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Multi-type facility location in printing and parcel delivery services

An appendix detailing instances and computational results

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1. The case of MPS

#	$\|I\|$ Clients	$\|J\|$ Locations	$\|L\|$ Facility Types	$\|K_l\|$ Copies	$\|M\|$ Bands	Variables	Constraints
1	91	91	33	10	12	$7.6 \cdot 10^5$	$2.8 \cdot 10^6$
2	206	206	12	20	12	$1.3 \cdot 10^6$	$1.0 \cdot 10^7$
3	191	191	18	20	12	$1.8 \cdot 10^6$	$1.3 \cdot 10^7$

Table 1: MPS Instances

#	Heuristics				Metaheuristics								LB		CPLEX						
					GrVND				ExVND						5%Err		2%Err		OPT		
	SS		FR		SS		FR		SS		FR									CPU	
	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	w UB	w/o UB
1	358933	53	450122	235	309312	69	366800	257	263893	554	266800	693	224194	2	260334	900	256781	1851	256781	3224	4212
2	1459228	458	1518561	812	1209855	500	1352511	888	915110	790	920056	1163	835703	5	888901	4433	880432	10523	879614	20966	37030
3	587710	212	623670	1031	510345	266	600356	1122	423111	621	421897	1463	372382	5	418001	1877	410089	8866	408221	18978	32166

Table 2: MPS: Cost and CPU time (in seconds) for (meta-)heuristics, LB and CPLEX

#	Ig	%Err		%Gap	
		GrVND	ExVND	GrVND	ExVND
1	1.14	20.46	2.77	37.97	17.71
2	1.05	37.54	4.04	44.77	9.50
3	1.09	25.02	3.35	37.05	13.30

Table 3: MPS: Performance guarantees of metaheuristics and LB

2. The case of parcel delivery through micro-hubs

#	$\lvert I\rvert$ Clients	$\lvert J\rvert$ Locations	$\lvert L\rvert$ Facility Types	$\lvert K_l\rvert$ Copies	$\lvert M\rvert$ Bands	Variables	Constraints
1	104	8	34	3	5	$4.8{\cdot}10^4$	$3.3{\cdot}10^4$
2	114	8	34	3	5	$5.2{\cdot}10^4$	$3.6{\cdot}10^4$
3	117	8	34	3	5	$5.3{\cdot}10^4$	$3.7{\cdot}10^4$
4	128	8	34	3	5	$5.8{\cdot}10^4$	$4.0{\cdot}10^4$
5	131	8	34	3	5	$6.0{\cdot}10^4$	$4.1{\cdot}10^4$
6	132	8	34	3	5	$6.0{\cdot}10^4$	$4.1{\cdot}10^4$
7	132	8	34	3	5	$6.0{\cdot}10^4$	$4.1{\cdot}10^4$
8	133	8	34	3	5	$6.0{\cdot}10^4$	$4.2{\cdot}10^4$
9	133	8	34	3	5	$6.0{\cdot}10^4$	$4.2{\cdot}10^4$
10	134	8	34	3	5	$6.1{\cdot}10^4$	$4.2{\cdot}10^4$
11	137	8	34	3	5	$6.2{\cdot}10^4$	$4.3{\cdot}10^4$
12	138	8	34	3	5	$6.3{\cdot}10^4$	$4.3{\cdot}10^4$
13	138	8	34	3	5	$6.3{\cdot}10^4$	$4.3{\cdot}10^4$
14	139	8	34	3	5	$6.3{\cdot}10^4$	$4.3{\cdot}10^4$
15	139	8	34	3	5	$6.3{\cdot}10^4$	$4.3{\cdot}10^4$
16	140	8	34	3	5	$6.4{\cdot}10^4$	$4.4{\cdot}10^4$
17	141	8	34	3	5	$6.4{\cdot}10^4$	$4.4{\cdot}10^4$
18	141	8	34	3	5	$6.4{\cdot}10^4$	$4.4{\cdot}10^4$
20	141	8	34	3	5	$6.4{\cdot}10^4$	$4.4{\cdot}10^4$
21	144	8	34	3	5	$6.5{\cdot}10^4$	$4.5{\cdot}10^4$
22	145	8	34	3	5	$6.6{\cdot}10^4$	$4.5{\cdot}10^4$
23	145	8	34	3	5	$6.6{\cdot}10^4$	$4.5{\cdot}10^4$
24	146	8	34	3	5	$6.6{\cdot}10^4$	$4.6{\cdot}10^4$
25	146	8	34	3	5	$6.6{\cdot}10^4$	$4.6{\cdot}10^4$
26	147	8	34	3	5	$6.7{\cdot}10^4$	$4.6{\cdot}10^4$
27	148	8	34	3	5	$6.7{\cdot}10^4$	$4.6{\cdot}10^4$
28	148	8	34	3	5	$6.7{\cdot}10^4$	$4.6{\cdot}10^4$
29	150	8	34	3	5	$6.8{\cdot}10^4$	$4.7{\cdot}10^4$
30	150	8	34	3	5	$6.8{\cdot}10^4$	$4.7{\cdot}10^4$
31	155	8	34	3	5	$7.0{\cdot}10^4$	$4.8{\cdot}10^4$
32	155	8	34	3	5	$7.0{\cdot}10^4$	$4.8{\cdot}10^4$
33	157	8	34	3	5	$7.1{\cdot}10^4$	$4.9{\cdot}10^4$
34	157	8	34	3	5	$7.1{\cdot}10^4$	$4.9{\cdot}10^4$
35	157	8	34	3	5	$7.1{\cdot}10^4$	$4.9{\cdot}10^4$
36	157	8	34	3	5	$7.1{\cdot}10^4$	$4.9{\cdot}10^4$
37	157	8	34	3	5	$7.1{\cdot}10^4$	$4.9{\cdot}10^4$
38	157	8	34	3	5	$7.1{\cdot}10^4$	$4.9{\cdot}10^4$
39	158	8	34	3	5	$7.1{\cdot}10^4$	$4.9{\cdot}10^4$
40	158	8	34	3	5	$7.1{\cdot}10^4$	$4.9{\cdot}10^4$
41	159	8	34	3	5	$7.2{\cdot}10^4$	$5.0{\cdot}10^4$
42	159	8	34	3	5	$7.2{\cdot}10^4$	$5.0{\cdot}10^4$
43	159	8	34	3	5	$7.2{\cdot}10^4$	$5.0{\cdot}10^4$
44	159	8	34	3	5	$7.2{\cdot}10^4$	$5.0{\cdot}10^4$
45	159	8	34	3	5	$7.2{\cdot}10^4$	$5.0{\cdot}10^4$
46	160	8	34	3	5	$7.2{\cdot}10^4$	$5.0{\cdot}10^4$
47	160	8	34	3	5	$7.2{\cdot}10^4$	$5.0{\cdot}10^4$
48	160	8	34	3	5	$7.2{\cdot}10^4$	$5.0{\cdot}10^4$
49	162	8	34	3	5	$7.3{\cdot}10^4$	$5.0{\cdot}10^4$
50	162	8	34	3	5	$7.3{\cdot}10^4$	$5.0{\cdot}10^4$
51	163	8	34	3	5	$7.4{\cdot}10^4$	$5.1{\cdot}10^4$
52	163	8	34	3	5	$7.4{\cdot}10^4$	$5.1{\cdot}10^4$
53	164	8	34	3	5	$7.4{\cdot}10^4$	$5.1{\cdot}10^4$
54	164	8	34	3	5	$7.4{\cdot}10^4$	$5.1{\cdot}10^4$
55	164	8	34	3	5	$7.4{\cdot}10^4$	$5.1{\cdot}10^4$
56	165	8	34	3	5	$7.5{\cdot}10^4$	$5.1{\cdot}10^4$
57	167	8	34	3	5	$7.5{\cdot}10^4$	$5.2{\cdot}10^4$
58	169	8	34	3	5	$7.6{\cdot}10^4$	$5.3{\cdot}10^4$
59	170	8	34	3	5	$7.7{\cdot}10^4$	$5.3{\cdot}10^4$
60	170	8	34	3	5	$7.7{\cdot}10^4$	$5.3{\cdot}10^4$
61	170	8	34	3	5	$7.7{\cdot}10^4$	$5.3{\cdot}10^4$
62	171	8	34	3	5	$7.7{\cdot}10^4$	$5.3{\cdot}10^4$
63	172	8	34	3	5	$7.8{\cdot}10^4$	$5.4{\cdot}10^4$
64	173	8	34	3	5	$7.8{\cdot}10^4$	$5.4{\cdot}10^4$
65	174	8	34	3	5	$7.9{\cdot}10^4$	$5.4{\cdot}10^4$
66	174	8	34	3	5	$7.9{\cdot}10^4$	$5.4{\cdot}10^4$
67	175	8	34	3	5	$7.9{\cdot}10^4$	$5.4{\cdot}10^4$
68	175	8	34	3	5	$7.9{\cdot}10^4$	$5.4{\cdot}10^4$
69	176	8	34	3	5	$7.9{\cdot}10^4$	$5.5{\cdot}10^4$
70	176	8	34	3	5	$7.9{\cdot}10^4$	$5.5{\cdot}10^4$
71	177	8	34	3	5	$8.0{\cdot}10^4$	$5.5{\cdot}10^4$
72	177	8	34	3	5	$8.0{\cdot}10^4$	$5.5{\cdot}10^4$
73	177	8	34	3	5	$8.0{\cdot}10^4$	$5.5{\cdot}10^4$
74	178	8	34	3	5	$8.0{\cdot}10^4$	$5.5{\cdot}10^4$
75	182	8	34	3	5	$8.2{\cdot}10^4$	$5.7{\cdot}10^4$
76	183	8	34	3	5	$8.3{\cdot}10^4$	$5.7{\cdot}10^4$
77	184	8	34	3	5	$8.3{\cdot}10^4$	$5.7{\cdot}10^4$
78	186	8	34	3	5	$8.4{\cdot}10^4$	$5.8{\cdot}10^4$
79	194	8	34	3	5	$8.7{\cdot}10^4$	$6.0{\cdot}10^4$

Table 4: Parcel delivery through micro-hubs Instances

#	Heuristics				Metaheuristics								LB		CPLEX								
	SS		FR		GrVND SS		GrVND FR		ExVND SS		ExVND FR				5%Err			2%Err			OPT		
	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU w UB	CPU w/o UB	Cost	CPU w UB	CPU w/o UB	Cost	CPU w UB	CPU w/o UB
1	533579	50	783741	1	525977	51	508173	2	406984	267	425603	211	290870	0	386910	69	77	381977	86	331	376590	105	934
2	634106	46	738490	1	577731	47	453501	2	345471	303	371385	250	255541	0	359233	59	150	348571	75	238	344001	82	262
3	367010	45	526825	2	367010	46	312579	3	250765	158	225182	121	139905	0	215801	55	78	218206	58	200	214792	72	9459
4	605832	37	780819	2	552351	38	469365	3	376020	325	396589	256	277518	0	375691	43	59	366988	59	196	365256	152	232
5	928347	55	939724	2	750979	56	570313	3	506670	460	530453	304	383224	0	485310	63	72	466750	66	87	464107	77	92
6	591935	86	594186	2	495444	87	371494	3	347843	327	334431	271	227338	0	320056	97	146	317236	103	376	315017	132	2412
7	852498	76	876235	2	785660	77	554940	3	442093	462	466828	439	340387	0	436782	105	132	428489	162	197	426379	213	243
8	938813	84	806304	2	781824	85	700701	3	538404	498	570482	425	435492	0	533480	88	160	510657	93	166	509605	112	188
9	919483	70	1190077	2	822548	70	700958	3	444325	403	460426	411	332458	0	440494	93	192	435242	132	360	429139	357	471
10	980647	61	1152958	2	980647	62	688706	3	558936	435	591120	416	444209	0	562528	87	91	550690	90	110	540851	93	137
11	1247938	125	1037200	2	1094774	126	650032	3	551913	526	586313	433	465699	0	534732	147	178	517568	147	380	515187	166	273
12	1048909	35	1183587	2	983823	36	699531	3	555634	597	592497	423	461571	0	549696	41	43	538118	41	157	532900	47	265
13	941057	67	884889	2	941057	68	581651	3	444891	484	471780	452	342943	0	436711	153	440	426801	1916	2135	425544	3396	22787
14	1270573	86	991802	2	1028427	86	604122	3	554868	517	586439	478	454915	0	549529	111	278	537455	151	557	534212	328	652
15	1126350	62	1036068	2	920730	62	676634	3	558878	592	578672	423	445478	0	531228	85	113	521396	112	169	514356	172	633
16	969439	90	927058	2	752905	91	564026	3	470935	502	500908	385	378049	0	481054	104	110	471799	107	117	462718	113	121
17	1102373	112	1046500	2	924351	113	687423	3	536456	484	567556	478	425109	0	521872	130	151	505563	136	163	503115	161	189
18	1117208	53	1332487	2	1117208	54	924130	3	587209	466	630043	447	480002	0	605473	57	145	583130	58	189	579246	68	219
19	977655	70	936111	2	886760	71	591309	3	456586	557	483536	493	359934	0	459160	76	217	456225	85	246	447752	95	1052
20	1225707	71	1087358	2	984855	72	745190	3	593489	583	627662	565	493879	0	611475	77	145	600516	89	262	589541	122	351
21	1062553	83	1157111	2	974096	84	741757	3	601469	642	634603	624	464019	0	602408	138	177	589914	217	748	584990	248	348
22	1065618	74	1117817	2	873328	75	730744	3	559526	527	592040	493	465442	0	553093	89	105	538624	91	133	536208	98	163
23	1080392	76	1283462	2	929527	77	814549	3	576847	584	611373	546	464697	0	581326	113	193	561654	121	264	556433	499	898
24	1075648	85	1016795	2	843529	86	708229	3	519248	565	552878	447	419435	0	511880	79	86	500305	98	105	491125	102	114
25	1137938	65	1057992	2	952137	66	681239	3	604293	625	630716	540	478468	0	612028	71	130	596400	100	216	590978	164	767
26	701402	69	870117	2	509284	70	564404	3	438100	548	458358	462	341833	0	444682	87	223	432774	107	288	424824	121	290
27	413862	61	704895	2	413024	62	432889	3	309387	440	346673	376	205573	0	308922	66	90	308896	79	259	304314	94	112
28	1481087	87	1335707	2	1481087	87	1068291	3	695977	1955	881642	1017	610508	0	719648	92	123	700803	98	187	692380	243	584
29	1202625	48	856536	2	949164	49	582317	3	504194	561	527325	475	386485	0	480922	55	68	469834	58	162	464125	69	654
30	976731	68	905657	3	838173	69	608725	4	526783	556	557047	506	429371	0	520531	88	118	503198	94	506	500431	278	314
31	1007252	89	981537	2	785726	89	566888	3	505957	570	533963	595	407822	0	486065	99	116	481468	106	166	472146	121	308
32	1019551	78	988006	2	743810	79	584791	3	508645	561	523934	553	388779	0	492569	91	108	483921	91	373	477053	105	214
33	996382	98	1085127	2	976701	99	850743	3	571221	569	610951	579	483707	0	576715	102	301	579727	104	465	571221	142	332
34	1042133	88	1111016	2	943996	89	675201	3	492799	643	518926	512	382601	0	495020	93	194	483298	146	539	480754	217	405
35	1494898	71	1518051	2	1489740	71	1261296	3	718967	987	918409	629	602083	0	719325	74	111	718698	76	168	717699	137	197
36	782310	72	833456	2	671737	73	521740	3	420991	602	440923	523	320930	0	410009	121	209	406652	351	677	405795	1402	4948
37	880487	76	915068	2	813808	76	625611	3	462396	555	488914	499	363102	0	469912	79	90	460425	88	365	453123	101	393
38	912250	83	906605	2	912250	84	643007	3	510906	585	538772	1488	394220	0	485272	95	103	483069	99	121	475372	120	186
39	1143607	64	1042148	3	948741	65	643853	4	538596	651	569441	619	435132	0	531994	71	99	521664	101	161	514968	622	1529
40	961990	66	1074030	2	722704	67	579781	3	519921	599	549210	448	406578	0	502504	73	107	497941	75	155	492835	98	204
41	1283648	87	1284803	3	1282514	88	977740	4	638389	1081	789320	849	546048	0	647877	95	121	639137	107	230	632365	192	350
42	1471306	113	1287419	3	1471059	114	1013049	4	840917	592	821970	2524	563874	0	676759	147	147	659812	163	697	656121	510	2132
43	1569262	77	1323182	3	1361387	77	911569	4	821197	630	823422	660	559436	0	653780	86	99	642534	91	134	641146	106	179
44	1317194	87	1134837	3	1102201	87	962452	4	564713	683	597921	680	478563	0	561195	99	221	557691	225	391	553314	3129	26224
45	969597	75	947122	3	941113	76	670972	4	494926	653	523727	555	385701	0	479809	92	100	467305	106	469	465574	119	481
46	1044858	63	976465	3	842331	64	606746	4	479327	724	500585	616	372330	0	473720	73	144	466617	79	355	460002	95	315
47	1297587	86	1202300	3	1281367	86	942766	4	592795	990	627655	851	499618	0	590667	91	119	590632	107	352	585574	170	596
48	1010383	107	1246761	3	925427	108	795957	4	839442	1019	792478	788	542969	0	642214	119	152	640116	127	492	635150	335	1190
49	1254224	86	1281613	3	1253711	87	1040584	4	633675	981	778275	623	530092	0	631565	99	206	627918	123	360	626562	474	891
50	886772	76	731617	3	668166	77	527698	4	418403	520	441298	457	300554	0	420449	107	110	407336	120	365	401153	143	1529
51	674785	88	829651	3	666809	88	528599	4	396886	474	417401	438	290226	0	376901	100	106	370204	123	254	366968	178	379
52	822777	79	1239912	3	822777	80	1018433	4	791759	688	825170	961	535157	0	662370	95	107	660545	99	217	652905	115	507
53	1362478	83	1217834	3	1252593	84	994024	4	777338	716	764135	791	531468	0	624005	105	205	615472	128	355	607951	506	601
54	560278	71	705338	3	553633	72	472246	4	379130	542	369042	426	253906	0	343098	89	95	340179	109	183	336320	144	956
55	866429	78	837919	3	767934	79	529016	4	421265	638	444811	631	316555	0	418929	166	413	407697	480	2068	406672	7277	7887
56	579020	77	681518	3	575825	77	448352	4	394826	513	411289	493	276741	0	384043	124	303	381029	304	1111	374462	4255	6792
57	1149890	116	1091119	3	1118988	117	744041	4	589523	697	613636	599	464801	0	587126	124	240	580965	176	264	570768	249	3035
58	806476	101	872120	3	741470	102	559970	4	442554	723	458222	581	328319	0	432419	107	120	429869	138	230	428951	246	252
59	1399369	140	1463150	3	1302495	141	1051905	4	806837	731	829958	1282	558737	0	688462	153	158	671371	157	521	666620	188	648
60	513147	67	644328	3	389671	68	432453	4	352628	544	334825	489	228543	0	320053	91	237	316311	108	296	313337	128	1552
61	939494	102	993317	3	856887	103	613938	4	475886	637	501071	741	359320	0	472554	107	179	469391	140	227	463173	206	2867
62	1184790	87	868409	3	1184441	88	718848	4	626304	1789	777441	932	528699	0	623897	102	276	620590	104	347	618597	223	788
63	741433	61	1173941	3	723147	61	931972	4	441443	739	453995	669	316087	0	429937	68	97	425812	77	592	421165	94	1169
64	844823	70	829863	3	737734	71	651932	4	455432	643	480698	629	352072	0	459629	77	101	454398	95	196	445540	185	255
65	839701	115	850679	3	639376	116	627946	4	407259	616	428716	564	288825	0	402940	151	189	391394	184	237	391034	263	351
66	1088711	78	1144365	3	1088711	79	806283	4	593712	777	631676	910	503668	0	598956	84	130	598411	99	225	591281	141	164
67	927961	83	904381	3	925410	84	567237	4	471775	737	504013	617	361345	0	475002	88	128	472423	146	221	468662	269	663
68	1079271	79	979310	3	997989	79	623956	4	547722	707	565985	615	404824	0	517327	86	125	515365	96	166	509224	330	1195
69	1085036	106	997056	3	1085036	107	712904	4	523618	757	550265	765	385507	0	514165	114	137	513841	121	216	508331	138	147
70	1050426	68	997589	3	795694	69	836714	4	502643	645	523098	672	368780	0	507156	75	94	494658	88	196	490295	138	196
71	645679	73	719667	3	642033	73	416384	4	399340	559	403574	658	275881	0	378500	81	147	374809	84	307	369691	117	291
72	872357	83	779641	3	731565	84	492500	4	397520	627	419463	542	291657	0	398990	126	271	395188	398	506	388446	508	585
73	695716	86	794018	3	690847	87	457707	4	378514	544	404743	525	276076	0	380001	153	301	368241	519	751	367596	1295	8883
74	1430022	94	1231794	3	1316367	95	978373	4	833064	739	833031	1219	573270	0	685906	100	250	675998	101	322	667951	186	11645
75	953267	73	805156	3	648164	74	692001	4	402605	585	423566	555	282859	0	397713	103	118	393388	205	412	391776	1805	2917
76	782026	70	821178	3	701913	71	821178	4	434060	626	450569	688	307672	0	414203	100	140	411763	162	294	404545	2208	2608
77	790418	51	888173	3	664562	52	621305	4	431267	761	449968	647	318454	0	425981	105	281	423272	240	590	421034	310	1102
78	1385900	92	1325254	3	1381441	93	1024607	4	811715	1180	841978	2553	584935	0	707231	126	131	689493	157	511	681650	1299	1868
79	896058	66	888925	3	826227	67	539900	4	456847	843	503375	697	350925	0	452885	72	74	450171	82	255	448611	144	322

Table 5: Parcel delivery: Cost and CPU time (in seconds) for (meta-)heuristics, LB and CPLEX

#	Ig	%Err		%Gap	
		GrVND	ExVND	GrVND	ExVND
1	1.29	34.94	8.07	74.71	39.92
2	1.35	31.83	0.43	77.47	35.19
3	1.54	45.53	4.84	123.42	60.95
4	1.32	28.50	2.95	69.13	35.49
5	1.21	22.88	9.17	48.82	32.21
6	1.39	17.93	6.16	63.41	47.11
7	1.25	30.15	3.69	63.03	29.88
8	1.17	37.50	5.65	60.90	23.63
9	1.29	63.34	3.54	110.84	33.65
10	1.22	27.34	3.34	55.04	25.83
11	1.11	26.17	7.13	39.58	18.51
12	1.15	31.27	4.27	51.55	20.38
13	1.24	36.68	4.55	69.61	29.73
14	1.17	13.09	3.87	32.80	21.97
15	1.15	31.55	8.66	51.89	25.46
16	1.22	21.89	1.78	49.19	24.57
17	1.18	36.63	6.63	61.71	26.19
18	1.21	59.54	1.37	92.53	22.33
19	1.24	32.06	1.97	64.28	26.85
20	1.19	26.40	0.67	50.89	20.17
21	1.26	26.80	2.82	59.85	29.62
22	1.15	36.28	4.35	57.00	20.21
23	1.20	46.39	3.67	75.29	24.13
24	1.17	44.21	5.73	68.85	23.80
25	1.24	15.27	2.25	42.38	26.30
26	1.24	19.88	3.12	48.99	28.16
27	1.48	35.72	1.67	100.91	50.50
28	1.13	54.29	0.52	74.98	14.00
29	1.20	25.47	8.63	50.67	30.46
30	1.17	21.64	5.27	41.77	22.69
31	1.16	20.07	7.16	39.00	24.06
32	1.23	22.58	6.62	50.42	30.83
33	1.18	48.93	0.00	75.88	18.09
34	1.26	40.45	2.51	76.48	28.80
35	1.19	75.74	0.18	109.49	19.41
36	1.26	28.57	3.74	62.57	31.18
37	1.25	38.07	2.05	72.30	27.35
38	1.21	35.26	7.47	63.11	29.60
39	1.18	25.03	4.59	47.97	23.78
40	1.21	17.64	5.50	42.60	27.88

#	Ig	%Err		%Gap	
		GrVND	ExVND	GrVND	ExVND
41	1.16	54.62	0.95	79.06	16.91
42	1.16	54.40	25.28	79.66	45.77
43	1.15	42.18	28.08	62.94	46.79
44	1.16	73.94	2.06	101.11	18.00
45	1.21	44.12	6.30	73.96	28.32
46	1.24	31.90	4.20	62.96	28.74
47	1.17	61.00	1.23	88.70	18.65
48	1.17	25.32	24.77	46.59	45.95
49	1.18	66.08	1.14	96.30	19.54
50	1.33	31.55	4.30	75.57	39.21
51	1.26	44.04	8.15	82.13	36.75
52	1.22	26.02	21.27	53.74	47.95
53	1.14	63.50	25.69	87.03	43.78
54	1.32	40.42	9.73	85.99	45.35
55	1.28	30.08	3.59	67.12	33.08
56	1.35	19.73	5.44	62.01	42.67
57	1.23	30.36	3.29	60.08	26.83
58	1.31	30.54	3.17	70.56	34.79
59	1.19	57.80	21.03	88.26	44.40
60	1.37	24.36	6.86	70.50	46.50
61	1.29	32.55	2.74	70.86	32.44
62	1.17	16.21	1.25	35.97	18.46
63	1.33	71.70	4.81	128.78	39.66
64	1.27	46.32	2.22	85.17	29.36
65	1.35	60.59	4.15	117.41	41.01
66	1.17	36.36	0.41	60.08	17.88
67	1.30	21.03	0.66	56.98	30.56
68	1.26	22.53	7.56	54.13	35.30
69	1.32	40.24	3.01	84.93	35.83
70	1.33	62.29	2.52	115.76	36.30
71	1.34	12.63	8.02	50.93	44.75
72	1.33	26.79	2.34	68.86	36.30
73	1.33	24.51	2.97	65.79	37.10
74	1.17	46.47	24.71	70.67	45.31
75	1.39	65.44	2.76	129.15	42.33
76	1.31	73.51	7.30	128.14	41.08
77	1.32	47.57	2.43	95.10	35.43
78	1.17	50.31	19.08	75.17	38.77
79	1.28	20.35	1.84	53.85	30.18

Table 6: Parcel delivery: Performance guarantees of GrVND, ExVND and LB

3. Benchmark Instances

#	$\|I\|$ Clients	$\|J\|$ Locations	$\|L\|$ Facility Types	$\|K_l\|$ Copies	$\|M\|$ Bands	Variables	Constraints
1	100	5	10	10	5	$5.4{\cdot}10^4$	$5.2{\cdot}10^4$
2	100	5	10	15	5	$8.0{\cdot}10^4$	$7.8{\cdot}10^4$
3	100	10	10	10	5	$5.7{\cdot}10^4$	$1.0{\cdot}10^5$
4	100	10	10	15	5	$8.5{\cdot}10^4$	$1.5{\cdot}10^5$
5	100	5	10	10	10	$1.1{\cdot}10^5$	$5.3{\cdot}10^4$
6	100	5	10	15	10	$1.6{\cdot}10^5$	$7.9{\cdot}10^4$
7	100	10	10	10	10	$1.1{\cdot}10^5$	$1.0{\cdot}10^5$
8	100	10	10	15	10	$1.7{\cdot}10^5$	$1.6{\cdot}10^5$
9	150	5	10	10	5	$7.9{\cdot}10^4$	$7.7{\cdot}10^4$
10	150	5	10	15	5	$1.2{\cdot}10^5$	$1.2{\cdot}10^5$
11	150	10	10	10	5	$8.3{\cdot}10^4$	$1.5{\cdot}10^5$
12	150	10	10	15	5	$1.2{\cdot}10^5$	$2.3{\cdot}10^5$
13	150	5	10	10	10	$1.6{\cdot}10^5$	$7.8{\cdot}10^4$
14	150	5	10	15	10	$2.3{\cdot}10^5$	$1.2{\cdot}10^5$
15	150	10	10	10	10	$1.6{\cdot}10^5$	$1.5{\cdot}10^5$
16	150	10	10	15	10	$2.4{\cdot}10^5$	$2.3{\cdot}10^5$
17	100	5	15	10	5	$8.0{\cdot}10^4$	$7.8{\cdot}10^4$
18	100	5	15	15	5	$1.2{\cdot}10^5$	$1.2{\cdot}10^5$
19	100	10	15	10	5	$8.5{\cdot}10^4$	$1.5{\cdot}10^5$
20	100	10	15	15	5	$1.3{\cdot}10^5$	$2.3{\cdot}10^5$
21	100	5	15	10	10	$1.6{\cdot}10^5$	$7.9{\cdot}10^4$
22	100	5	15	15	10	$2.4{\cdot}10^5$	$1.2{\cdot}10^5$
23	100	10	15	10	10	$1.7{\cdot}10^5$	$1.6{\cdot}10^5$
24	100	10	15	15	10	$2.5{\cdot}10^5$	$2.3{\cdot}10^5$
25	150	5	15	10	5	$1.2{\cdot}10^5$	$1.2{\cdot}10^5$
26	150	5	15	15	5	$1.8{\cdot}10^5$	$1.7{\cdot}10^5$
27	150	10	15	10	5	$1.2{\cdot}10^5$	$2.3{\cdot}10^5$
28	150	10	15	15	5	$1.8{\cdot}10^5$	$3.4{\cdot}10^5$
29	150	5	15	10	10	$2.3{\cdot}10^5$	$1.2{\cdot}10^5$
30	150	5	15	15	10	$3.5{\cdot}10^5$	$1.8{\cdot}10^5$
31	150	10	15	10	10	$2.4{\cdot}10^5$	$2.3{\cdot}10^5$
32	150	10	15	15	10	$3.6{\cdot}10^5$	$3.5{\cdot}10^5$

Table 7: Benchmark instances

#	Heuristics				Meta-heuristics								LB		CPLEX					
					GrVND				ExVND						5%Err		2%Err		OPT	
	SS		FR		SS		FR		SS		FR									
	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU
1	2804	8	3486	9	2804	10	2884	14	2740	27	2740	29	1942	1	2850	20	2768	35	2740	44
2	3675	18	3124	13	3098	23	3103	23	2465	37	2465	33	1802	1	2514	73	2490	99	2465	114
3	6221	16	6468	16	4726	18	5147	20	4201	35	4201	36	3589	1	4327	63	4201	125	4201	239
4	4459	13	5194	17	3086	16	3653	24	2911	32	2911	37	2127	1	2969	50	2940	72	2911	118
5	4236	9	4518	21	3057	13	3062	24	2853	28	2853	41	2032	1	2973	56	2859	59	2859	78
6	5039	22	5281	26	4259	24	3994	33	3337	41	3337	46	2478	1	3403	171	3337	1130	3337	1482
7	3266	24	4219	26	3053	26	3958	30	2707	43	2708	46	1962	1	2789	130	2735	168	2707	214
8	3249	13	3916	36	3244	24	3857	45	2778	32	2778	56	1874	1	2833	129	2806	193	2778	282
9	2440	8	3212	17	2440	11	2839	25	2377	27	2377	37	1810	1	2448	34	2377	62	2377	70
10	2884	16	3561	26	3343	27	3395	38	2612	35	2612	46	1818	2	2691	180	2612	323	2612	487
11	6251	15	6149	30	4551	16	5096	34	4064	34	4064	50	3161	1	4226	196	4064	1535	4064	2242
12	4947	22	5507	32	4415	35	4535	44	4132	41	4132	52	2925	3	4184	1362	4143	3147	4102	7227
13	3934	10	4767	43	3913	12	4336	51	3621	29	3621	63	2308	1	3729	123	3621	200	3621	421
14	5582	35	6096	49	5331	37	5445	68	3715	54	3715	69	2970	2	3790	319	3715	1266	3715	2552
15	7097	45	6122	55	4658	59	4742	61	3562	64	3562	75	2604	3	3684	292	3578	3863	3542	8160
16	3710	19	4545	68	3402	21	3614	88	2351	38	2351	88	1675	2	2422	106	2351	163	2351	187
17	5440	10	6004	64	3761	24	3785	70	3491	29	3491	84	2530	2	3561	245	3491	965	3491	1657
18	3154	12	4016	31	3154	19	3133	47	3091	31	3091	51	1996	1	3184	68	3122	101	3091	499
19	2626	7	3368	44	3010	11	3100	48	2544	26	2544	64	1817	1	2646	51	2569	87	2544	110
20	5831	34	5574	49	4656	44	4238	59	3619	53	3619	69	2683	2	3691	495	3655	9345	3619	10556
21	3438	24	4120	51	3244	33	4082	58	2322	43	2322	71	1591	2	2415	232	2345	336	2322	435
22	2568	24	3229	71	2517	40	3069	87	2490	43	2490	91	1720	2	2565	107	2515	143	2490	156
23	5943	36	6851	82	3978	43	4050	89	3788	55	3788	102	3037	2	3864	364	3826	2425	3788	3014
24	4578	44	5311	90	3960	54	4233	101	3382	63	3382	110	2582	2	3517	416	3382	5487	3382	10263
25	6150	22	6927	57	5179	37	4847	71	3660	41	3660	77	3014	2	3769	322	3696	1014	3660	9788
26	6359	24	6013	63	4842	30	4528	106	3999	43	3999	83	3158	3	4079	364	4039	923	3999	10161
27	2288	12	3409	79	2288	24	2579	92	2226	31	2226	99	1684	2	2315	138	2226	163	2226	199
28	5217	46	5335	95	4312	59	5011	127	3206	65	3206	115	2001	3	3302	1247	3206	3625	3206	12642
29	5911	25	6232	104	3932	36	4186	119	3353	44	3326	124	2422	3	3391	466	3325	5138	3325	16080
30	2985	21	3656	142	2985	45	3085	172	2823	40	2823	162	2115	3	2880	257	2851	257	2823	691
31	5367	31	5710	164	4732	35	5397	178	4485	50	4485	184	3610	3	4572	3537	4482	7946	4482	15748
32	5402	38	6001	181	4059	49	5065	215	3515	57	3515	201	2307	4	3620	822	3550	3160	3515	7250

Table 8: Benchmark instances: Cost and CPU time (in seconds) for (meta-)heuristics, LB and CPLEX

#	Ig	%Err		%Gap	
		GrVND	ExVND	GrVND	ExVND
1	1.41	2.34	0.00	44.39	41.09
2	1.37	25.70	0.00	71.96	36.80
3	1.17	12.49	0.00	31.67	17.05
4	1.37	6.02	0.00	45.09	36.85
5	1.41	6.94	0.00	50.47	40.41
6	1.35	19.71	0.00	61.16	34.62
7	1.38	12.75	0.00	55.61	38.02
8	1.48	16.77	0.00	73.13	48.26
9	1.31	2.64	0.00	34.83	31.36
10	1.44	27.97	0.01	83.90	43.72
11	1.29	11.99	0.00	43.95	28.54
12	1.40	7.64	0.75	50.93	41.27
13	1.57	8.09	0.00	69.54	56.86
14	1.25	43.47	0.00	79.50	25.11
15	1.36	31.49	0.55	78.83	36.75
16	1.40	44.70	0.00	103.10	40.36
17	1.38	7.73	0.00	48.67	38.00
18	1.55	1.37	0.00	57.02	54.90
19	1.40	18.33	0.00	65.71	40.05
20	1.35	17.11	0.00	57.96	34.88
21	1.46	39.70	0.00	103.95	45.99
22	1.45	1.07	0.00	46.31	44.75
23	1.25	5.00	0.00	30.99	24.75
24	1.31	17.09	0.00	53.39	30.99
25	1.21	32.44	0.00	60.80	21.41
26	1.27	13.22	0.01	43.38	26.64
27	1.32	2.77	0.00	35.86	32.20
28	1.60	34.51	0.00	115.48	60.20
29	1.37	18.28	0.03	62.37	37.32
30	1.33	5.73	0.00	41.11	33.46
31	1.24	5.56	0.07	31.06	24.24
32	1.52	15.49	0.00	75.95	52.35

Table 9: Benchmark instances: Performance guarantees of metaheuristics and LB

4. Large instances

#	$\|I\|$ Clients	$\|J\|$ Locations	$\|L\|$ Facility Types	$\|K_l\|$ Copies	$\|M\|$ Bands	Variables	Constraints
1	500	20	25	15	5	$9.9{\cdot}10^5$	$3.8{\cdot}10^6$
2	500	20	15	25	5	$9.9{\cdot}10^5$	$3.8{\cdot}10^6$
3	500	15	20	20	5	$1.0{\cdot}10^6$	$3.0{\cdot}10^6$
4	1000	20	10	20	5	$1.0{\cdot}10^6$	$4.0{\cdot}10^6$
5	1000	20	20	10	5	$1.0{\cdot}10^6$	$4.0{\cdot}10^6$
6	500	20	20	20	5	$1.1{\cdot}10^6$	$4.0{\cdot}10^6$
7	500	25	20	20	5	$1.1{\cdot}10^6$	$5.0{\cdot}10^6$
8	1000	15	15	15	5	$1.2{\cdot}10^6$	$3.4{\cdot}10^6$
9	1000	20	15	15	5	$1.2{\cdot}10^6$	$4.5{\cdot}10^6$
10	1000	25	15	15	5	$1.2{\cdot}10^6$	$5.6{\cdot}10^6$

Table 10: Large instances

#	Heuristics				Metaheuristics								LB	
					GrVND					ExVND				
	SS		FR		SS		FR		%Gap	SS	FR	%Gap		
	Cost	CPU	Cost	CPU	Cost	CPU	Cost	CPU		Cost	Cost		Cost	CPU
1	17368	4925	15541	7186	16112	1088	15189	217	60.22	13279	13741	40.08	9480	113
2	16673	3586	17312	5078	16202	1103	16902	1311	70.53	11814	11142	17.26	9501	117
3	15894	2287	16523	4988	15119	1254	16407	1260	57.95	11685	11910	22.07	9572	125
4	28625	7561	31074	9111	28105	1634	29305	1931	55.19	27004	27572	49.11	18110	162
5	29753	5030	31579	8669	28515	1591	30438	1828	46.71	27134	27826	39.60	19437	154
6	14797	4812	16212	9022	14478	1573	15333	1990	65.71	11015	10229	17.07	8737	167
7	15578	5158	15209	8304	15496	2562	15018	2002	61.30	12513	12585	34.40	9311	182
8	29813	4194	31055	7709	29209	2101	29619	2504	54.52	27195	27812	43.87	18902	191
9	30478	5766	29262	7593	29101	2333	29376	2607	51.95	26956	27017	40.75	19152	202
10	28386	9451	30368	10216	28148	2200	29669	3005	53.73	27690	27800	51.23	18310	198

Table 11: Large instances: Cost and CPU time (in seconds) for (meta-)heuristics and LB