makespan and the mean makespan obtained with the TSDE over the Hurink et al. (1994) RData instances are presented.

Instance	LB	GRASP	HA	SSPR	$\underline{\text{TSDE}}$	$\overline{\text{TSDE}}$
mt06	47	47	47	47	47	47
mt10	679	686	686	686	686	686
mt20	1022	1022	1022	1022	1022	1022
la1	570	570	570	571	570	570.75
la2	529	529	530	530	529	529
la3	477	477	477	477	477	477
la4	502	502	502	502	502	502
la5	457	457	457	457	457	457
la6	799	799	799	799	799	799
la7	749	749	749	749	749	749
la8	765	765	765	765	765	765
la9	853	853	853	853	853	853
la10	804	804	804	804	804	804
la11	1071	1071	1071	1071	1071	1071
la12	936	936	936	936	936	936
la13	1038	1038	1038	1038	1038	1038
la14	1070	1070	1070	1070	1070	1070
la15	1089	1089	1090	1089	1089	1089
la16	717	717	717	717	717	717
la17	646	646	646	646	646	646
la18	666	666	666	666	666	666
la19	647	700	700	700	700	700
la20	756	756	756	756	756	756
la21	808	832	835	830	833	836.75
la22	737	757	760	756	760	764.38
la23	816	836	840	835	839	842
la24	775	802	806	802	801	805
la25	752	784	789	784	785	789.75
la26	1056	1060	1061	1059	1060	1061.75
la27	1085	1089	1089	1089	1090	1090.88
la28	1075	1077	1079	1078	1078	1078.75
la29	993	996	997	996	996	996.62
la30	1068	1074	1078	1074	1078	1079.12
la31	1520	1521	1521	1520	1520	1520
la32	1657	1658	1659	1658	1658	1658
la33	1497	1498	1499	1498	1498	1498
la34	1535	1535	1536	1535	1535	1535.25
la35	1549	1550	1550	1550	1549	1549.75
la36	1016	1023	1028	1023	1028	1028.5
la37	989	1066	1074	1069	1067	1073.88
la38	943	958	960	961	960	963
la39	966	1018	1024	1024	1024	1024.12
la40	955	958	970	961	966	971.5

Table 6: The lower bound considered for each VData instance proposed in (Hurink et al., 1994). The best makespan and the mean makespan obtained with the TSDE over the Hurink et al. (1994) VData instances are presented.

Instance	LB	GRASP	HA	SSPR	$\underline{\text{TSDE}}$	$\overline{\text{TSDE}}$
mt06	47	47	47	47	47	47
mt10	655	655	655	655	655	655
mt20	1022	1022	1022	1022	1022	1022
la1	570	570	570	570	570	570
la2	529	529	529	529	529	529
la3	477	477	477	477	477	477
la4	502	502	502	502	502	502
la5	457	457	457	457	457	457
la6	799	799	799	799	799	799
la7	749	749	749	749	749	749
la8	765	765	765	765	765	765
la9	853	853	853	853	853	853
la10	804	804	804	804	804	804
la11	1071	1071	1071	1071	1071	1071
la12	936	936	936	936	936	936
la13	1038	1038	1038	1038	1038	1038
la14	1070	1070	1070	1070	1070	1070
la15	1089	1089	1089	1089	1089	1089
la16	717	717	717	717	717	717
la17	646	646	646	646	646	646
la18	663	663	663	663	663	663
la19	617	617	617	617	617	617
la20	756	756	756	756	756	756
la21	800	804	804	802	802	803.12
la22	733	737	738	734	734	734.75
la23	809	813	813	811	810	811
la24	773	776	777	775	774	775.12
la25	751	755	754	753	752	753.62
la26	1052	1054	1053	1053	1052	1052.5
la27	1084	1086	1085	1084	1084	1084
la28	1069	1070	1070	1069	1069	1069
la29	993	995	994	994	994	994
la30	1068	1070	1069	1069	1069	1069
la31	1520	1521	1520	1520	1520	1520
la32	1657	1658	1658	1658	1657	1657.75
la33	1497	1498	1497	1497	1497	1497.5
la34	1535	1535	1535	1535	1535	1535
la35	1549	1549	1549	1549	1549	1549
la36	948	948	948	948	948	948
la37	986	986	986	986	986	986
la38	943	943	943	943	943	943
la39	922	922	922	922	922	922
la40	955	955	955	955	955	955

Table 7: The lower bound considered for each YFJS instance proposed in (Birgin et al., 2014). The best makespan and the mean makespan obtained with the TSDE over the Birgin et al. (2014) YFJS instances are presented.

Instance	CPO		BS	GA	GWO	KCSA	ICA	ICA+TS	$\underline{\text{TSDE}}$	$\overline{\text{TSDE}}$
	LB	UB								
YFJS01	773	773	825	773	773	792	773	773	773	773
YFJS02	825	825	876	848	843	832	843	825	825	825
YFJS03	347	347	372	356	348	362	347	347	347	347
YFJS04	390	390	458	390	390	401	390	390	390	390
YFJS05	445	445	486	452	452	495	452	445	445	445
YFJS06	446	446	493	450	450	497	447	446	446	446
YFJS07	444	444	487	480	455	792	455	444	444	444
YFJS08	353	353	372	353	353	387	353	353	353	353
YFJS09	242	242	283	242	242	295	242	242	242	242
YFJS10	399	399	418	399	399	415	399	399	399	399
YFJS11	526	526	590	529	529	612	529	526	526	526
YFJS12	512	512	561	540	517	606	517	512	512	512
YFJS13	405	405	455	409	409	488	405	405	405	405
YFJS14	1317	1317	1380	1317	1317	1397	1317	1317	1317	1317
YFJS15	1239	1239	1310	1269	1270	1308	1270	1239	1239	1239
YFJS16	1222	1222	1387	1301	1301	1324	1254	1222	1222	1222
YFJS17	1133	1133	1304	1204	1204	1295	1167	1133	1133	1133
YFJS18	1220	1220	1364	1283	1283	1503	1221	1220	1220	1220
YFJS19	926	926	1256	1080	1153	1350	1080	941	926	926
YFJS20	968	968	1271	1204	1204	1290	1079	973	968	968

Table 8: The lower bound considered for each DAFJS instance proposed in (Birgin et al., 2014). The best makespan and the mean makespan obtained with the TSDE over the Birgin et al. (2014) DAFJS instances are presented.

Instance	CPO		BS	GA	GWO	KCSA	ICA	ICA+TS	$\underline{\text{TSDE}}$	$\overline{\text{TSDE}}$
	LB	UB								
DAFJS01	257	257	277	257	257	264	257	257	257	257
DAFJS02	289	289	306	289	289	291	289	289	289	289
DAFJS03	576	576	576	576	576	592	576	576	576	576
DAFJS04	606	606	606	606	606	606	606	606	606	606
DAFJS05	384	384	425	421	421	395	424	389	384	384
DAFJS06	404	404	434	414	414	449	423	412	404	404.08
DAFJS07	505	505	542	583	583	566	610	512	505	505
DAFJS08	628	628	632	655	655	631	642	628	628	628
DAFJS09	324	461	482	474	483	490	466	464	460	460.04
DAFJS10	337	522	549	537	537	555	533	533	517	517
DAFJS11	658	658	675	732	732	701	750	659	658	658
DAFJS12	530	600	643	731	731	720	698	645	591	591.21
DAFJS13	306	636	670	655	655	707	653	653	633	633.54
DAFJS14	367	708	755	737	737	818	735	726	708	708
DAFJS15	512	640	705	736	747	818	747	671	631	632.25
DAFJS16	641	644	700	778	780	798	768	679	643	643
DAFJS17	309	777	824	806	812	904	800	787	772	772.29
DAFJS18	328	778	817	790	799	892	790	789	768	768.04
DAFJS19	512	512	545	540	546	585	540	524	512	512
DAFJS20	434	666	711	700	700	810	696	696	662	663.96
DAFJS21	504	771	839	810	810	959	803	803	757	759.04
DAFJS22	464	672	735	722	722	851	697	697	661	663.54
DAFJS23	450	467	490	515	515	537	519	476	460	460.58
DAFJS24	476	543	595	634	635	648	635	564	537	537
DAFJS25	584	699	774	810	810	879	783	752	696	696
DAFJS26	565	697	783	790	806	898	765	745	684	684.96
DAFJS27	503	784	856	876	876	981	842	831	773	773
DAFJS28	535	535	565	620	623	584	594	543	535	535
DAFJS29	609	630	663	744	748	710	725	654	615	618.46
DAFJS30	467	531	572	604	609	637	595	555	523	523.38

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