

Datasets in "Heuristic solutions to minimise
makespan in a hybrid flow shop scheduling
environment with energy consumption constraints
in steel making"

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1 Experiment 1

1.1 The Makespan

Jobs	LLH1		LLH2		LLH3		LLH4		LLH5		LLH6	
	HNEH	GA	HNEH	HGA	HNEH	HGA	HNEH	HGA	HNEH	HGA	HNEH	HGA
6	15,55	15,55	6	6	21,8	27,55	27,6	15,85	15,65	15,25	15,75	15,85
8	19,9	19,35	7,05	7,05	38	43,85	36,5	19,9	20,1	19,95	19,95	19,5
10	23,85	23,2	8,75	8,7	50,35	53,95	43,6	23,8	23,85	23,5	24,05	25,55
16	35,95	36,2	12,55	12,6	85,7	89,35	64,7	53,5	36,15	36,1	36,35	52,1
18	39,9	39,2	13,85	15,15	100,8	105,7	70,8	61,8	39,5	39,9	40,55	60,75
20	44,2	43,55	15,3	18,05	116,8	113,25	79,1	69,15	45,35	45,6	43,9	68,95
30	65,9	63,4	22,15	31,95	182,2	184,45	115,5	101,5	63,85	63,2	116,5	98,45
40	84,45	87,65	29	45,45	236	241,1	150,8	130	86,65	85,7	148,9	131,55
50	106,9	107,4	35,5	58,55	298	310,55	190	164,4	105,3	107	185,9	165,85

Figure 1: The average C_{max} values for the 6LLHs for experiment 1

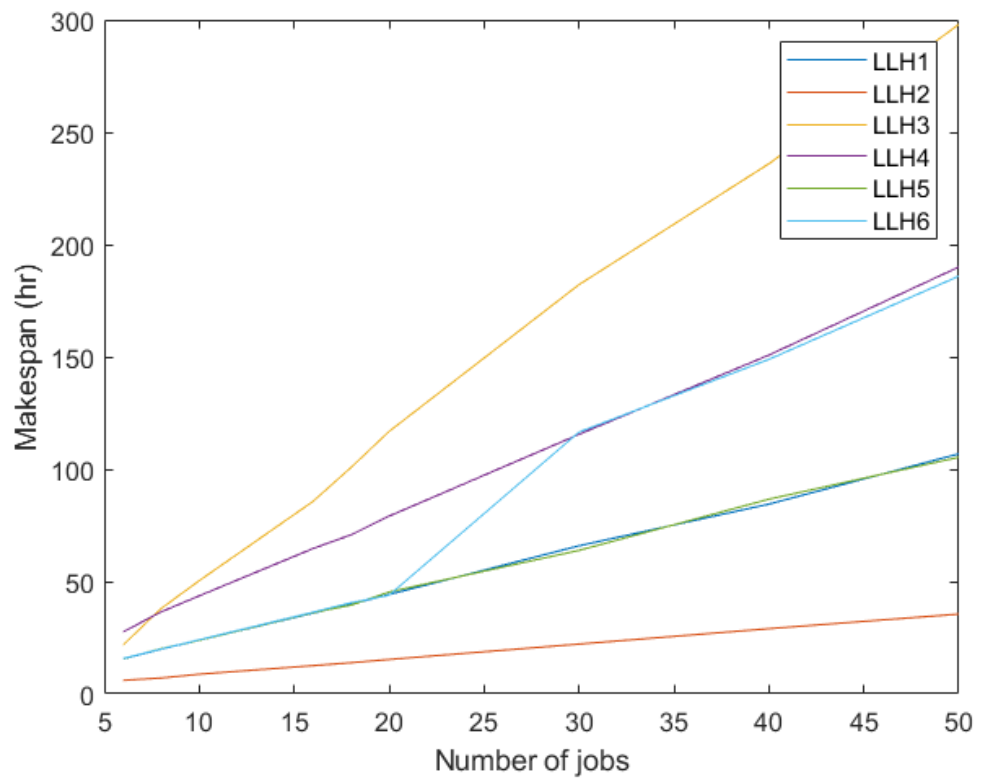


Figure 2: The average C_{max} values for the 6LLHs when used with the NEH for experiment 1

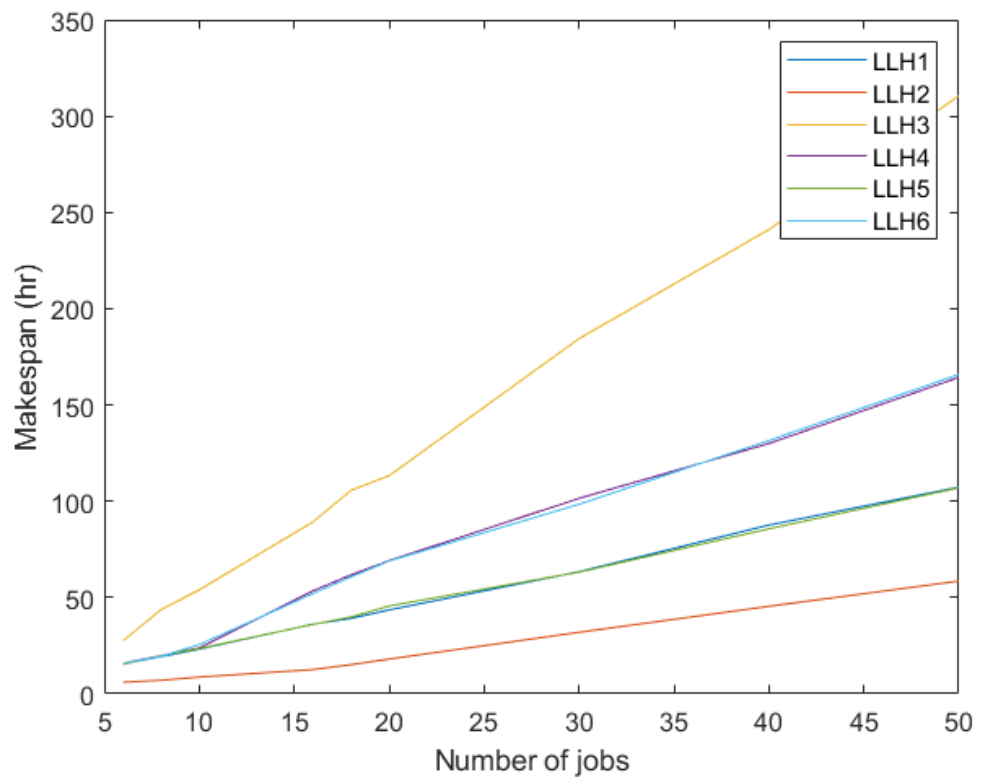


Figure 3: The average C_{max} values for the 6LLHs when used with the GA for experiment 1

1.2 Energy consumption

Jobs	LLH1		LLH2		LLH3		LLH4		LLH5		LLH6	
	HNEH	HGA	HNEH	HGA	HNEH	HGA	HNEH	HGA	HNEH	HGA	HNEH	HGA
6	7251	6914	2255,15	2742,95	8933,1	9186,35	7107,65	7041,25	6973,25	6532,25	7339,25	7063
8	9752,25	9051,75	2956,3	3597,45	12439,45	12584,35	9929,65	9309,25	9530	9005	9810,5	9149,75
10	12066,5	11155	3682,95	4477,45	15043,5	15132	12367,3	11519	11748,25	11074,25	12171,25	11570,95
16	19282,75	18357,25	5902,15	7176,95	23629,9	23814	19347,85	18588,25	18980,25	18025	19417,5	18304,95
18	21449,75	20092,5	6671,65	8122,65	27137,65	27559,3	21494,35	20855,45	20957,75	20271,75	21840	20493,15
20	24011,5	22431	7388,75	8993,2	30831,95	29663,3	24292,2	23155,25	24189,5	23043	23828,25	23224,2
30	36523,25	33485,25	11166,7	13588,15	46810,7	46277,05	36168,55	34954,2	35186	33202,75	36356,5	34103,85
40	36523,25	33485,25	11166,7	13588,15	46810,7	46277,05	36168,55	34954,2	35186	33202,75	36356,5	34103,85
50	60610,5	57620,75	18484,6	22488,8	74766,45	76948,05	60704,9	57852,2	59243,75	57106,75	59922,6	58871,4

Figure 4: The average energy consumption values for the 6LLHs for experiment 1

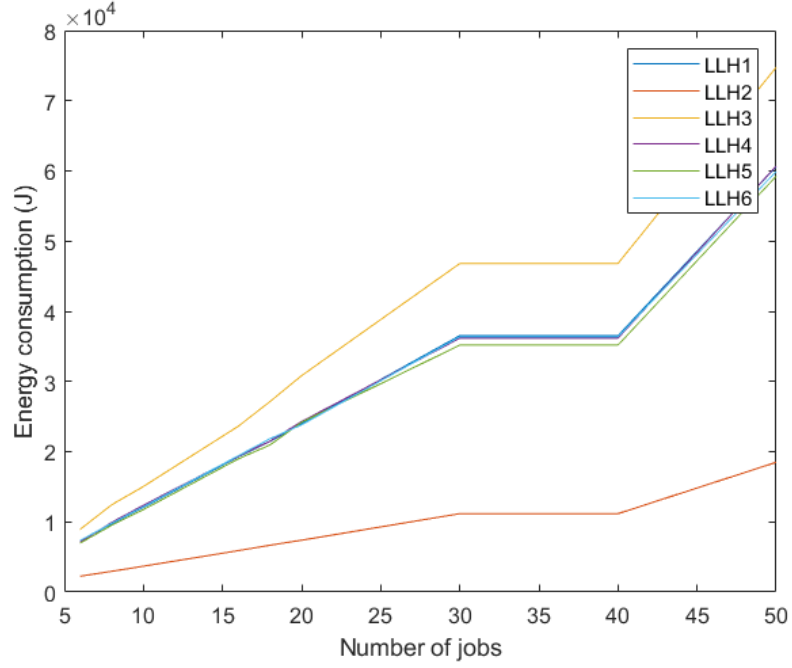


Figure 5: The average energy consumption values for the 6LLHs when used with the NEH for experiment 1

1.3 Computational time

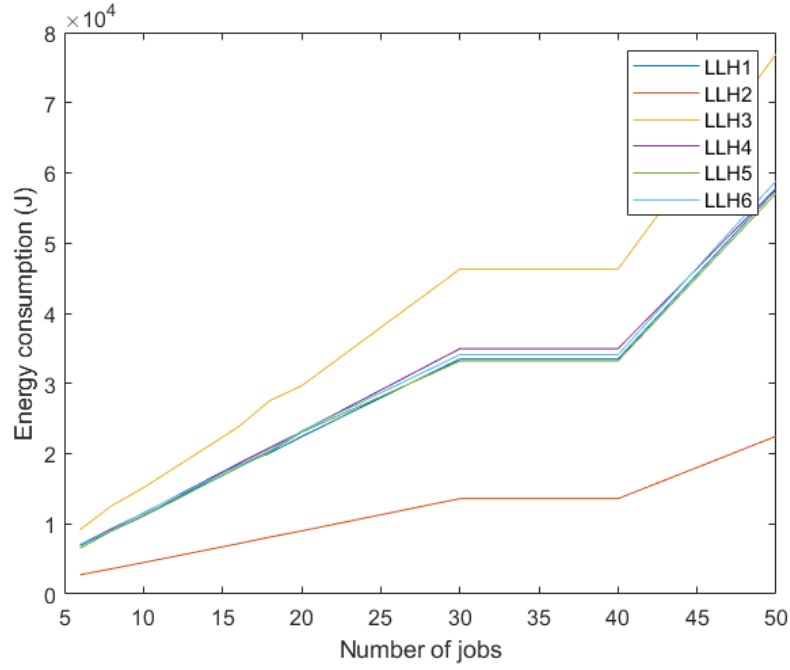


Figure 6: The average energy consumption values for the 6LLHs when used with the GA for experiment 1

Jobs	LLH1		LLH2		LLH3		LLH4		LLH5		LLH6	
	HNEH	GA	HNEH	HGA	HNEH	HGA	HNEH	HGA	HNEH	HGA	HNEH	HGA
6	0,001192	0,008192	0,000989	0,007878	0,001026	0,007873	0,001096	0,007988	0,001114	0,007732	0,00102	0,007469
8	0,001081	0,007777	0,001192	0,007868	0,001279	0,00795	0,001283	0,007875	0,001211	0,007904	0,001155	0,00793
10	0,001809	0,008214	0,002035	0,008162	0,002021	0,008106	0,001957	0,008209	0,002025	0,008343	0,002064	0,008156
16	0,004132	0,00941	0,004122	0,009782	0,004076	0,009954	0,004048	0,009873	0,003856	0,009382	0,003856	0,009306
18	0,003246	0,009464	0,003319	0,009346	0,003194	0,009272	0,003297	0,009515	0,003192	0,009312	0,00321	0,009671
20	0,004101	0,009628	0,004356	0,010102	0,004421	0,010549	0,004382	0,01057	0,004488	0,010681	0,004314	0,010081
30	0,009652	0,011841	0,0096	0,011849	0,00927	0,012255	0,010033	0,012114	0,010636	0,011632	0,009083	0,011547
40	0,01417	0,013239	0,015123	0,013275	0,014146	0,013202	0,014442	0,013403	0,013553	0,013147	0,014663	0,0132
50	0,021305	0,013981	0,02093	0,014105	0,0213	0,014248	0,021019	0,014077	0,021049	0,014035	0,021896	0,01419

Figure 7: The average computational time values for the 6LLHs for experiment 1

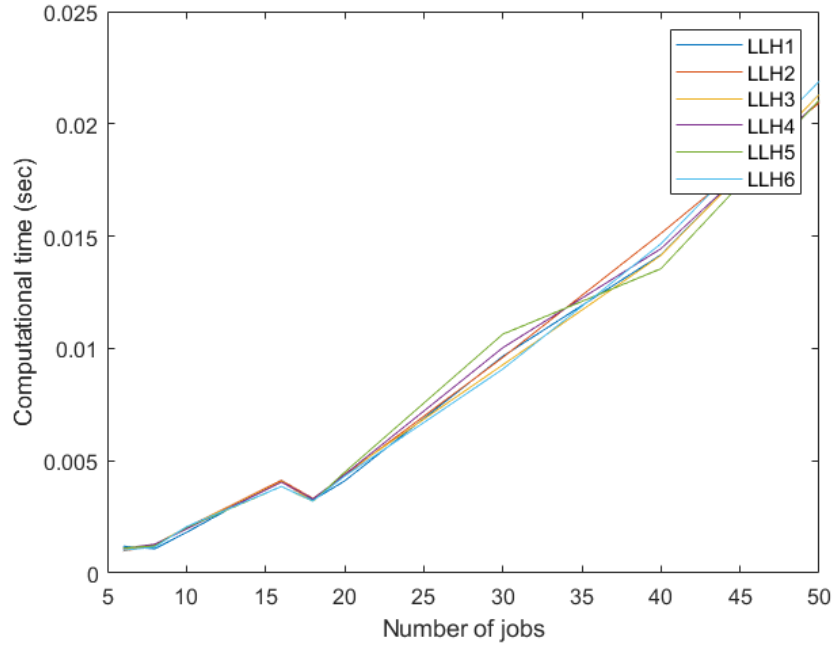


Figure 8: The average computational time values for the 6LLHs when used with the NEH for experiment 1.

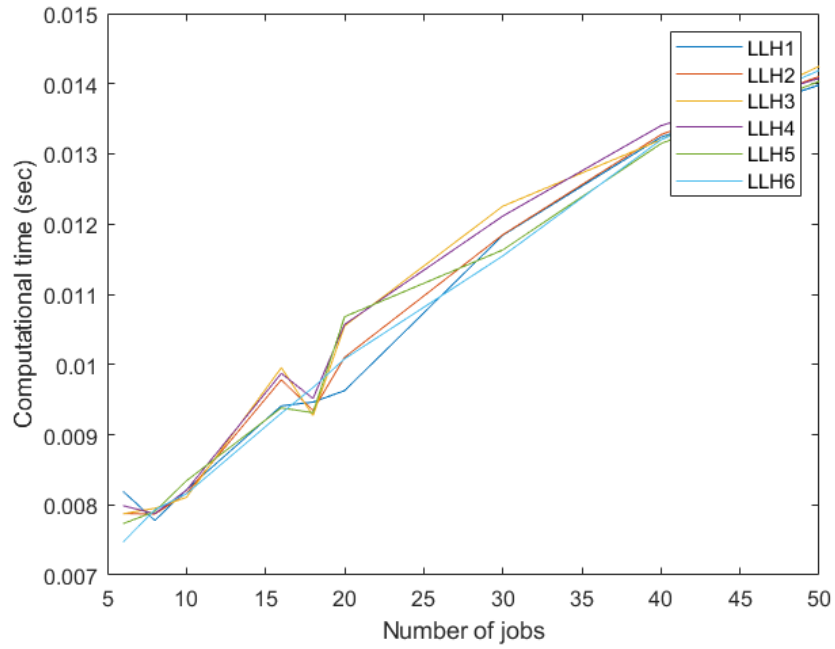


Figure 9: The average computational time values for the 6LLHs when used with the GA for experiment 1.

2 Experiment 2

2.1 Makespan

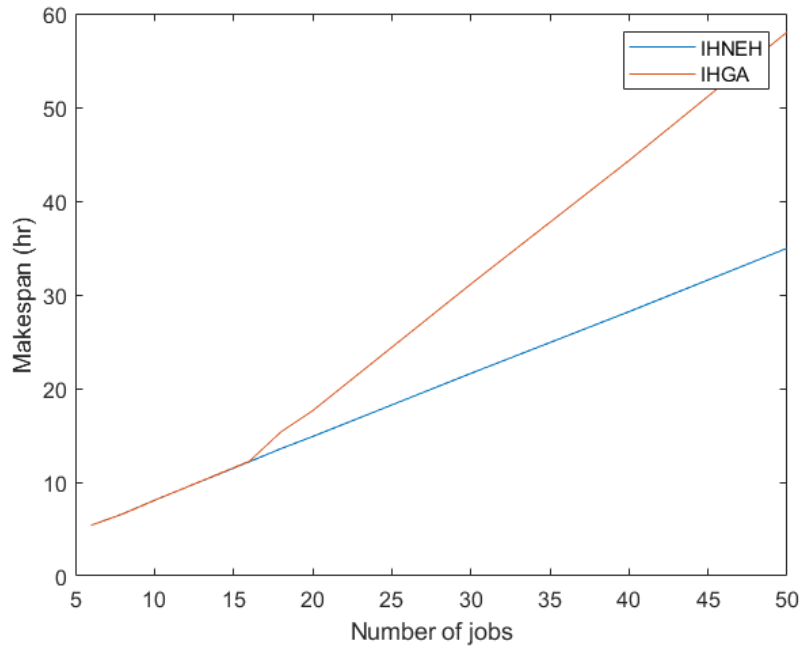


Figure 10: The average C_{max} values of the IHNEH and the IHGA for experiment 2.

2.2 Energy consumption

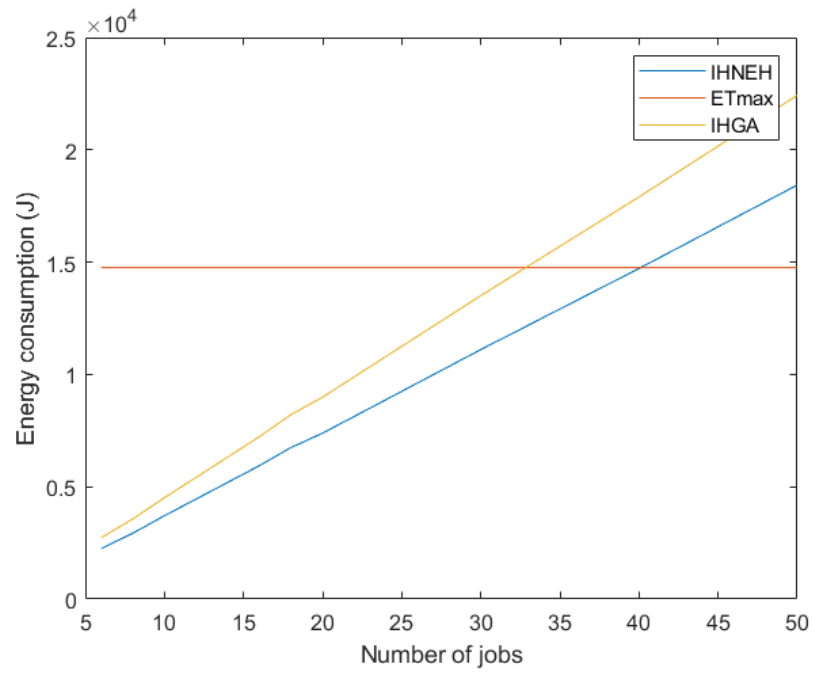


Figure 11: The average energy consumption values of the IHNEH and the IHGA for experiment 2.

2.3 Computational time

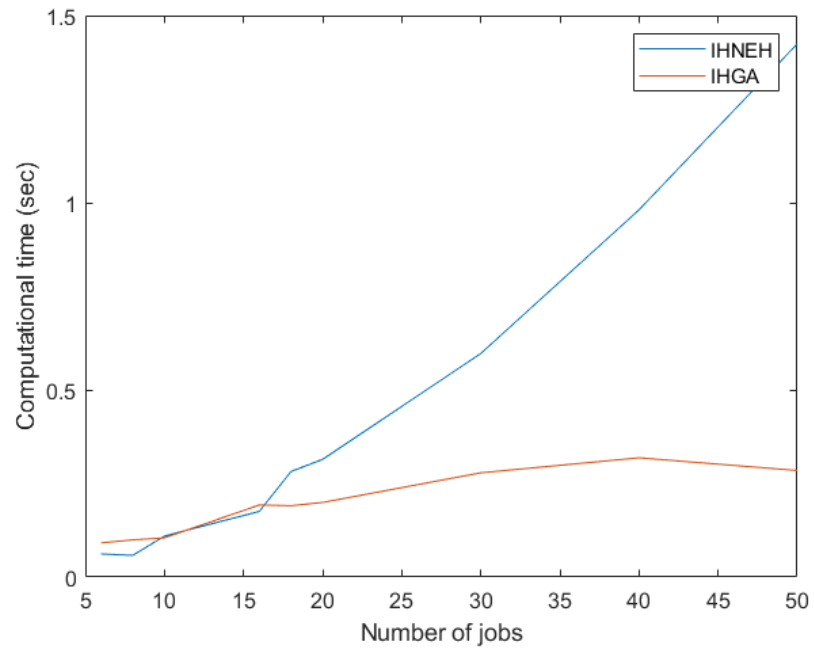


Figure 12: The average energy computational time of the IHNEH and the IHGA for experiment 2.

3 Experiment 3

3.1 Effectiveness of the proposed heuristics

$$GoH = \frac{C_{max} - ActualC_{max}}{ActualC_{max}} * 100 \quad (1)$$

Solution approach	6 jobs	8 jobs	10 jobs
IHNEH	2,040816	1,449275	1,265823
IHGA	2,040816	1,449275	1,265823
B&B	0	0	0

Figure 13: GoH using the C_{max} .

Solution approach	6 jobs	8 jobs	10 jobs
IHNEH	0	0	0
IHGA	21,46919	21,1342	21,41072
B&B	0	0	0

Figure 14: GoH using the energy consumption.

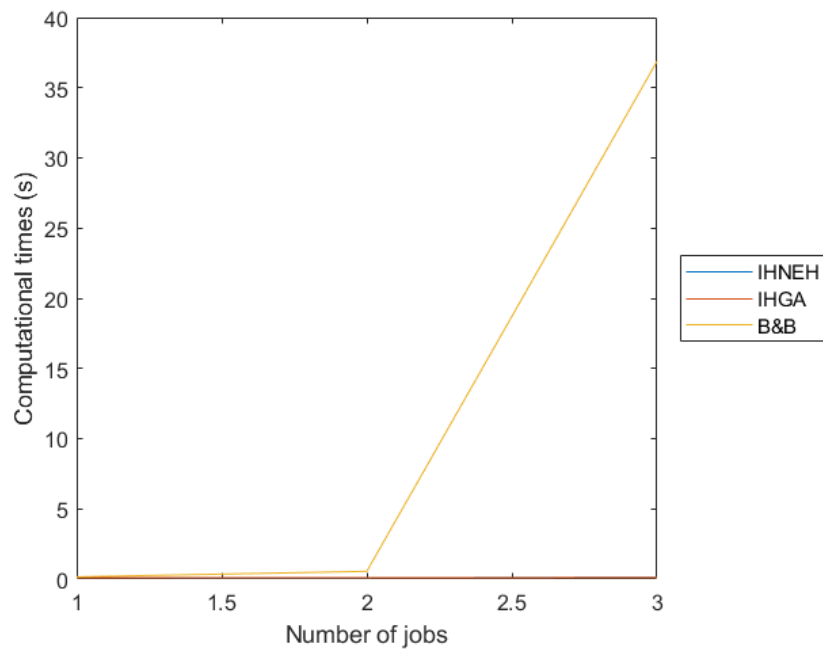


Figure 15: Computational times with 1, 2, and 3 on the x-axis representing 6, 8, and 10 jobs respectively

3.2 Efficiency of the proposed heuristics

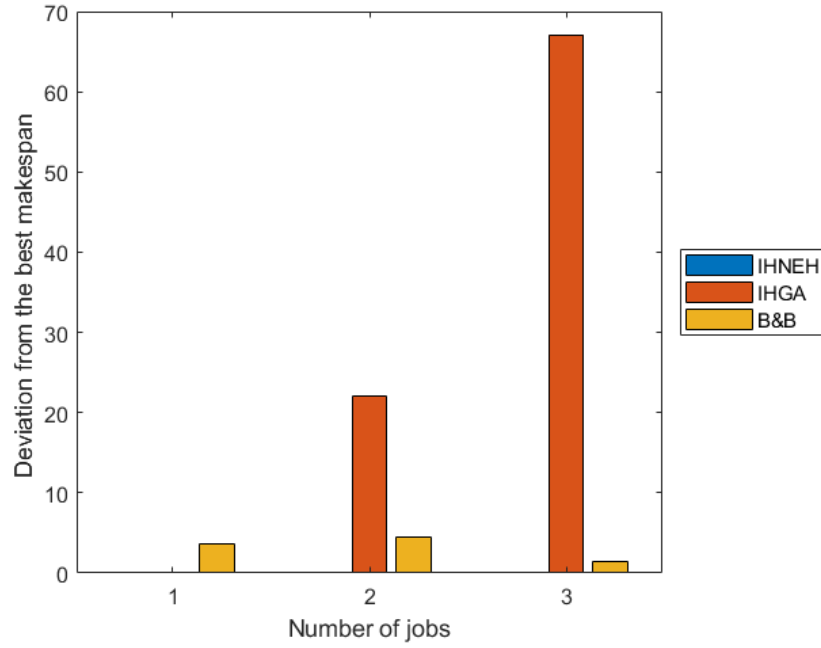


Figure 16: Deviation from the C_{max} for the three methods for the 16, 20, and 40 job sizes.

4 Sensitivity analysis

4.1 GA convergence

4.1.1 50 iterations

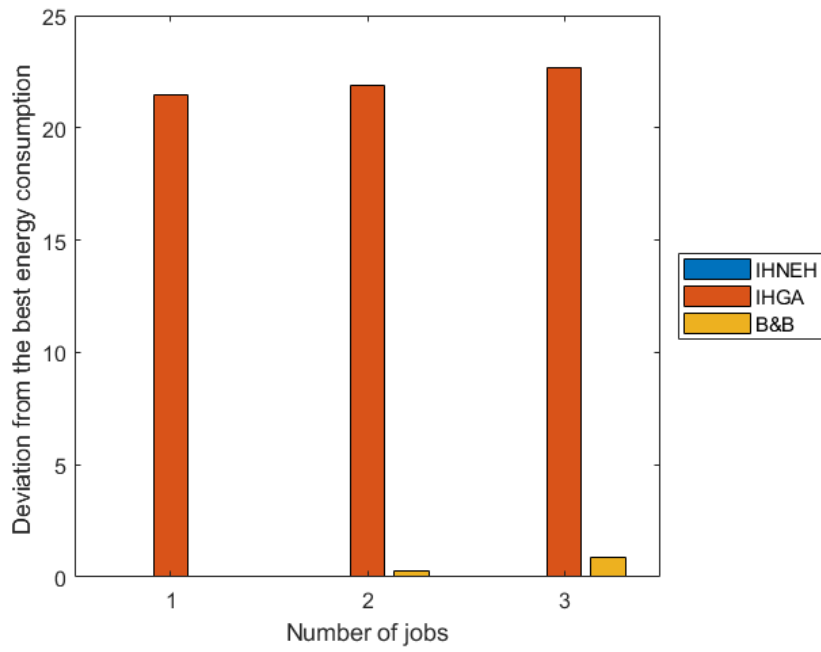


Figure 17: Deviation from energy consumption for the three methods for the 16, 20, and 40 job sizes.

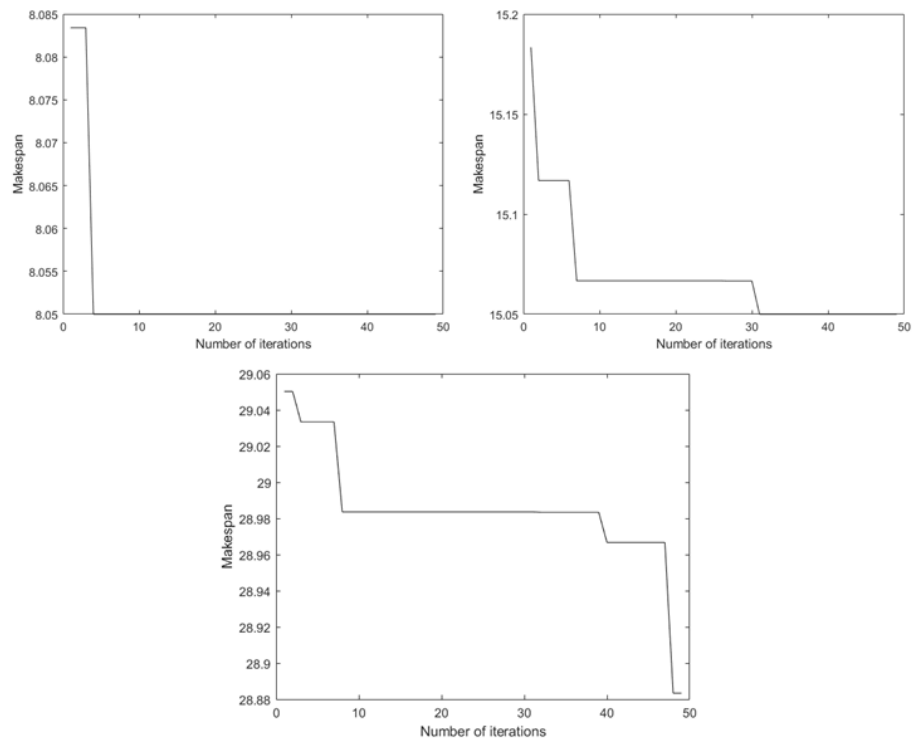


Figure 18: Influence of 50 iterations on the C_{max} for the 10 (top left), 20 (top right), and the 40 (bottom) job sizes .

4.1.2 300 iterations

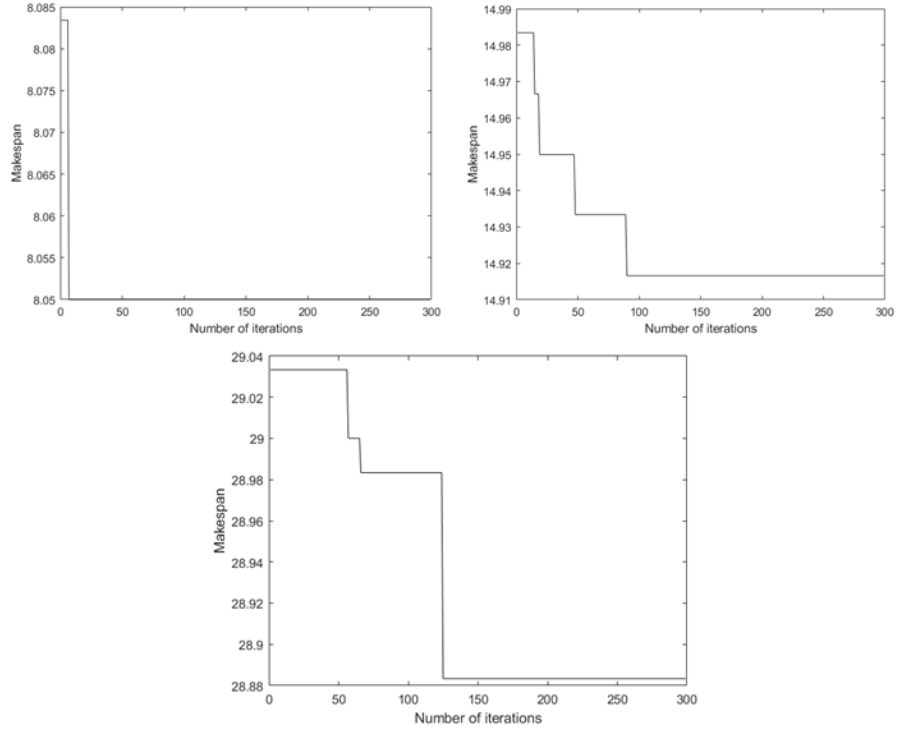


Figure 19: Influence of 300 iterations on the C_{max} for a problem with 10 (top left), 20 (top right), and 40 (bottom) jobs.

4.1.3 650 iterations

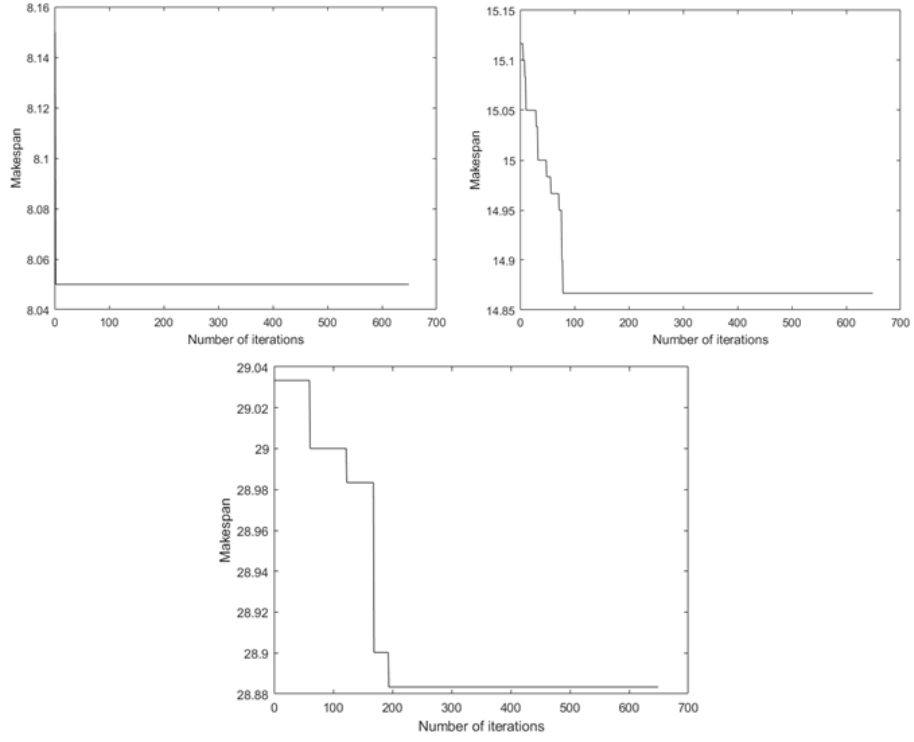


Figure 20: Influence of 650 iterations on the C_{max} for a problem with 10 (top left), 20 (top right), and 40 (bottom) jobs.

4.2 Energy threshold reduction factor

4.2.1 10 jobs

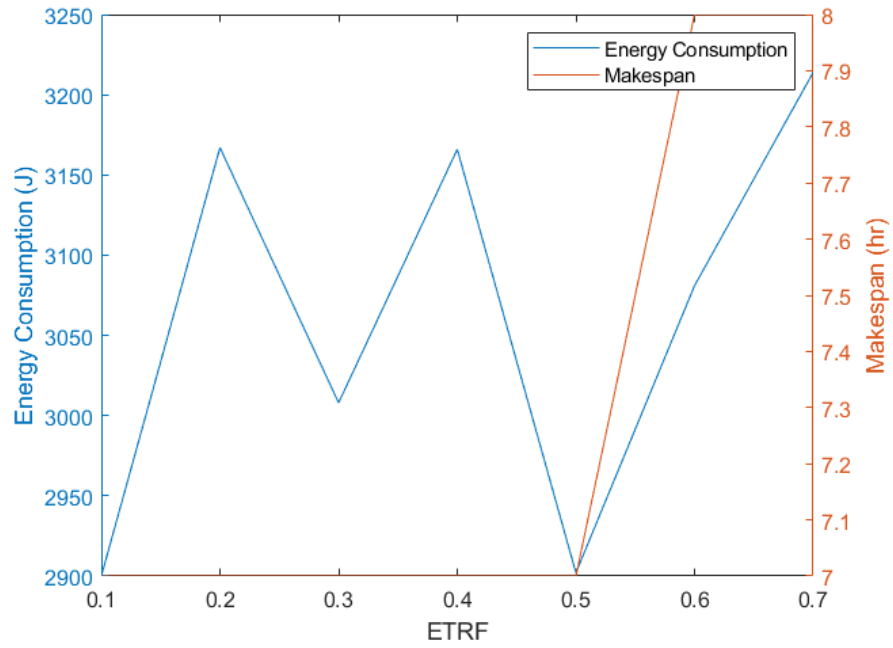


Figure 21: Influence of the ETRF on the EC and C_{max} for the 10 job size.

4.2.2 20 jobs

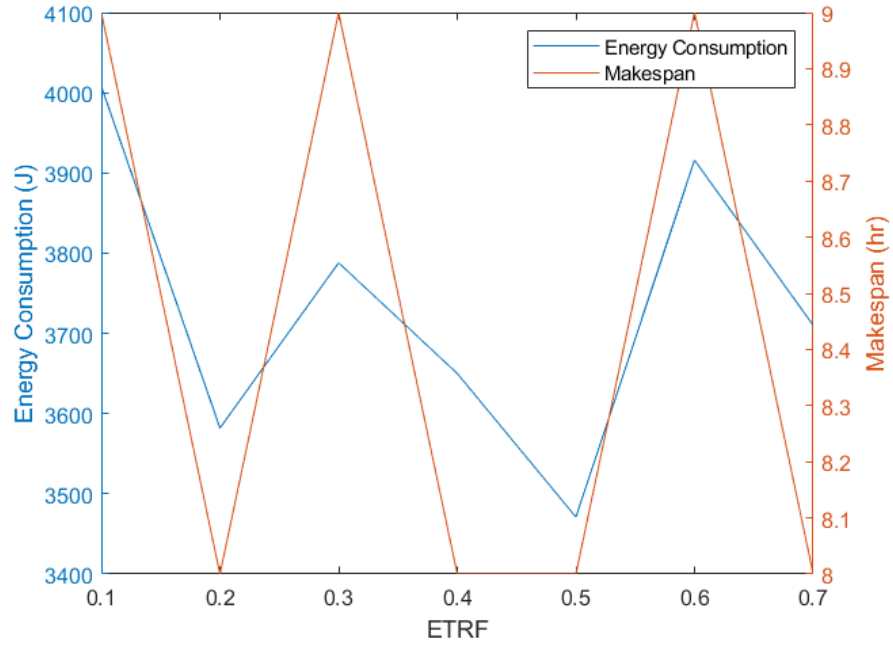


Figure 22: Influence of the ETRF on the EC and C_{max} for the 20 job size.

4.2.3 The 40 job size

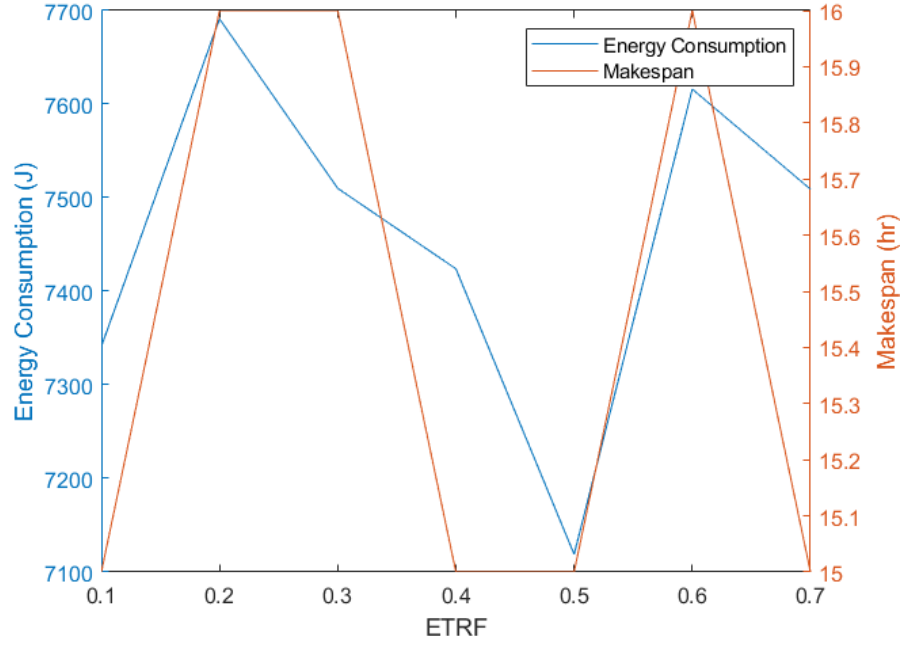


Figure 23: Influence of the ETRF on the EC and C_{max} for the 40 job size.