

# Failure-directed Search for Constraint-based Scheduling

## Detailed Experimental Results

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**Abstract.** This is an appendix of the paper *Failure-directed Search for Constraint-based Scheduling* [1] by the same authors that lists all improved lower and upper bounds.

## 1 Introduction

The paper *Failure-directed Search for Constraint-based Scheduling* presents a new constraint programming search algorithm that is designed for a broad class of scheduling problems. Failure-directed Search (FDS) assumes that there is no (better) solution or that such a solution is very hard to find. Therefore, instead of looking for solution(s), it focuses on a systematic exploration of the search space, first eliminating assignments that are most likely to fail. It is a “plan B” strategy that is used once a less systematic “plan A” strategy – here, Large Neighborhood Search (LNS) – is not able to improve current solution any more. LNS and FDS form the basis of the automatic search for scheduling problems in CP Optimizer, part of CPLEX Optimization Studio.

FDS and LNS+FDS (the default search in CP Optimizer) are tested on a range of scheduling benchmarks: Job Shop, Job Shop with Operators, Flexible Job Shop, RCPSP, RCPSP/max, Multi-mode RCPSP and Multi-mode RCPSP/max. Results show that the proposed search algorithm often improves best-known lower and upper bounds and closes many open instances.

## 2 Detailed Experimental Results

This section lists improvements of lower and upper bounds achieved by failure-directed search (FDS) as reported in [1]. For the details please see [1].

## Job Shop

Instance	LB	UB	Instance	LB	UB	Instance	LB	UB	Instance	LB	UB
tail11	1357	1357	tail24	1644	1644	tail44	1948	1979	swv06	1630	1671
tail12	1367	1367	tail25	1558	1595	tail46	1957	2004	swv07	1513	1595
tail13	1342	1342	tail26	1591	1643	tail47	1807	1889	swv08	1671	1752
tail15	1339	1339	tail27	1652	1680	tail49	1931	1961	swv09	1633	1655
tail16	1360	1360	tail28	1603	1603	tail50	1833	1923	swv10	1663	1743
tail18	1377	1396	tail29	1573	1625	abz07	656	656	yam1	854	884
tail19	1332	1332	tail30	1519	1584	abz08	648	667	yam2	870	904
tail20	1348	1348	tail33	1788	1791	abz09	678	678	yam3	859	892
tail21	1642	1642	tail40	1651	1669	swv03	1398	1398	yam4	929	968
tail22	1561	1600	tail41	1906	2005	swv04	1464	1464			
tail23	1518	1557	tail42	1884	1937	swv05	1424	1424			

Instance	LB	UB	Instance	LB	UB	Instance	LB	UB	Instance	LB	UB
Mk02	26	26	edata-la28	1142	1142	rdata-la22	737	755	sdata-la29	1152	1152
Mk06	57	57	edata-la29	1107	1107	rdata-la25	752	784	sdata-la36	1268	1268
01a	2505	2505	edata-la30	1188	1188	rdata-la35	1549	1549	sdata-la38	1196	1196
02a	2228	2230	edata-la31	1532	1532	rdata-la37	1062	1062	sdata-la40	1222	1222
07a	2216	2276	edata-orb1	977	977	rdata-la40	955	955	sdata-orb1	1059	1059
09a	2061	2061	edata-orb10	933	933	rdata-orb1	746	746	sdata-orb10	944	944
10a	2212	2263	edata-orb2	865	865	rdata-orb10	742	742	sdata-orb2	888	888
13a	2197	2245	edata-orb3	951	951	rdata-orb2	696	696	sdata-orb3	1005	1005
16a	2193	2232	edata-orb4	984	984	rdata-orb3	712	712	sdata-orb4	1005	1005
edata-abz5	1167	1167	edata-orb5	842	842	rdata-orb5	639	639	sdata-orb5	887	887
edata-abz6	925	925	edata-orb6	958	958	rdata-orb6	754	754	sdata-orb6	1010	1010
edata-abz7	604	613	edata-orb7	939	939	rdata-orb7	302	302	sdata-orb7	397	397
edata-abz8	625	636	edata-orb9	933	933	rdata-orb8	639	639	sdata-orb8	899	899
edata-abz9	646	666	rdata-abz5	925	925	rdata-orb9	654	925	sdata-abz5	937	934
edata-car1	6176	6176	rdata-car1	5034	5034	sdata-abz6	943	943	vdata-abz9	497	498
edata-car2	6327	6327	rdata-car2	5985	5985	sdata-abz7	656	656	vdata-car3	5597	5597
edata-car3	6856	6856	rdata-car3	5622	5623	sdata-abz8	608	667	vdata-car4	6514	6514
edata-car6	7990	7990	rdata-car5	5615	5615	sdata-abz9	678	678	vdata-car5	4909	4912
edata-car7	6123	6123	rdata-car6	6147	6147	sdata-car5	7702	7702	vdata-la21	800	800
edata-car8	7689	7689	rdata-car7	4425	4425	sdata-car6	8313	8313	vdata-la22	733	733
edata-la21	1009	1009	rdata-car8	5692	5692	sdata-car7	6558	6558	vdata-la27	1084	1084
edata-la26	1106	1106	rdata-la01	570	570	sdata-car8	8264	8264			

Instance	LB	UB	Instance	LB	UB	Instance	LB	UB	Instance	LB	UB
j60_9.5	<b>82</b>	85	j90_13.7	<b>117</b>	124	j120_11.3	<b>190</b>	203	j120_37.3	<b>136</b>	139
j60_9.10	<b>91</b>	93	j90_25.2	<b>123</b>	131	j120_11.4	<b>183</b>	196	j120_37.4	<b>157</b>	163
j60_13.5	<b>93</b>	97	j90_25.3	<b>115</b>	123	j120_11.10	<b>166</b>	181	j120_37.7	<b>152</b>	161
j60_25.8	<b>96</b>	99	j90_25.7	<b>123</b>	130	j120_12.3	<b>133</b>	136	j120_39.2	<b>106</b>	108
j60_29.3	<b>115</b>	121	j90_25.8	<b>133</b>	140	j120_16.5	<b>185</b>	200	j120_46.5	<b>140</b>	149
j60_29.6	<b>145</b>	154	j90_29.2	<b>123</b>	126	j120_16.9	<b>190</b>	205	j120_47.8	<b>127</b>	133
j60_29.10	<b>112</b>	119	j90_29.4	<b>141</b>	149	j120_17.4	<b>118</b>	120	j120_48.2	<b>112</b>	113
j60_45.5	<b>100</b>	106	j90_41.2	<b>158</b>	168	j120_17.9	<b>130</b>	134	j120_48.6	<b>103</b>	105
j60_45.6	<b>133</b>	144	j90_41.4	<b>144</b>	154	j120_26.3	<b>161</b>	167	j120_51.1	<b>187</b>	206
j60_45.10	<b>105</b>	114	j90_41.7	<b>146</b>	157	j120_31.6	<b>184</b>	192	j120_52.10	<b>135</b>	144
j90_5.4	<b>101</b>	<b>102</b>	j90_41.10	<b>147</b>	150	j120_31.8	<b>177</b>	192	j120_57.2	<b>152</b>	161
j90_9.1	<b>100</b>	104	j90_45.5	<b>164</b>	174	j120_31.10	<b>203</b>	227	j120_58.1	<b>134</b>	141
j90_9.9	<b>107</b>	116	j120_8.5	<b>101</b>	104	j120_36.10	<b>199</b>	216	j120_59.2	<b>104</b>	106
j90_13.6	<b>118</b>	124									

# RCPSP/max

Instance	LB	UB	Instance	LB	UB	Instance	LB	UB
psp_c_61	<b>338</b>	<b>378</b>	psp_d_158	<b>662</b>	687	psp_ubo200_3	<b>482</b>	906
psp_c_63	<b>343</b>	366	psp_d_246	<b>443</b>	463	psp_ubo200_4	<b>514</b>	963
psp_c_66	<b>340</b>	368	psp_j30_64	<b>141</b>	169	psp_ubo200_5	<b>499</b>	852
psp_c_67	<b>346</b>	350	psp_j30_65	<b>144</b>	162	psp_ubo200_8	<b>505</b>	911
psp_c_69	<b>352</b>	380	<b>psp_j30_73</b>	<b>53</b>	53	psp_ubo200_32	<b>753</b>	<b>867</b>
psp_c_70	<b>376</b>	379	psp_j30_151	<b>142</b>	157	psp_ubo200_33	<b>784</b>	<b>841</b>
psp_c_125	<b>309</b>	316	psp_j30_153	<b>163</b>	176	psp_ubo200_34	<b>595</b>	816
psp_c_152	<b>361</b>	369	psp_j30_155	<b>125</b>	154	psp_ubo200_35	<b>607</b>	<b>850</b>
psp_c_160	<b>360</b>	374	psp_ubo100_4	<b>303</b>	<b>396</b>	psp_ubo200_37	<b>656</b>	<b>764</b>
psp_c_218	<b>305</b>	309	psp_ubo100_7	<b>281</b>	<b>400</b>	psp_ubo200_39	<b>692</b>	<b>828</b>
psp_c_241	<b>401</b>	416	psp_ubo100_8	<b>364</b>	<b>385</b>	psp_ubo200_62	<b>621</b>	<b>812</b>
psp_c_245	<b>396</b>	<b>448</b>	psp_ubo100_10	<b>381</b>	<b>447</b>	psp_ubo200_65	<b>728</b>	<b>820</b>
psp_c_310	<b>258</b>	<b>261</b>	psp_ubo100_32	<b>353</b>	<b>439</b>	psp_ubo200_66	<b>615</b>	899
psp_c_331	<b>346</b>	<b>377</b>	psp_ubo100_33	<b>328</b>	<b>409</b>	psp_ubo200_67	<b>870</b>	<b>900</b>
psp_c_336	<b>349</b>	371	psp_ubo100_34	<b>391</b>	425	psp_ubo200_70	<b>724</b>	<b>882</b>
psp_c_337	<b>269</b>	<b>285</b>	psp_ubo100_37	<b>405</b>	426	psp_ubo50_3	<b>184</b>	<b>194</b>
psp_c_339	<b>403</b>	412	psp_ubo100_40	<b>412</b>	473	psp_ubo50_4	<b>194</b>	216
psp_d_35	<b>392</b>	408	psp_ubo100_70	<b>375</b>	<b>408</b>	psp_ubo50_10	<b>154</b>	<b>187</b>
psp_d_63	<b>474</b>	524	psp_ubo200_2	<b>682</b>	938			

# Multi-mode RCPSP/max

Instance	LB	UB	Instance	LB	UB
mm50_159_sch	42	42	mm100_216_sch	57	<b>57</b>
mm50_188_sch	30	30	mm100_217_sch	65	<b>65</b>
mm50_189_sch	32	32	mm100_218_sch	59	<b>59</b>
mm50_214_sch	28	28	mm100_220_sch	50	50
mm50_218_sch	32	32	mm100_230_sch	53	<b>53</b>
mm50_249_sch	28	28	mm100_236_sch	64	64
mm50_93_sch	38	38	mm100_241_sch	52	<b>52</b>
mm100_1_sch	118	<b>118</b>	mm100_242_sch	52	<b>52</b>
mm100_10_sch	95	95	mm100_243_sch	45	<b>45</b>
mm100_100_sch	79	79	mm100_244_sch	55	<b>55</b>
mm100_121_sch	79	79	mm100_245_sch	56	<b>56</b>
mm100_122_sch	96	96	mm100_246_sch	48	<b>48</b>
mm100_123_sch	61	61	mm100_247_sch	62	<b>62</b>
mm100_124_sch	76	<b>76</b>	mm100_248_sch	49	<b>49</b>
mm100_125_sch	67	67	mm100_249_sch	61	<b>61</b>
mm100_126_sch	59	59	mm100_250_sch	44	44
mm100_127_sch	67	67	mm100_254_sch	54	54
mm100_128_sch	63	63	mm100_265_sch	52	<b>52</b>
mm100_129_sch	65	65	mm100_266_sch	60	<b>60</b>
mm100_130_sch	80	80	mm100_3_sch	103	<b>103</b>
mm100_151_sch	62	62	mm100_31_sch	83	<b>83</b>
mm100_153_sch	68	68	mm100_32_sch	78	<b>78</b>
mm100_154_sch	77	77	mm100_35_sch	121	<b>121</b>
mm100_155_sch	60	60	mm100_37_sch	80	80
mm100_156_sch	49	49	mm100_40_sch	72	<b>72</b>
mm100_157_sch	56	56	mm100_5_sch	88	<b>88</b>
mm100_158_sch	73	73	mm100_61_sch	100	100
mm100_160_sch	84	84	mm100_62_sch	98	<b>98</b>
mm100_181_sch	52	52	mm100_63_sch	80	<b>80</b>
mm100_182_sch	56	56	mm100_64_sch	104	104
mm100_183_sch	62	62	mm100_66_sch	94	94
mm100_184_sch	46	46	mm100_67_sch	84	84
mm100_185_sch	58	58	mm100_7_sch	113	113
mm100_186_sch	57	57	mm100_8_sch	105	<b>105</b>
mm100_187_sch	54	54	mm100_9_sch	101	101
mm100_188_sch	56	56	mm100_93_sch	65	<b>65</b>
mm100_189_sch	46	46	mm100_94_sch	56	<b>56</b>
mm100_190_sch	56	56	mm100_95_sch	64	64
mm100_211_sch	48	48	mm100_96_sch	75	<b>75</b>
mm100_212_sch	63	63	mm100_97_sch	62	<b>62</b>
mm100_213_sch	53	53	mm100_98_sch	75	<b>75</b>
mm100_214_sch	70	70	mm100_99_sch	69	<b>69</b>
mm100_215_sch	53	53			

# Job Shop with Operators

Instance	LB	UB	Instance	LB	UB	Instance	LB	UB	Instance	LB	UB
abz5 10	1234	1234	la25 5	1502	1502	la35 6	2581	2581	la40 9	1276	1282
abz5 6	1299	1299	la25 6	1252	1252	la35 7	2213	2213	orb01 3	1803	1803
abz5 7	1234	1234	la25 7	1073	1073	la35 8	1936	1936	orb01 4	1375	1375
abz5 8	1234	1234	la25 8	977	977	la36 10	1268	1268	orb01 5	1117	1163
abz5 9	1234	1234	la25 9	977	977	la36 11	1268	1268	orb01 6	1071	1071
abz6 6	991	991	la26 10	1218	1218	la36 12	1268	1268	orb01 7	1059	1059
abz6 7	945	945	la26 5	2103	2103	la36 13	1268	1268	orb02 10	888	888
ft10 10	930	930	la26 6	1753	1753	la36 14	1268	1268	orb02 5	1059	1059
ft10 5	1057	1057	la26 7	1503	1503	la36 15	1268	1268	orb02 6	907	907
ft10 6	946	946	la26 8	1315	1315	la36 5	2348	2348	orb02 7	889	889
ft10 7	937	937	la26 9	1218	1218	la36 6	1957	1957	orb02 8	888	888
ft10 8	930	930	la27 10	1235	1235	la36 7	1677	1677	orb02 9	888	888
ft10 9	930	930	la27 4	2708	2708	la36 8	1468	1468	orb03 10	1005	1005
ft20 4	1295	1298	la27 5	2167	2167	la36 9	1305	1305	orb03 4	1342	1342
la02 4	667	667	la27 6	1806	1806	la37 10	1397	1397	orb03 5	1098	1129
la16 10	945	945	la27 7	1548	1548	la37 11	1397	1397	orb03 6	1036	1036
la16 5	1071	1071	la27 8	1354	1355	la37 12	1397	1397	orb03 7	1008	1008
la16 6	945	945	la27 9	1235	1235	la37 13	1397	1397	orb03 8	1005	1005
la16 7	945	945	la28 10	1216	1216	la37 14	1397	1397	orb03 9	1005	1005
la16 8	945	945	la28 6	1781	1781	la37 15	1397	1397	orb04 10	1005	1005
la16 9	945	945	la28 7	1526	1526	la37 5	2514	2514	orb04 5	1164	1164
la17 5	936	936	la28 8	1336	1336	la37 6	2095	2095	orb04 6	1027	1027
la17 6	784	784	la28 9	1216	1216	la37 7	1796	1796	orb04 7	1011	1011
la17 7	784	784	la29 10	1134	1177	la37 8	1572	1572	orb04 8	1005	1005
la18 5	1038	1038	la29 4	2483	2483	la37 9	1410	1418	orb05 10	887	887
la18 6	865	865	la29 5	1986	1986	la38 10	1196	1196	orb05 4	1236	1236
la18 7	848	848	la29 6	1655	1655	la38 11	1196	1196	orb05 5	1003	1003
la19 4	1337	1337	la29 7	1419	1419	la38 12	1196	1196	orb05 6	891	891
la19 5	1071	1071	la29 8	1242	1249	la38 13	1196	1196	orb05 7	887	887
la19 6	906	906	la29 9	1134	1178	la38 14	1196	1196	orb05 8	887	887
la19 7	842	842	la30 10	1355	1355	la38 15	1196	1196	orb05 9	887	887
la20 5	1089	1089	la30 5	2136	2136	la38 5	2244	2244	orb06 10	1010	1010
la20 6	915	915	la30 6	1780	1780	la38 6	1870	1870	orb06 4	1408	1408
la20 7	902	902	la30 7	1526	1526	la38 7	1603	1603	orb06 5	1154	1158
la21 10	1046	1046	la30 8	1355	1355	la38 8	1403	1403	orb06 6	1036	1036
la21 5	1599	1599	la30 9	1355	1355	la38 9	1247	1267	orb06 7	1010	1010
la21 6	1333	1333	la31 4	3798	3798	la39 10	1233	1233	orb06 8	1010	1010
la21 7	1145	1145	la31 5	3039	3039	la39 11	1233	1233	orb06 9	1010	1010
la21 8	1048	1048	la31 6	2532	2532	la39 12	1233	1233	orb07 6	414	414
la21 9	1046	1046	la31 7	2171	2171	la39 13	1233	1233	orb07 7	401	401
la22 10	927	927	la31 8	1899	1899	la39 14	1233	1233	orb08 4	1145	1145
la22 6	1221	1221	la32 5	3314	3314	la39 15	1233	1233	orb08 5	946	946
la22 7	1046	1046	la32 6	2762	2762	la39 5	2311	2311	orb08 6	899	899
la22 8	928	928	la32 7	2367	2367	la39 6	1926	1926	orb08 7	899	899
la22 9	927	927	la32 8	2072	2072	la39 7	1651	1651	orb09 10	934	934
la23 5	1617	1617	la32 9	1850	1850	la39 8	1445	1445	orb09 5	1067	1067
la23 6	1348	1348	la33 5	2994	2994	la39 9	1284	1286	orb09 6	943	943
la23 7	1155	1155	la33 6	2495	2495	la40 10	1222	1222	orb09 7	934	934
la23 8	1032	1032	la33 7	2139	2139	la40 11	1222	1222	orb09 8	934	934
la24 10	935	935	la33 8	1872	1872	la40 12	1222	1222	orb09 9	934	934
la24 5	1546	1546	la34 5	3069	3069	la40 13	1222	1222	orb10 4	1400	1400
la24 6	1288	1288	la34 6	2557	2557	la40 14	1222	1222	orb10 5	1135	1135
la24 7	1104	1104	la34 7	2192	2192	la40 15	1222	1222	orb10 6	979	979
la24 8	967	974	la34 8	1918	1918	la40 6	1912	1912	orb10 7	944	944
la24 9	936	936	la34 9	1721	1721	la40 7	1639	1639			
la25 10	977	977	la35 5	3097	3097	la40 8	1434	1434			

## Multi-mode RCPSP

Instance	LB	UB	Instance	LB	UB	Instance	LB	UB	Instance	LB	UB
j30_10.1.mm	26	26	j30_16.9.mm	24	24	j30_23.8.mm	23	23	j30_30.7.mm	27	27
j30_10.10.mm	32	32	j30_17.1.mm	34	34	j30_23.9.mm	26	26	j30_30.8.mm	28	28
j30_10.2.mm	28	28	j30_17.10.mm	26	26	j30_24.1.mm	27	27	j30_30.9.mm	36	36
j30_10.3.mm	24	24	j30_17.2.mm	26	26	j30_24.10.mm	37	37	j30_31.1.mm	25	25
j30_10.4.mm	36	36	j30_17.3.mm	33	33	j30_24.2.mm	31	31	j30_31.10.mm	20	20
j30_10.5.mm	33	33	j30_17.4.mm	39	39	j30_24.3.mm	21	21	j30_31.2.mm	43	43
j30_10.6.mm	25	25	j30_17.5.mm	29	29	j30_24.4.mm	29	29	j30_31.3.mm	31	31
j30_10.7.mm	22	22	j30_17.6.mm	33	33	j30_24.5.mm	37	37	j30_31.4.mm	29	29
j30_10.8.mm	31	31	j30_17.7.mm	32	32	j30_24.6.mm	30	30	j30_31.5.mm	43	43
j30_10.9.mm	38	38	j30_17.8.mm	31	31	j30_24.7.mm	29	29	j30_31.6.mm	32	32
j30_11.1.mm	35	35	j30_17.9.mm	34	34	j30_24.8.mm	38	38	j30_31.7.mm	45	45
j30_11.10.mm	35	35	j30_18.1.mm	28	28	j30_24.9.mm	31	31	j30_31.8.mm	26	26
j30_11.2.mm	28	28	j30_18.10.mm	33	33	j30_25.1.mm	34	34	j30_31.9.mm	33	33
j30_11.3.mm	31	31	j30_18.2.mm	33	33	j30_25.10.mm	27	27	j30_32.1.mm	31	31
j30_11.4.mm	35	35	j30_18.3.mm	35	35	j30_25.2.mm	32	32	j30_32.10.mm	29	29
j30_11.5.mm	35	35	j30_18.4.mm	31	31	j30_25.3.mm	24	24	j30_32.2.mm	32	32
j30_11.6.mm	33	33	j30_18.5.mm	21	21	j30_25.4.mm	30	30	j30_32.3.mm	28	28
j30_11.7.mm	32	32	j30_18.6.mm	25	25	j30_25.5.mm	27	27	j30_32.4.mm	27	27
j30_11.8.mm	30	30	j30_18.7.mm	35	35	j30_25.6.mm	32	32	j30_32.5.mm	29	29
j30_11.9.mm	26	26	j30_18.8.mm	18	18	j30_25.7.mm	33	33	j30_32.6.mm	29	29
j30_12.1.mm	29	29	j30_18.9.mm	25	25	j30_25.8.mm	33	33	j30_32.7.mm	36	36
j30_12.10.mm	28	28	j30_19.1.mm	35	35	j30_25.9.mm	51	51	j30_32.8.mm	29	29
j30_12.2.mm	31	31	j30_19.10.mm	29	29	j30_26.1.mm	21	21	j30_32.9.mm	22	22
j30_12.3.mm	34	34	j30_19.2.mm	21	21	j30_26.10.mm	22	22	j30_33.1.mm	47	47
j30_12.4.mm	29	29	j30_19.3.mm	31	31	j30_26.2.mm	22	22	j30_33.10.mm	39	39
j30_12.5.mm	25	25	j30_19.4.mm	30	30	j30_26.3.mm	42	42	j30_33.2.mm	45	45
j30_12.6.mm	34	34	j30_19.5.mm	27	27	j30_26.4.mm	34	34	j30_33.3.mm	45	45
j30_12.7.mm	27	27	j30_19.6.mm	24	24	j30_26.5.mm	22	22	j30_33.4.mm	57	57
j30_12.8.mm	28	28	j30_19.7.mm	36	36	j30_26.6.mm	29	29	j30_33.5.mm	48	48
j30_12.9.mm	22	22	j30_19.8.mm	34	34	j30_26.7.mm	29	29	j30_33.6.mm	41	41
j30_13.1.mm	37	37	j30_19.9.mm	25	25	j30_26.8.mm	40	40	j30_33.7.mm	45	45
j30_13.10.mm	41	42	j30_20.1.mm	30	30	j30_26.9.mm	21	21	j30_33.8.mm	39	39
j30_13.2.mm	40	40	j30_20.10.mm	28	28	j30_27.1.mm	38	38	j30_33.9.mm	44	44
j30_13.3.mm	39	41	j30_20.2.mm	25	25	j30_27.10.mm	29	29	j30_34.1.mm	39	39
j30_13.4.mm	41	41	j30_20.3.mm	27	27	j30_27.2.mm	29	29	j30_34.10.mm	54	54
j30_13.5.mm	37	38	j30_20.4.mm	35	35	j30_27.3.mm	28	28	j30_34.2.mm	32	32
j30_13.6.mm	38	38	j30_20.5.mm	29	29	j30_27.4.mm	28	28	j30_34.3.mm	38	38
j30_13.7.mm	41	41	j30_20.6.mm	24	24	j30_27.5.mm	40	40	j30_34.4.mm	42	42
j30_13.8.mm	28	28	j30_20.7.mm	30	30	j30_27.6.mm	25	25	j30_34.5.mm	43	43
j30_13.9.mm	30	30	j30_20.8.mm	33	33	j30_27.7.mm	30	30	j30_34.6.mm	41	41
j30_14.1.mm	37	37	j30_20.9.mm	26	26	j30_27.8.mm	42	42	j30_34.7.mm	44	44
j30_14.10.mm	29	29	j30_21.1.mm	38	38	j30_27.9.mm	37	37	j30_34.8.mm	47	47
j30_14.2.mm	32	32	j30_21.10.mm	45	45	j30_28.1.mm	37	37	j30_34.9.mm	38	38
j30_14.3.mm	30	30	j30_21.2.mm	34	34	j30_28.10.mm	26	26	j30_35.1.mm	34	34
j30_14.4.mm	34	34	j30_21.3.mm	35	36	j30_28.2.mm	25	25	j30_35.10.mm	51	51
j30_14.5.mm	26	26	j30_21.4.mm	37	37	j30_28.3.mm	31	31	j30_35.2.mm	35	35
j30_14.6.mm	29	29	j30_21.5.mm	37	37	j30_28.4.mm	33	33	j30_35.3.mm	39	39
j30_14.7.mm	34	34	j30_21.6.mm	33	33	j30_28.5.mm	23	23	j30_35.4.mm	47	47
j30_14.8.mm	41	41	j30_21.7.mm	36	36	j30_28.6.mm	29	29	j30_35.5.mm	42	42
j30_14.9.mm	31	31	j30_21.8.mm	44	44	j30_28.7.mm	37	37	j30_35.6.mm	41	41
j30_15.1.mm	40	40	j30_21.9.mm	32	32	j30_28.8.mm	36	36	j30_35.7.mm	35	35
j30_15.10.mm	38	38	j30_22.1.mm	26	26	j30_28.9.mm	28	28	j30_35.8.mm	40	40
j30_15.2.mm	34	34	j30_22.10.mm	23	23	j30_29.1.mm	46	46	j30_35.9.mm	36	36
j30_15.3.mm	33	33	j30_22.2.mm	36	36	j30_29.10.mm	36	36	j30_37.1.mm	51	54
j30_15.4.mm	30	30	j30_22.3.mm	25	25	j30_29.2.mm	34	34	j30_37.10.mm	42	42
j30_15.5.mm	24	24	j30_22.4.mm	26	26	j30_29.3.mm	32	32	j30_37.2.mm	54	58
j30_15.6.mm	22	22	j30_22.5.mm	30	30	j30_29.4.mm	33	33	j30_37.3.mm	56	56
j30_15.7.mm	27	27	j30_22.6.mm	31	31	j30_29.5.mm	34	34	j30_37.4.mm	54	54
j30_15.8.mm	23	23	j30_22.7.mm	38	38	j30_29.6.mm	42	42	j30_37.5.mm	50	50
j30_15.9.mm	28	28	j30_22.8.mm	33	33	j30_29.7.mm	38	38	j30_37.6.mm	62	62
j30_16.1.mm	27	27	j30_22.9.mm	34	34	j30_29.8.mm	50	50	j30_37.7.mm	57	57
j30_16.10.mm	32	32	j30_23.1.mm	25	25	j30_29.9.mm	37	37	j30_37.8.mm	44	44
j30_16.2.mm	41	41	j30_23.10.mm	21	21	j30_30.1.mm	36	36	j30_37.9.mm	52	59
j30_16.3.mm	23	23	j30_23.2.mm	33	33	j30_30.10.mm	19	19	j30_38.1.mm	46	46
j30_16.4.mm	19	19	j30_23.3.mm	23	23	j30_30.2.mm	30	30	j30_38.10.mm	37	37
j30_16.5.mm	30	30	j30_23.4.mm	24	24	j30_30.3.mm	29	29	j30_38.2.mm	44	44
j30_16.6.mm	30	30	j30_23.5.mm	32	32	j30_30.4.mm	35	35	j30_38.3.mm	34	34
j30_16.7.mm	22	22	j30_23.6.mm	27	27	j30_30.5.mm	30	30	j30_38.4.mm	50	50
j30_16.8.mm	25	25	j30_23.7.mm	24	24	j30_30.6.mm	41	41	j30_38.5.mm	50	50

Instance	LB	UB	Instance	LB	UB	Instance	LB	UB	Instance	LB	UB
j30_38.6.mm	36	36	j30_45.5.mm	41	41	j30_52.4.mm	29	29	j30_59.3.mm	34	34
j30_38.7.mm	38	38	j30_45.6.mm	43	46	j30_52.5.mm	30	30	j30_59.4.mm	25	25
j30_38.8.mm	40	40	j30_45.7.mm	46	46	j30_52.6.mm	30	30	j30_59.5.mm	28	28
j30_38.9.mm	45	45	j30_45.8.mm	43	48	j30_52.7.mm	30	30	j30_59.6.mm	27	27
j30_39.1.mm	43	43	j30_45.9.mm	42	42	j30_52.8.mm	26	26	j30_59.7.mm	34	34
j30_39.10.mm	44	44	j30_46.1.mm	33	33	j30_52.9.mm	31	31	j30_59.8.mm	26	26
j30_39.2.mm	42	42	j30_46.10.mm	37	37	j30_53.1.mm	42	42	j30_59.9.mm	34	34
j30_39.3.mm	49	49	j30_46.2.mm	40	40	j30_53.10.mm	37	37	j30_60.1.mm	22	22
j30_39.4.mm	49	49	j30_46.3.mm	30	30	j30_53.2.mm	38	38	j30_60.10.mm	23	23
j30_39.5.mm	32	32	j30_46.4.mm	37	37	j30_53.3.mm	34	34	j30_60.2.mm	38	38
j30_39.6.mm	36	36	j30_46.5.mm	33	33	j30_53.4.mm	44	44	j30_60.3.mm	39	39
j30_39.7.mm	38	38	j30_46.6.mm	33	33	j30_53.5.mm	47	49	j30_60.4.mm	23	23
j30_39.8.mm	42	42	j30_46.7.mm	43	43	j30_53.6.mm	43	43	j30_60.5.mm	34	34
j30_39.9.mm	42	42	j30_46.8.mm	33	33	j30_53.7.mm	35	37	j30_60.6.mm	36	36
j30_40.1.mm	38	38	j30_46.9.mm	40	40	j30_53.8.mm	36	38	j30_60.7.mm	25	25
j30_40.10.mm	44	44	j30_47.1.mm	39	39	j30_53.9.mm	41	42	j30_60.8.mm	29	29
j30_40.2.mm	41	41	j30_47.10.mm	42	42	j30_54.1.mm	33	33	j30_60.9.mm	31	31
j30_40.3.mm	36	36	j30_47.2.mm	29	29	j30_54.10.mm	29	29	j30_61.1.mm	37	37
j30_40.4.mm	40	40	j30_47.3.mm	29	29	j30_54.2.mm	28	28	j30_61.10.mm	41	41
j30_40.5.mm	48	48	j30_47.4.mm	38	38	j30_54.3.mm	22	22	j30_61.2.mm	36	36
j30_40.6.mm	41	41	j30_47.5.mm	26	26	j30_54.4.mm	30	30	j30_61.3.mm	39	39
j30_40.7.mm	48	48	j30_47.6.mm	34	34	j30_54.5.mm	28	28	j30_61.4.mm	38	38
j30_40.8.mm	41	41	j30_47.7.mm	28	28	j30_54.6.mm	30	30	j30_61.5.mm	39	39
j30_40.9.mm	43	43	j30_47.8.mm	38	38	j30_54.7.mm	39	39	j30_61.6.mm	35	35
j30_41.1.mm	35	35	j30_47.9.mm	34	34	j30_54.8.mm	31	31	j30_61.7.mm	44	44
j30_41.10.mm	38	38	j30_48.1.mm	28	28	j30_54.9.mm	28	28	j30_61.8.mm	46	46
j30_41.2.mm	34	34	j30_48.10.mm	28	28	j30_55.1.mm	29	29	j30_61.9.mm	44	44
j30_41.3.mm	40	40	j30_48.2.mm	30	30	j30_55.10.mm	29	29	j30_62.1.mm	26	26
j30_41.4.mm	33	33	j30_48.3.mm	35	35	j30_55.2.mm	31	31	j30_62.10.mm	26	26
j30_41.5.mm	37	37	j30_48.4.mm	24	24	j30_55.3.mm	28	28	j30_62.2.mm	33	33
j30_41.6.mm	32	32	j30_48.5.mm	25	25	j30_55.4.mm	41	41	j30_62.3.mm	26	26
j30_41.7.mm	39	39	j30_48.6.mm	31	31	j30_55.5.mm	24	24	j30_62.4.mm	33	33
j30_41.8.mm	30	30	j30_48.7.mm	32	32	j30_55.6.mm	25	25	j30_62.5.mm	42	42
j30_41.9.mm	42	42	j30_48.8.mm	28	28	j30_55.7.mm	44	44	j30_62.6.mm	36	36
j30_42.1.mm	35	35	j30_48.9.mm	37	37	j30_55.8.mm	44	44	j30_62.7.mm	27	27
j30_42.10.mm	36	36	j30_49.1.mm	33	33	j30_55.9.mm	27	27	j30_62.8.mm	38	38
j30_42.2.mm	26	26	j30_49.10.mm	30	30	j30_56.1.mm	21	21	j30_62.9.mm	26	26
j30_42.3.mm	37	37	j30_49.2.mm	49	49	j30_56.10.mm	39	39	j30_63.1.mm	29	29
j30_42.4.mm	28	28	j30_49.3.mm	35	35	j30_56.2.mm	31	31	j30_63.10.mm	27	27
j30_42.5.mm	35	35	j30_49.4.mm	37	37	j30_56.3.mm	34	34	j30_63.2.mm	30	30
j30_42.6.mm	30	30	j30_49.5.mm	37	37	j30_56.4.mm	32	32	j30_63.3.mm	24	24
j30_42.7.mm	29	29	j30_49.6.mm	31	31	j30_56.5.mm	29	29	j30_63.4.mm	31	31
j30_42.8.mm	28	28	j30_49.7.mm	36	36	j30_56.6.mm	26	26	j30_63.5.mm	37	37
j30_42.9.mm	31	31	j30_49.8.mm	34	34	j30_56.7.mm	30	30	j30_63.6.mm	39	39
j30_43.1.mm	29	29	j30_49.9.mm	33	33	j30_56.8.mm	29	29	j30_63.7.mm	26	26
j30_43.10.mm	30	30	j30_50.1.mm	28	28	j30_56.9.mm	33	33	j30_63.8.mm	31	31
j30_43.2.mm	32	32	j30_50.10.mm	30	30	j30_57.1.mm	30	30	j30_63.9.mm	25	25
j30_43.3.mm	26	26	j30_50.2.mm	37	37	j30_57.10.mm	32	32	j30_64.1.mm	25	25
j30_43.4.mm	27	27	j30_50.3.mm	43	43	j30_57.2.mm	32	32	j30_64.10.mm	36	36
j30_43.5.mm	44	44	j30_50.4.mm	34	34	j30_57.3.mm	29	29	j30_64.2.mm	23	23
j30_43.6.mm	28	28	j30_50.5.mm	37	37	j30_57.4.mm	29	29	j30_64.3.mm	34	34
j30_43.7.mm	33	33	j30_50.6.mm	37	37	j30_57.5.mm	27	27	j30_64.4.mm	25	25
j30_43.8.mm	34	34	j30_50.7.mm	22	22	j30_57.6.mm	23	23	j30_64.5.mm	36	36
j30_43.9.mm	38	38	j30_50.8.mm	27	27	j30_57.7.mm	27	27	j30_64.6.mm	29	29
j30_44.1.mm	41	41	j30_50.9.mm	25	25	j30_57.8.mm	29	29	j30_64.7.mm	34	34
j30_44.10.mm	31	31	j30_51.1.mm	32	32	j30_57.9.mm	26	26	j30_64.8.mm	23	23
j30_44.2.mm	27	27	j30_51.10.mm	27	27	j30_58.1.mm	30	30	j30_64.9.mm	31	31
j30_44.3.mm	34	34	j30_51.2.mm	23	23	j30_58.10.mm	27	27	j30_7.8.mm	47	47
j30_44.4.mm	33	33	j30_51.3.mm	27	27	j30_58.2.mm	32	32	j30_8.6.mm	46	46
j30_44.5.mm	29	29	j30_51.4.mm	51	51	j30_58.3.mm	31	31	j30_9.1.mm	31	31
j30_44.6.mm	25	25	j30_51.5.mm	33	33	j30_58.4.mm	27	27	j30_9.10.mm	25	25
j30_44.7.mm	35	35	j30_51.6.mm	38	38	j30_58.5.mm	28	28	j30_9.2.mm	27	27
j30_44.8.mm	36	36	j30_51.7.mm	26	26	j30_58.6.mm	24	24	j30_9.3.mm	34	34
j30_44.9.mm	35	35	j30_51.8.mm	33	33	j30_58.7.mm	26	26	j30_9.4.mm	30	30
j30_45.1.mm	39	40	j30_51.9.mm	35	35	j30_58.8.mm	28	28	j30_9.5.mm	27	27
j30_45.10.mm	37	42	j30_52.1.mm	32	32	j30_58.9.mm	30	30	j30_9.6.mm	31	31
j30_45.2.mm	48	48	j30_52.10.mm	29	29	j30_59.1.mm	24	24	j30_9.7.mm	35	35
j30_45.3.mm	40	42	j30_52.2.mm	23	23	j30_59.10.mm	29	29	j30_9.8.mm	26	26
j30_45.4.mm	47	49	j30_52.3.mm	22	22	j30_59.2.mm	23	23	j30_9.9.mm	32	32

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