



FACULTAD DE INGENIERÍA

71.14 Modelos y optimización I

Trabajo Práctico N°3

1C 2024

Padrón: 93042

Nombre: Johana Añez

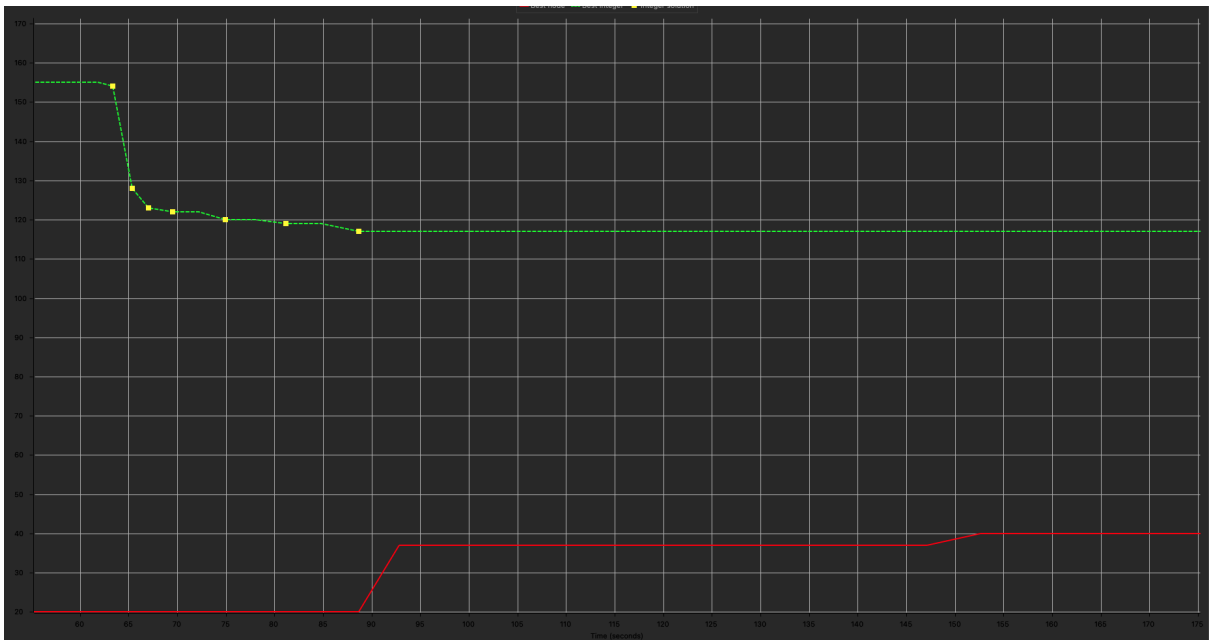
1.Resultado de mi heurística

```
Washes quantity: 11
Washes time: 123
Execution time 0.026001930236816406 seconds

Process finished with exit code 0
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2.Resultado de los primeros 3 minutos

Luego de dejarlo ejecutándose 3 minutos, puede verse que ambos resultados están lejos de converger, dando los resultados:
Mejor nodo: 40
No considero a este valor óptimo, además 3 minutos es un valor muy alto de ejecución con un resultado muy pobre.



Statistic	Value
▼ Cplex	
▼ MIP	
Objective	40
Incumbent	117
Nodes	5975
Remaining nodes	1829
Iterations	11025153

Elapsed time = 103.80 sec. (149247.04 ticks, tree = 13.34 MB, solutions = 15)
1721 1167 112.0000 271 117.0000 37.0000 3342640 68.38%

1738	1152	46.7436	1137	117.0000	37.0000	3292077	68.38%
1757	1187	54.1335	699	117.0000	37.0000	3421415	68.38%
1771	1201	46.2868	1451	117.0000	37.0000	3461316	68.38%
1787	1255	84.0000	524	117.0000	37.0000	3617610	68.38%
1800	1264	81.0000	751	117.0000	37.0000	3656682	68.38%
1818	1278	98.4936	408	117.0000	37.0000	3686069	68.38%
1844	1270	108.0000	303	117.0000	37.0000	3641192	68.38%
1890	1292	59.9613	1046	117.0000	37.0000	3733792	68.38%
1910	1292	50.5064	1279	117.0000	37.0000	3709694	68.38%
Elapsed time = 113.45 sec. (159251.65 ticks, tree = 15.20 MB, solutions = 15)							
1936	1351	110.9577	172	117.0000	37.0000	3902150	68.38%
1961	1368	53.0000	730	117.0000	37.0000	3936467	68.38%
1976	1356	37.0000	1574	117.0000	37.0000	3909364	68.38%
1992	1391	79.9752	954	117.0000	37.0000	3997917	68.38%
2010	1421	50.5064	1009	117.0000	37.0000	4101630	68.38%
2034	1422	53.0000	1169	117.0000	37.0000	4105204	68.38%
2059	1410	114.0000	371	117.0000	37.0000	4047716	68.38%
2084	1460	93.0000	552	117.0000	37.0000	4196701	68.38%
2116	1462	97.3999	532	117.0000	37.0000	4201476	68.38%
2151	1468	112.0000	552	117.0000	37.0000	4209223	68.38%
Elapsed time = 122.60 sec. (169166.98 ticks, tree = 17.25 MB, solutions = 15)							
2172	1518	112.0000	326	117.0000	37.0000	4355978	68.38%
2192	1572	102.0000	495	117.0000	37.0000	4478528	68.38%
2214	1524	66.0000	741	117.0000	37.0000	4380876	68.38%
2232	1552	59.0000	921	117.0000	37.0000	4448347	68.38%
2249	1542	47.4464	815	117.0000	37.0000	4424419	68.38%
2262	1599	99.8087	460	117.0000	37.0000	4558474	68.38%
2283	1604	109.0769	352	117.0000	37.0000	4567737	68.38%
2311	1610	57.0000	890	117.0000	37.0000	4610955	68.38%
2330	1618	58.6038	1035	117.0000	37.0000	4637670	68.38%
2393	1747	78.0000	629	117.0000	37.0000	5003371	68.38%
Elapsed time = 135.80 sec. (182237.36 ticks, tree = 20.69 MB, solutions = 15)							
2488	1792	93.0000	551	117.0000	37.0000	5133025	68.38%
2582	1900	48.4117	1287	117.0000	37.0000	5446139	68.38%
2679	1934	46.2868	979	117.0000	37.5963	5530060	67.87%
2762	2049	82.0000	661	117.0000	39.9816	5839728	65.83%
2864	2095	103.0000	450	117.0000	40.0000	5991596	65.81%
3016	2121	93.0000	610	117.0000	40.0000	6075934	65.81%
3165	2233	82.0000	765	117.0000	40.0000	6341977	65.81%
3247	2415	52.0000	1026	117.0000	40.0000	6703873	65.81%
3339	2437	84.4712	630	117.0000	40.0000	6768894	65.81%
3423	2562	95.0000	627	117.0000	40.0000	7144600	65.81%
Elapsed time = 172.05 sec. (221014.55 ticks, tree = 30.33 MB, solutions = 15)							
3532	2645	74.0000	445	117.0000	40.0000	7412180	65.81%
3578	2683	69.0000	664	117.0000	40.0000	7507880	65.81%

Performing restart 1

Repeating presolve.

Tried aggregator 1 time.

MIP Presolve eliminated 1108 rows and 552 columns.

Reduced MIP has 33675 rows, 18630 columns, and 119155 nonzeros.

Reduced MIP has 18492 binaries, 138 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.08 sec. (170.22 ticks)

Tried aggregator 1 time.

Reduced MIP has 33675 rows, 18630 columns, and 119155 nonzeros.

Reduced MIP has 18492 binaries, 138 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.08 sec. (167.19 ticks)

Represolve time = 0.35 sec. (464.32 ticks)

3599	0	22.7369	2077	117.0000	Cuts: 1228	7941322	65.81%
3599	0	23.1255	1915	117.0000	Cuts: 1381	7956059	65.81%
3599	0	23.4591	1692	117.0000	Cuts: 1812	7968707	65.81%
3599	0	23.6934	2032	117.0000	Cuts: 1554	7977739	65.81%
3599	0	23.8216	1840	117.0000	Cuts: 1153	7992473	65.81%
3599	0	24.0117	1985	117.0000	Cuts: 1588	8002945	65.81%
3599	0	24.1082	1838	117.0000	Cuts: 1465	8011696	65.81%

3599	0	24.2692	2246	117.0000	Cuts: 1618	8024004	65.81%
3599	2	24.2692	2246	117.0000	40.0000	8024004	65.81%
3600	3	24.4396	1856	117.0000	40.0000	8037019	65.81%
3602	3	32.3500	1012	117.0000	40.0000	8053550	65.81%
3608	9	39.0000	813	117.0000	40.0000	8090747	65.81%
3626	21	79.0112	540	117.0000	40.0000	8148740	65.81%
3654	41	79.6643	403	117.0000	40.0000	8226341	65.81%
3681	42	25.9967	1300	117.0000	40.0000	8275835	65.81%
3699	86	71.0000	563	117.0000	40.0000	8412357	65.81%
Elapsed time = 288.27 sec. (405769.15 ticks, tree = 5.48 MB, solutions = 15)							
3728	122	84.5809	419	117.0000	40.0000	8513209	65.81%
3775	152	72.0000	552	117.0000	40.0000	8636953	65.81%
3822	202	82.6294	448	117.0000	40.0000	8700656	65.81%
3856	135	33.0287	894	117.0000	40.0000	8624129	65.81%
3894	257	53.0000	875	117.0000	40.0000	8792043	65.81%
3939	268	50.3491	736	117.0000	40.0000	8801929	65.81%
4031	383	108.7908	229	117.0000	40.0000	8928889	65.81%
4124	402	34.2703	748	117.0000	40.0000	8992662	65.81%
4168	425	51.9958	553	117.0000	40.0000	9014018	65.81%
4231	560	85.8659	405	117.0000	40.0000	9167554	65.81%
Elapsed time = 329.55 sec. (445221.77 ticks, tree = 95.10 MB, solutions = 15)							
4315	604	94.1974	369	117.0000	40.0000	9177391	65.81%
4364	649	55.3286	698	117.0000	40.0000	9338616	65.81%
4405	611	40.1189	764	117.0000	40.0000	9281580	65.81%
4455	789	63.8774	517	117.0000	40.0000	9512399	65.81%
4497	751	78.3932	546	117.0000	40.0000	9458239	65.81%
4555	886	72.0934	587	117.0000	40.0000	9691014	65.81%
4622	891	80.0722	773	117.0000	40.0000	9701630	65.81%
4727	964	59.6506	636	117.0000	40.0000	9781159	65.81%
4853	933	103.0417	327	117.0000	40.0000	9745827	65.81%
5001	1085	37.0000	831	117.0000	40.0000	9876759	65.81%

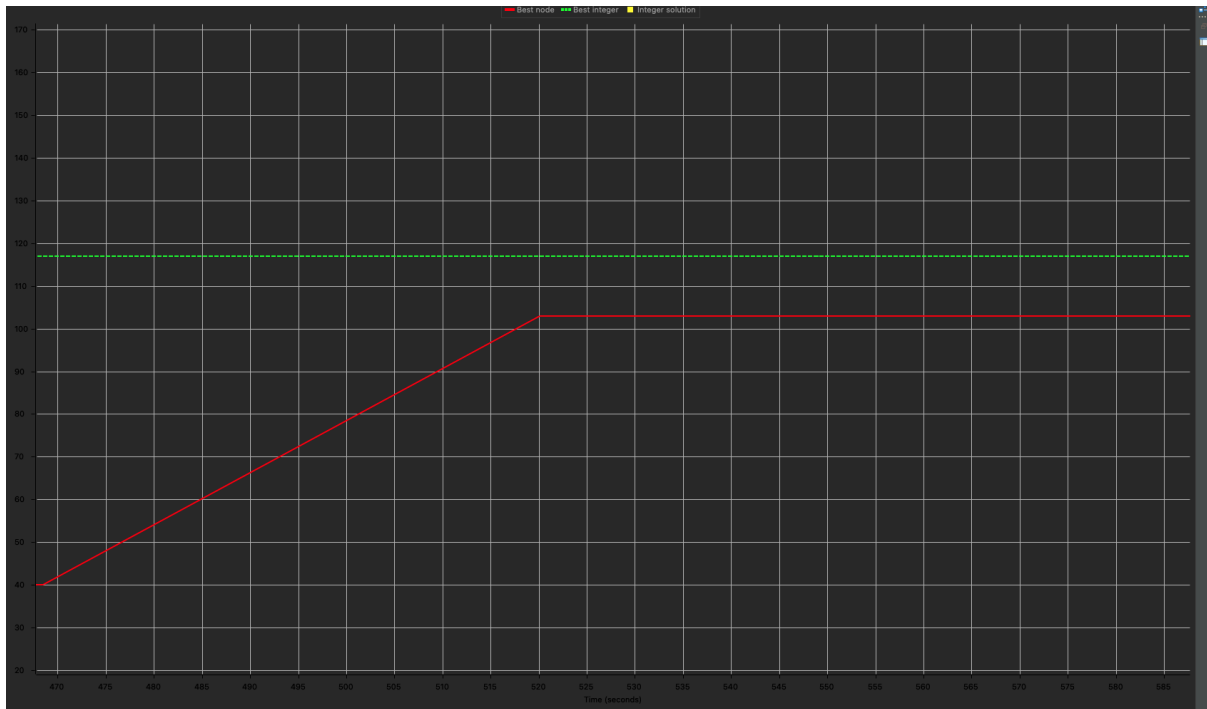
Resultado de los primeros 10 minutos

Luego de dejarlo ejecutándose 10 minutos, puede verse que ambos resultados están más cerca de converger, dando los resultados:

Mejor nodo: 103

Mejor entero: 117

Considero a este valor óptimo, siendo mejor resultado que la heurística propuesta, pero siendo el costo de ejecución muy alto.



✓ Cplex	
✓ MIP	
Objective	103
Incumbent	117
Nodes	21699
Remaining nodes	12479
Iterations	20883681

Elapsed time = 371.77 sec. (483984.85 ticks, tree = 230.83 MB, solutions = 15)

5052	1173	96.2356	529	117.0000	40.0000	9973893	65.81%
5112	1317	42.0000	596	117.0000	40.0000	10118828	65.81%
5170	1351	71.8158	451	117.0000	40.0000	10168584	65.81%
5262	1487	75.5055	483	117.0000	40.0000	10364889	65.81%
5315	1499	41.0132	899	117.0000	40.0000	10411443	65.81%
5390	1524	86.0000	457	117.0000	40.0000	10441344	65.81%
5507	1560	110.4000	377	117.0000	40.0000	10486768	65.81%
5711	1736	62.5375	624	117.0000	40.0000	10710284	65.81%
5827	1844	67.0000	558	117.0000	40.0000	10798910	65.81%
5937	1945	103.6400	213	117.0000	40.0000	10764640	65.81%

Elapsed time = 413.34 sec. (522516.95 ticks, tree = 476.28 MB, solutions = 15)

6075	1942	91.0000	506	117.0000	40.0000	10875351	65.81%
6255	2169	100.7438	361	117.0000	40.0000	11018194	65.81%
6501	2296	103.0813	393	117.0000	40.0000	11124339	65.81%
6748	2437	99.5010	275	117.0000	40.0000	11214909	65.81%
6920	2705	88.5607	318	117.0000	40.0000	11350272	65.81%
7145	2591	87.5570	399	117.0000	40.0000	11347994	65.81%
7281	3008	96.8057	299	117.0000	40.0000	11520962	65.81%
7369	3145	79.8982	365	117.0000	40.0000	11618329	65.81%
7471	3283	86.2812	563	117.0000	40.0000	11735248	65.81%
7571	3274	60.7416	628	117.0000	40.0000	11723654	65.81%

Elapsed time = 453.98 sec. (561118.63 ticks, tree = 856.66 MB, solutions = 15)

7616	3469	64.0000	761	117.0000	40.0000	11936786	65.81%
7684	3444	87.3505	571	117.0000	40.0000	11893539	65.81%
7776	3493	78.5714	433	117.0000	40.0000	11991204	65.81%
7921	3622	102.6988	372	117.0000	40.0000	12152705	65.81%
8025	3718	109.7917	338	117.0000	40.0000	12249923	65.81%
8072	3772	41.0000	848	117.0000	40.0000	12349176	65.81%
8095	3775	60.5000	587	117.0000	40.0000	12361375	65.81%

Performing restart 2

Repeating presolve.

Tried aggregator 1 time.

MIP Presolve eliminated 1034 rows and 0 columns.

Reduced MIP has 32641 rows, 18630 columns, and 160840 nonzeros.

Reduced MIP has 18492 binaries, 138 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.10 sec. (191.43 ticks)

Tried aggregator 1 time.

Reduced MIP has 32641 rows, 18630 columns, and 160840 nonzeros.

Reduced MIP has 18492 binaries, 138 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.11 sec. (168.56 ticks)

Represolve time = 0.42 sec. (505.67 ticks)

8098	0	102.0500	510	117.0000	Cuts: 345 12606090	12.78%
8098	0	103.0000	527	117.0000	Cuts: 707 12610006	11.97%
8098	0	103.0000	560	117.0000	Cuts: 618 12614233	11.97%
8098	0	103.0000	397	117.0000	Cuts: 47 12618013	11.97%
8098	0	103.0000	432	117.0000	Cuts: 627 12620759	11.97%
8098	0	103.0000	311	117.0000	Cuts: 33 12622883	11.97%
8098	0	103.0000	468	117.0000	Cuts: 516 12626657	11.97%
8098	0	103.0000	364	117.0000	Cuts: 91 12628900	11.97%
8098	0	103.0000	398	117.0000	Cuts: 528 12631574	11.97%
8098	0	103.0000	379	117.0000	Cuts: 144 12634636	11.97%
8098	0	103.0000	517	117.0000	Cuts: 528 12638625	11.97%
8098	0	103.0000	396	117.0000	Cuts: 123 12641203	11.97%
8098	0	103.0000	529	117.0000	Cuts: 552 12643977	11.97%
8098	2	103.0000	274	117.0000	103.0000 12643977	11.97%
8107	3	103.0000	283	117.0000	103.0000 12646248	11.97%
8160	32	103.0000	389	117.0000	103.0000 12697814	11.97%

Elapsed time = 527.44 sec. (656706.36 ticks, tree = 0.40 MB, solutions = 15)

8426	224	104.0000	412	117.0000	103.0000 12925301	11.97%
8637	430	109.0000	212	117.0000	103.0000 13167412	11.97%
9015	676	113.0000	171	117.0000	103.0000 13386564	11.97%
9297	859	106.0833	313	117.0000	103.0000 13578428	11.97%
9421	964	104.0000	408	117.0000	103.0000 13789719	11.97%
9581	1059	104.0000	405	117.0000	103.0000 13939317	11.97%
9667	1206	104.0000	416	117.0000	103.0000 14166338	11.97%
9845	1281	cutoff		117.0000	103.0000 14273537	11.97%
9991	1421	105.0000	389	117.0000	103.0000 14419560	11.97%
10270	1587	105.0000	284	117.0000	103.0000 14559878	11.97%

Elapsed time = 570.86 sec. (694970.32 ticks, tree = 19.93 MB, solutions = 15)

10617	2004	105.0000	285	117.0000	103.0000 14860184	11.97%
10955	2262	105.0000	306	117.0000	103.0000 15018401	11.97%
11457	2796	113.0000	206	117.0000	103.0000 15280228	11.97%
11815	3170	106.2500	226	117.0000	103.0000 15488062	11.97%
12004	3420	103.0000	772	117.0000	103.0000 15684944	11.97%
12163	3586	103.0000	570	117.0000	103.0000 15872112	11.97%
12373	3708	105.0000	351	117.0000	103.0000 15962139	11.97%
12549	3929	104.0000	417	117.0000	103.0000 16158364	11.97%
12683	4138	105.0000	456	117.0000	103.0000 16432744	11.97%
12817	4271	105.0000	380	117.0000	103.0000 16579126	11.97%

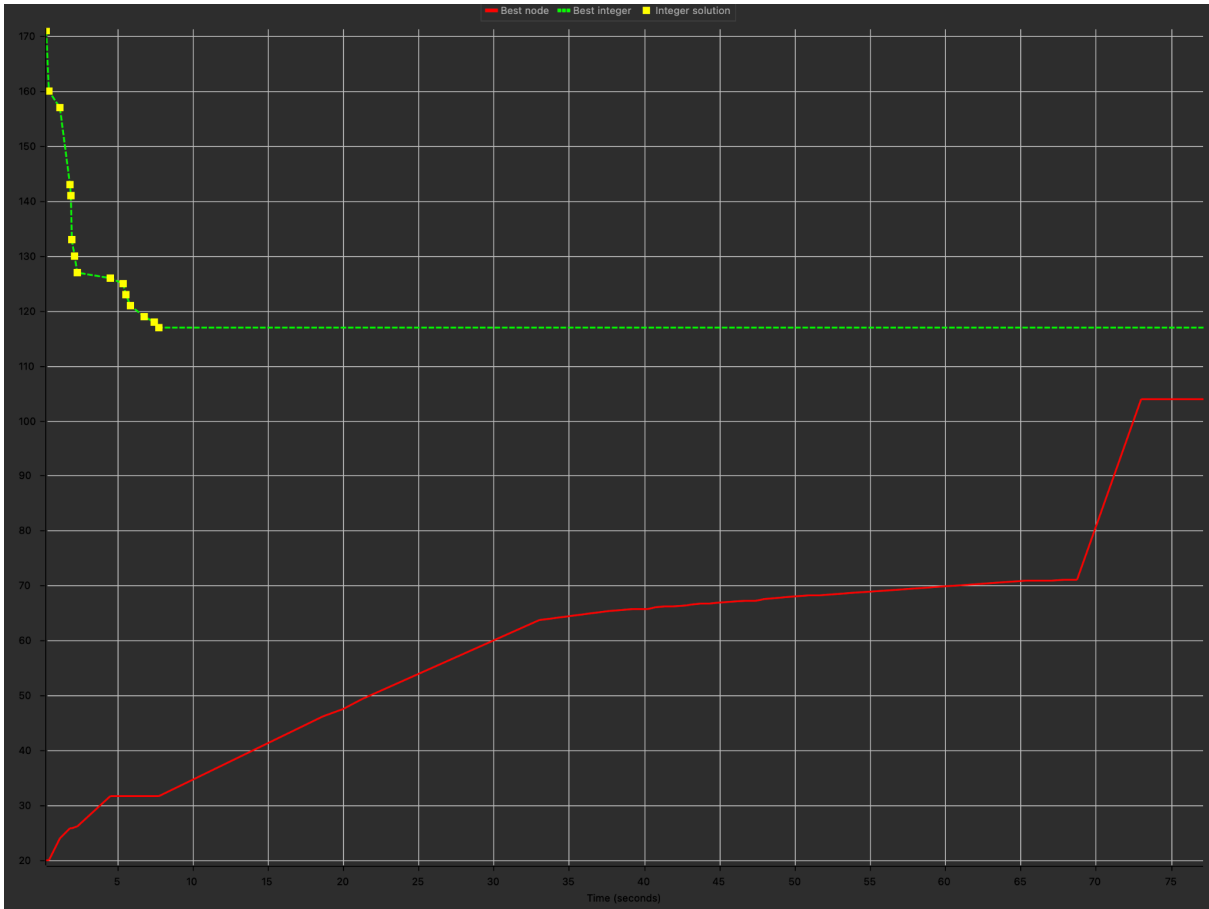
Elapsed time = 613.48 sec. (733264.55 ticks, tree = 49.91 MB, solutions = 15)

12914	4356	106.0000	380	117.0000	103.0000 16661831	11.97%
13091	4473	105.0000	381	117.0000	103.0000 16805965	11.97%
13351	4632	105.0000	282	117.0000	103.0000 16953242	11.97%
13595	4881	105.0000	274	117.0000	103.0000 17121247	11.97%
13904	5301	106.0000	315	117.0000	103.0000 17380096	11.97%
14166	5462	103.0000	348	117.0000	103.0000 17511949	11.97%
14534	5748	105.0000	336	117.0000	103.0000 17662577	11.97%
14890	5934	103.0000	549	117.0000	103.0000 17792298	11.97%
15340	6499	105.0000	308	117.0000	103.0000 18025760	11.97%
15791	7051	116.0000	146	117.0000	103.0000 18216262	11.97%

3. Resultado con cota de 15 lavados

Como puede verse en el gráfico, el óptimo del mejor entero vuelve a dar 117 pero

esta vez tarda solo menos de 6 segundos en arrojar dicho resultado.



Cplex	
MIP	
Objective	105
Incumbent	117
Nodes	82975
Remaining nodes	5262
Iterations	7853308

Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
Legacy callback pi
Tried aggregator 1 time.
MIP Presolve eliminated 13053 rows and 0 columns.
MIP Presolve modified 1347 coefficients.
Reduced MIP has 3945 rows, 2085 columns, and 13532 nonzeros.
Reduced MIP has 2070 binaries, 15 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.02 sec. (23.27 ticks)
Found incumbent of value 300.000000 after 0.02 sec. (37.25 ticks)
Probing time = 0.01 sec. (4.04 ticks)
Tried aggregator 1 time.
Detecting symmetries...
Reduced MIP has 3945 rows, 2085 columns, and 13532 nonzeros.
Reduced MIP has 2070 binaries, 15 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.01 sec. (12.94 ticks)
Probing time = 0.01 sec. (4.04 ticks)

Clique table members: 1875.

MIP emphasis: balance optimality and feasibility.

MIP search method: dynamic search.

Parallel mode: deterministic, using up to 10 threads.

Root relaxation solution time = 0.07 sec. (148.58 ticks)

Nodes		Cuts/					
Node	Left	Objective	Inf	Best Integer	Best Bound	ItCnt	Gap
*	0+	0		300.0000	0.0000	100.00%	
*	0+	0		171.0000	0.0000	100.00%	
	0	0	20.0000	1122	171.0000	20.0000	1881 88.30%
*	0+	0		160.0000	20.0000	87.50%	
	0	0	20.0000	1011	160.0000	Cuts: 421	3208 87.50%
	0	0	22.4548	989	160.0000	Cuts: 1063	7791 85.97%
	0	0	23.9665	989	160.0000	Cuts: 801	10265 85.02%
*	0+	0		158.0000	23.9665	84.83%	
*	0+	0		157.0000	23.9665	84.73%	
	0	0	-1.00000e+75	0	157.0000	23.9665	10265 84.73%
	0	0	24.4613	965	157.0000	Cuts: 740	12052 84.42%
	0	0	24.9326	850	157.0000	Cuts: 675	13256 84.12%
	0	0	25.1386	1022	157.0000	Cuts: 585	14443 83.99%
	0	0	25.3150	991	157.0000	Cuts: 591	15295 83.88%
	0	0	25.5137	947	157.0000	Cuts: 600	16090 83.75%
	0	0	25.7034	915	157.0000	Cuts: 472	16735 83.63%
	0	0	25.7748	918	157.0000	Cuts: 471	17307 83.58%
*	0+	0		143.0000	25.7748	81.98%	
	0	0	25.8173	979	143.0000	Cuts: 488	17842 81.95%
*	0+	0		141.0000	25.8173	81.69%	
	0	0	-1.00000e+75	0	141.0000	25.8173	17842 81.69%
*	0+	0		133.0000	25.8173	80.59%	
	0	0	25.8957	916	133.0000	Cuts: 506	18725 80.53%
	0	0	25.9713	938	133.0000	Cuts: 455	20147 80.47%
*	0+	0		130.0000	25.9713	80.02%	
	0	0	26.0392	917	130.0000	Cuts: 475	20717 79.97%
	0	0	26.1145	929	130.0000	Cuts: 515	21354 79.91%
	0	0	26.1361	1039	130.0000	Cuts: 418	21836 79.90%
*	0+	0		127.0000	26.1361	79.42%	
	0	0	26.1602	1020	127.0000	Cuts: 394	22228 79.40%
	0	0	26.1655	1122	127.0000	Cuts: 411	22642 79.40%
	0	0	26.1803	1057	127.0000	Cuts: 346	23010 79.39%
	0	0	26.1832	1047	127.0000	Cuts: 265	23309 79.38%
	0	0	26.1857	996	127.0000	Cuts: 136	23419 79.38%
	0	0	26.1952	1010	127.0000	Cuts: 403	23808 79.37%
	0	0	26.1995	1005	127.0000	Cuts: 387	24246 79.37%
	0	2	26.1995	969	127.0000	26.1995	24246 79.37%
Elapsed time = 3.10 sec. (5651.92 ticks, tree = 0.02 MB, solutions = 10)							
	2	4	27.2998	1004	127.0000	26.1995	28009 79.37%
	5	4	39.0723	751	127.0000	26.1995	29546 79.37%
	15	16	65.0000	488	127.0000	28.1924	50774 77.80%
	38	24	65.3557	570	127.0000	28.1944	59633 77.80%
	72	56	88.6830	322	127.0000	31.6330	90196 75.09%
	97	81	88.0000	437	127.0000	31.6330	107762 75.09%
	201	169	126.0000	24	127.0000	31.6330	126545 75.09%
*	208+	160	126.0000		31.6330	74.89%	
	240	211	96.0000	326	126.0000	31.6330	152861 74.89%
	299	274	111.7188	265	126.0000	31.6330	170300 74.89%
	558	478	109.0000	273	126.0000	31.6330	229642 74.89%
Elapsed time = 5.15 sec. (9013.96 ticks, tree = 6.45 MB, solutions = 11)							
*	596+	494	125.0000		31.6330	74.69%	
*	691+	566	124.0000		31.6330	74.49%	
*	691+	564	123.0000		31.6330	74.28%	
*	852+	650	122.0000		31.6330	74.07%	
*	873+	678	121.0000		31.6330	73.86%	
	926	654	96.0000	381	121.0000	31.6330	284032 73.86%
	1097	875	77.0000	508	121.0000	31.6330	353200 73.86%

* 1207+	914			120.0000	31.6330		73.64%
* 1227	909	integral	0	119.0000	31.6330	383923	73.42%
1538	1008	70.0000	530	119.0000	31.6330	404056	73.42%
* 1654	1137	integral	0	118.0000	31.6330	423539	73.19%
* 1841	1357	integral	0	117.0000	31.6330	472797	72.96%
1893	1350	77.0000	424	117.0000	31.6330	477146	72.96%
2209	1617	96.0000	316	117.0000	31.6330	552119	72.96%
2450	1891	88.6830	310	117.0000	40.8489	615323	65.09%
2908	2173	52.0000	609	117.0000	41.6000	668567	64.44%
3274	2399	88.0000	313	117.0000	43.2314	724317	63.05%
3624	2833	114.0000	139	117.0000	43.2618	789207	63.02%

Performing restart 1

Repeating presolve.

Tried aggregator 1 time.

MIP Presolve eliminated 124 rows and 60 columns.

Reduced MIP has 3821 rows, 2025 columns, and 13232 nonzeros.

Reduced MIP has 2010 binaries, 15 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.01 sec. (15.58 ticks)

Tried aggregator 1 time.

Reduced MIP has 3821 rows, 2025 columns, and 13232 nonzeros.

Reduced MIP has 2010 binaries, 15 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.01 sec. (12.70 ticks)

Represolve time = 0.05 sec. (54.55 ticks)

3766	0	39.5690	738	117.0000	Cuts: 482	848015	62.91%
3766	0	40.2732	806	117.0000	Cuts: 729	848994	62.91%
3766	0	41.1429	721	117.0000	Cuts: 782	850907	62.91%
3766	0	42.0545	689	117.0000	Cuts: 733	852342	62.91%
3766	0	42.6427	664	117.0000	Cuts: 751	853344	62.91%
3766	0	43.3274	731	117.0000	Cuts: 768	855230	62.91%
3766	0	43.6261	729	117.0000	Cuts: 727	856183	62.71%
3766	0	44.0244	705	117.0000	Cuts: 721	857334	62.37%
3766	0	44.4345	705	117.0000	Cuts: 699	858237	62.02%
3766	0	45.0832	725	117.0000	Cuts: 660	859293	61.47%
3766	0	45.2199	688	117.0000	Cuts: 731	860502	61.35%
3766	0	45.3624	697	117.0000	Cuts: 671	861822	61.23%
3766	0	45.4222	659	117.0000	Cuts: 614	862528	61.18%
3766	0	45.4734	691	117.0000	Cuts: 623	863430	61.13%
3766	0	45.4790	706	117.0000	Cuts: 626	863851	61.13%
3766	0	45.6013	715	117.0000	Cuts: 624	864375	61.02%
3766	0	45.6504	707	117.0000	Cuts: 672	865226	60.98%
3766	0	45.6667	700	117.0000	Cuts: 677	866062	60.97%
3766	0	45.7092	693	117.0000	Cuts: 732	866528	60.93%
3766	0	45.7439	700	117.0000	Cuts: 676	867179	60.90%
3766	0	45.7929	741	117.0000	Cuts: 645	867728	60.86%
3766	0	45.8166	672	117.0000	Cuts: 720	868396	60.84%
3766	0	45.8785	710	117.0000	Cuts: 735	869493	60.79%
3766	0	45.9312	662	117.0000	Cuts: 707	870662	60.74%
3766	0	45.9574	695	117.0000	Cuts: 719	871620	60.72%
3766	0	45.9958	695	117.0000	Cuts: 723	872355	60.69%
3766	0	46.0422	661	117.0000	Cuts: 657	873444	60.65%
3766	0	46.0719	673	117.0000	Cuts: 782	874151	60.62%
3766	0	46.1237	633	117.0000	Cuts: 732	874604	60.58%
3766	0	46.1540	688	117.0000	Cuts: 708	875660	60.55%
3766	0	46.1593	680	117.0000	Cuts: 642	876357	60.55%
3766	0	46.2216	626	117.0000	Cuts: 251	877030	60.49%
3766	0	46.2216	668	117.0000	Cuts: 746	877409	60.49%
3766	0	46.2228	670	117.0000	Cuts: 301	877735	60.49%
3766	0	46.2425	666	117.0000	Cuts: 385	878209	60.48%
3766	0	46.2599	653	117.0000	Cuts: 670	878774	60.46%
3766	0	46.2668	673	117.0000	Cuts: 596	879371	60.46%
3766	2	46.2668	632	117.0000	46.2668	879371	60.46%

Elapsed time = 18.56 sec. (29021.91 ticks, tree = 0.02 MB, solutions = 20)

3769	4	64.3177	423	117.0000	46.7037	881424	60.08%
3791	11	63.8769	483	117.0000	47.0496	885871	59.79%

3840	46	48.2961	568	117.0000	48.2997	898214	58.72%
3937	125	61.6758	494	117.0000	49.2879	923635	57.87%
4076	205	73.9716	390	117.0000	49.2879	944346	57.87%
4486	550	100.1451	297	117.0000	49.2879	997130	57.87%
5030	1038	98.1521	430	117.0000	51.7716	1063586	55.75%
5475	1370	67.5912	517	117.0000	51.7716	1136209	55.75%
6029	1817	81.7903	424	117.0000	54.3729	1214276	53.53%
6824	2240	97.1059	360	117.0000	54.3729	1256208	53.53%
Elapsed time = 24.00 sec. (38723.26 ticks, tree = 61.04 MB, solutions = 20)							
7704	3356	82.0417	373	117.0000	55.4813	1348176	52.58%
8622	4082	99.3137	332	117.0000	55.4813	1409402	52.58%
9517	5098	101.0000	269	117.0000	57.8379	1499913	50.57%
10285	5723	70.5642	406	117.0000	58.1958	1554243	50.26%
11025	6582	93.4295	322	117.0000	59.4200	1655124	49.21%
12015	7171	89.4308	364	117.0000	59.4200	1713329	49.21%
12730	7994	113.0901	275	117.0000	59.9890	1786378	48.73%
13715	8857	114.9000	167	117.0000	60.1206	1856214	48.61%
14677	9759	108.9167	265	117.0000	60.6339	1930347	48.18%
15463	10284	110.0000	218	117.0000	60.9422	1983232	47.91%
Elapsed time = 29.49 sec. (48274.08 ticks, tree = 277.42 MB, solutions = 20)							
16386	11109	108.7914	179	117.0000	61.4250	2065033	47.50%
17200	11797	86.5882	387	117.0000	62.4291	2136940	46.64%
18110	12849	91.5405	420	117.0000	62.8209	2232520	46.31%
19019	13670	107.1250	290	117.0000	63.3163	2310299	45.88%
19675	14471	106.6695	283	117.0000	63.6595	2389821	45.59%
20408	15196	115.1417	213	117.0000	63.8958	2475371	45.39%
21220	15513	91.9814	364	117.0000	64.0000	2525068	45.30%
22107	16585	87.7090	371	117.0000	64.2297	2634833	45.10%
23127	17368	109.0000	236	117.0000	64.4077	2699843	44.95%
24101	18461	92.0186	393	117.0000	64.5685	2788588	44.81%
Elapsed time = 35.25 sec. (57823.78 ticks, tree = 533.56 MB, solutions = 20)							
24828	19098	82.7976	407	117.0000	64.8067	2852974	44.61%
25699	19782	104.0000	276	117.0000	64.8818	2929529	44.55%
26437	20178	83.0758	357	117.0000	65.2265	2974141	44.25%
27337	21304	88.0000	424	117.0000	65.2667	3084710	44.22%
28483	22178	99.4308	299	117.0000	65.4418	3155539	44.07%
29308	22751	85.5556	389	117.0000	65.6300	3205700	43.91%
29944	23836	109.1510	279	117.0000	65.6395	3303010	43.90%
30755	24616	93.6073	430	117.0000	65.7509	3397674	43.80%
31682	25083	101.0000	331	117.0000	65.8864	3452351	43.69%
32698	26202	81.8969	428	117.0000	66.0259	3552726	43.57%
Elapsed time = 40.85 sec. (67370.59 ticks, tree = 749.68 MB, solutions = 20)							
33546	26474	87.0662	396	117.0000	66.2898	3576137	43.34%
34350	27836	83.5405	409	117.0000	66.3438	3707807	43.30%
35122	28104	101.7062	302	117.0000	66.4935	3739978	43.17%
36009	28967	75.4986	420	117.0000	66.6016	3826232	43.08%
36577	29908	108.9615	261	117.0000	66.6910	3918665	43.00%
37491	30303	110.4308	263	117.0000	66.7301	3965209	42.97%
38557	31089	112.8667	185	117.0000	66.8804	4032071	42.84%
39171	31648	87.0662	396	117.0000	67.0508	4086934	42.69%
39765	33083	92.0186	372	117.0000	67.1834	4233786	42.58%
40180	33443	110.0109	372	117.0000	67.2185	4280644	42.55%
Elapsed time = 46.76 sec. (76925.00 ticks, tree = 942.40 MB, solutions = 20)							
40780	33481	88.0000	351	117.0000	67.2185	4287693	42.55%
41708	34481	90.8603	390	117.0000	67.4119	4386491	42.38%
42620	35224	101.3081	277	117.0000	67.6647	4454930	42.17%
43452	36047	96.6429	364	117.0000	67.8910	4541621	41.97%
44427	36443	91.5405	347	117.0000	67.9889	4577037	41.89%
45346	37368	102.1250	260	117.0000	68.0985	4656076	41.80%
46252	38685	104.0000	262	117.0000	68.2061	4778432	41.70%
47234	39042	110.7883	277	117.0000	68.2421	4815365	41.67%
48040	40168	90.8601	427	117.0000	68.3243	4907538	41.60%
48981	40572	87.5607	368	117.0000	68.3243	4952927	41.60%
Elapsed time = 52.50 sec. (86474.63 ticks, tree = 1148.28 MB, solutions = 20)							
49888	41216	110.0000	266	117.0000	68.5638	5014068	41.40%
50829	42119	111.9000	301	117.0000	68.6332	5092487	41.34%

51832	42777	87.0662	454	117.0000	68.7911	5148787	41.20%
52880	43604	96.0000	394	117.0000	68.9289	5232936	41.09%
53931	45013	103.7164	293	117.0000	69.0079	5346398	41.02%
54724	45674	101.7995	277	117.0000	69.1030	5398696	40.94%
55731	46706	92.0000	443	117.0000	69.2273	5488289	40.83%
56551	47808	91.5405	357	117.0000	69.3229	5589228	40.75%
57457	48296	96.0000	370	117.0000	69.4701	5639700	40.62%
58404	49800	113.1250	201	117.0000	69.5635	5771741	40.54%

Elapsed time = 58.37 sec. (96018.64 ticks, tree = 1430.47 MB, solutions = 20)

59152	49994	78.7542	437	117.0000	69.6977	5787425	40.43%
59999	50308	97.9929	372	117.0000	69.7976	5825555	40.34%
60679	51395	83.6637	433	117.0000	69.9694	5936010	40.20%
61553	52255	89.3527	315	117.0000	70.0598	6027413	40.12%
62257	52735	96.6429	369	117.0000	70.0637	6080650	40.12%
63286	53284	114.0000	122	117.0000	70.2268	6126543	39.98%
64224	55229	96.0000	312	117.0000	70.3287	6314673	39.89%
65045	54887	112.0000	220	117.0000	70.3401	6277247	39.88%
65929	56050	101.6307	298	117.0000	70.5574	6377329	39.69%
69611	60124	110.1705	247	117.0000	70.8829	6739034	39.42%

Elapsed time = 65.85 sec. (108438.21 ticks, tree = 1766.78 MB, solutions = 20)

73005	62312	87.0662	291	117.0000	71.0539	6949199	39.27%
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Performing restart 2

Repeating presolve.

Tried aggregator 1 time.

MIP Presolve eliminated 130 rows and 0 columns.

Reduced MIP has 3691 rows, 2025 columns, and 19179 nonzeros.

Reduced MIP has 2010 binaries, 15 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.01 sec. (19.74 ticks)

Tried aggregator 1 time.

Reduced MIP has 3691 rows, 2025 columns, and 19179 nonzeros.

Reduced MIP has 2010 binaries, 15 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.01 sec. (17.13 ticks)

Represolve time = 0.34 sec. (120.04 ticks)

75619	0	104.0000	344	117.0000	Cuts: 130	7287490	11.11%
75619	0	104.0000	416	117.0000	Cuts: 430	7288051	11.11%
75619	0	104.0000	307	117.0000	Cuts: 83	7288483	11.11%
75619	0	104.0000	332	117.0000	Cuts: 494	7288777	11.11%
75619	0	104.0000	288	117.0000	Cuts: 40	7289128	11.11%
75619	0	104.0000	376	117.0000	Cuts: 440	7289590	11.11%
75619	0	104.0000	330	117.0000	Cuts: 117	7290205	11.11%
75619	0	104.0000	339	117.0000	Cuts: 359	7290559	11.11%
75619	0	104.0000	204	117.0000	Cuts: 46	7290867	11.11%
75619	0	104.0000	318	117.0000	Cuts: 343	7291281	11.11%
75619	0	104.0000	282	117.0000	Cuts: 132	7291630	11.11%
75619	0	104.0000	325	117.0000	Cuts: 379	7292006	11.11%
75619	2	104.0000	147	117.0000	104.0000	7292006	11.11%
75660	27	106.0000	258	117.0000	104.0000	7299273	11.11%
75888	121	112.0000	212	117.0000	104.0000	7331327	11.11%
77529	692	109.3333	320	117.0000	105.0000	7404946	10.26%
81113	4249	112.0000	270	117.0000	105.0000	7676313	10.26%
83527	6480	105.2000	456	117.0000	105.0000	7876219	10.26%
85960	8797	108.0000	383	117.0000	105.2552	8095891	10.04%
88633	10730	115.0000	226	117.0000	106.0000	8284606	9.40%
91358	13415	114.0000	291	117.0000	106.0000	8516490	9.40%

Elapsed time = 91.37 sec. (150481.99 ticks, tree = 350.92 MB, solutions = 20)

93960	15351	116.0000	205	117.0000	106.0000	8701775	9.40%
96785	17922	114.0000	320	117.0000	106.0000	8924195	9.40%
99193	20345	115.0000	213	117.0000	106.0000	9143861	9.40%
101752	22283	115.5464	429	117.0000	106.0000	9330109	9.40%
104045	24318	115.0000	227	117.0000	106.0000	9527102	9.40%
106449	26479	114.0000	300	117.0000	106.0000	9730865	9.40%
108535	28249	116.0000	239	117.0000	106.0000	9925969	9.40%
110762	30010	107.0000	429	117.0000	106.0000	10096806	9.40%
112790	31671	115.7500	307	117.0000	106.0000	10278945	9.40%

114409 33062	110.7222	314	117.0000	106.0000	10426317	9.40%
Elapsed time = 113.93 sec. (188642.95 ticks, tree = 1020.51 MB, solutions = 20)						
115958 34916	107.6010	449	117.0000	106.0000	10645655	9.40%
117322 36023	106.1236	365	117.0000	106.0021	10788224	9.40%
119036 37092	116.0000	241	117.0000	106.0036	10931446	9.40%
120852 38458	116.0000	293	117.0000	106.0166	11087836	9.39%
122573 40417	110.7473	359	117.0000	106.0323	11284497	9.37%
123861 41497	112.0000	331	117.0000	106.0626	11445173	9.35%
125612 42763	112.0000	327	117.0000	106.1176	11610620	9.30%
127184 44403	116.0000	309	117.0000	106.1520	11793919	9.27%
128763 45961	112.0000	355	117.0000	106.2789	12001185	9.16%
130635 47041	114.0000	312	117.0000	106.3086	12129830	9.14%
Elapsed time = 135.29 sec. (226830.27 ticks, tree = 1513.30 MB, solutions = 20)						
132135 48608	116.0000	286	117.0000	106.4061	12322904	9.05%

4. Resultado con simetría

Como vemos, en este caso el resultado converge rápidamente a 117, y solo le tomó 69 segundos, en ese momento el programa terminó de correr y no cambió el output generado.



Statistic	Value
▼ Cplex	
▼ MIP	
Objective	103.739244
Incumbent	117
Nodes	5458
Remaining nodes	1
Iterations	439510

Scripting log

solution: 117 /size: 138 /time: 1718767192.069113016

Nodo 1: 1
Nodo 2: 1
Nodo 3: 1
Nodo 4: 1
Nodo 5: 1
Nodo 6: 3
Nodo 7: 3
Nodo 8: 3
Nodo 9: 1
Nodo 10: 2
Nodo 11: 1
Nodo 12: 2
Nodo 13: 2
Nodo 14: 1
Nodo 15: 1
Nodo 16: 3
Nodo 17: 1
Nodo 18: 4
Nodo 19: 1
Nodo 20: 9
Nodo 21: 7
Nodo 22: 1
Nodo 23: 1
Nodo 24: 2
Nodo 25: 1
Nodo 26: 5
Nodo 27: 2
Nodo 28: 3
Nodo 29: 2
Nodo 30: 1
Nodo 31: 1
Nodo 32: 5
Nodo 33: 1
Nodo 34: 1
Nodo 35: 2
Nodo 36: 8
Nodo 37: 4
Nodo 38: 1
Nodo 39: 1
Nodo 40: 2
Nodo 41: 2
Nodo 42: 1
Nodo 43: 1
Nodo 44: 3
Nodo 45: 6
Nodo 46: 2
Nodo 47: 1
Nodo 48: 1
Nodo 49: 1
Nodo 50: 2
Nodo 51: 1
Nodo 52: 2
Nodo 53: 2
Nodo 54: 8
Nodo 55: 1
Nodo 56: 1
Nodo 57: 6
Nodo 58: 11
Nodo 59: 1
Nodo 60: 3
Nodo 61: 4
Nodo 62: 1
Nodo 63: 1
Nodo 64: 9

Nodo 65: 1
Nodo 66: 1
Nodo 67: 2
Nodo 68: 1
Nodo 69: 4
Nodo 70: 4
Nodo 71: 1
Nodo 72: 7
Nodo 73: 2
Nodo 74: 11
Nodo 75: 1
Nodo 76: 2
Nodo 77: 1
Nodo 78: 10
Nodo 79: 1
Nodo 80: 1
Nodo 81: 10
Nodo 82: 1
Nodo 83: 6
Nodo 84: 2
Nodo 85: 1
Nodo 86: 1
Nodo 87: 1
Nodo 88: 1
Nodo 89: 3
Nodo 90: 1
Nodo 91: 1
Nodo 92: 3
Nodo 93: 1
Nodo 94: 7
Nodo 95: 3
Nodo 96: 1
Nodo 97: 4
Nodo 98: 1
Nodo 99: 6
Nodo 100: 5
Nodo 101: 3
Nodo 102: 1
Nodo 103: 1
Nodo 104: 1
Nodo 105: 1
Nodo 106: 1
Nodo 107: 1
Nodo 108: 6
Nodo 109: 1
Nodo 110: 1
Nodo 111: 3
Nodo 112: 1
Nodo 113: 1
Nodo 114: 1
Nodo 115: 10
Nodo 116: 9
Nodo 117: 2
Nodo 118: 7
Nodo 119: 1
Nodo 120: 2
Nodo 121: 1
Nodo 122: 6
Nodo 123: 2
Nodo 124: 2
Nodo 125: 1
Nodo 126: 6
Nodo 127: 1
Nodo 128: 1
Nodo 129: 1
Nodo 130: 3

Nodo 131: 4
 Nodo 132: 1
 Nodo 133: 2
 Nodo 134: 3
 Nodo 135: 7
 Nodo 136: 2
 Nodo 137: 2
 Nodo 138: 5

Engine log

Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
 Legacy callback pi
 Tried aggregator 1 time.
 MIP Presolve eliminated 120489 rows and 0 columns.
 MIP Presolve modified 11991 coefficients.
 Reduced MIP has 34898 rows, 19182 columns, and 122062 nonzeros.
 Reduced MIP has 19044 binaries, 138 generals, 0 SOSs, and 0 indicators.
 Presolve time = 0.17 sec. (253.34 ticks)
 Found incumbent of value 2760.000000 after 0.27 sec. (465.00 ticks)
 Probing time = 0.05 sec. (13.12 ticks)
 Tried aggregator 1 time.
 Detecting symmetries...
 Reduced MIP has 34898 rows, 19182 columns, and 122062 nonzeros.
 Reduced MIP has 19044 binaries, 138 generals, 0 SOSs, and 0 indicators.
 Presolve time = 0.07 sec. (144.06 ticks)
 Probing time = 0.05 sec. (12.15 ticks)
 Clique table members: 15717.
 MIP emphasis: balance optimality and feasibility.
 MIP search method: dynamic search.
 Parallel mode: deterministic, using up to 10 threads.
 Root relaxation solution time = 2.16 sec. (1116.33 ticks)

	Nodes			Cuts/					
	Node	Left	Objective	Inf	Best Integer	Best Bound	ItCnt	Gap	
*	0+	0			2760.0000	0.0000	100.00%		
*	0+	0			2631.0000	0.0000	100.00%		
*	0+	0			2442.0000	0.0000	100.00%		
*	0+	0			2298.0000	0.0000	100.00%		
*	0+	0			2201.0000	0.0000	100.00%		
*	0+	0			2126.0000	0.0000	100.00%		
*	0+	0			2116.0000	0.0000	100.00%		
	0	0	20.0000	10405	2116.0000	20.0000	12	99.05%	
*	0+	0			2008.0000	20.0000	99.00%		
*	0+	0			1917.0000	20.0000	98.96%		
	0	0	20.9262	10062	1917.0000	Cuts: 1840	2328	98.91%	
	0	0	25.2400	8574	1917.0000	Cuts: 1302	18593	98.68%	
*	0+	0			203.0000	25.2400	87.57%		
	0	0	31.6025	6106	203.0000	Cuts: 950	64697	84.43%	
*	0+	0			199.0000	31.6025	84.12%		
	0	0	-1.00000e+75	0	199.0000	31.6025	64697	84.12%	
*	0+	0			177.0000	31.6025	82.15%		
*	0+	0			152.0000	31.6025	79.21%		
*	0+	0			146.0000	31.6025	78.35%		
*	0+	0			134.0000	31.6025	76.42%		
*	0+	0			131.0000	31.6025	75.88%		
*	0+	0			127.0000	31.6025	75.12%		
*	0+	0			126.0000	31.6025	74.92%		
*	0+	0			125.0000	31.6025	74.72%		
*	0+	0			124.0000	31.6025	74.51%		
	0	0	-1.00000e+75	0	124.0000	31.6025	90806	74.51%	

Repeating presolve.

Tried aggregator 1 time.

MIP Presolve eliminated 8221 rows and 4805 columns.

MIP Presolve modified 1935 coefficients.

Reduced MIP has 26677 rows, 14377 columns, and 92212 nonzeros.

Reduced MIP has 14239 binaries, 138 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.06 sec. (104.68 ticks)

Probing time = 0.06 sec. (24.30 ticks)

Tried aggregator 1 time.

Detecting symmetries...

Reduced MIP has 26677 rows, 14377 columns, and 92212 nonzeros.

Reduced MIP has 14239 binaries, 138 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.06 sec. (103.50 ticks)

Represolve time = 0.24 sec. (383.95 ticks)

Probing time = 0.06 sec. (24.27 ticks)

Clique table members: 12304.

MIP emphasis: balance optimality and feasibility.

MIP search method: dynamic search.

Parallel mode: deterministic, using up to 10 threads.

Root relaxation solution time = 5.49 sec. (953.00 ticks)

Nodes		Cuts/					
Node	Left	Objective	Inf	Best Integer	Best Bound	ItCnt	Gap
*	0+	0		124.0000	31.6025	74.51%	
	0	0	36.0588	680	124.0000	36.0588	90840 70.92%
*	0+	0		122.0000	36.0588	70.44%	
	0	0	40.4295	2139	122.0000	Cuts: 288	116038 66.86%
*	0+	0		121.0000	40.4295	66.59%	
	0	0	43.9915	1463	121.0000	Cuts: 312	124273 55.99%
	0	0	44.0690	1196	121.0000	Cuts: 212	126863 55.99%
*	0+	0		120.0000	53.2484	55.63%	
*	0+	0		119.0000	53.2484	55.25%	
*	0+	0		118.0000	53.2484	54.87%	
*	0+	0		117.0000	53.2484	54.49%	
	0	0	-1.00000e+75	0	117.0000	53.2484	126863 54.49%
	0	0	44.1898	1109	117.0000	Cuts: 128	128720 54.49%
	0	0	44.2728	1028	117.0000	Cuts: 132	129447 54.49%
	0	0	44.3409	1009	117.0000	Cuts: 143	130103 54.49%
	0	0	44.3611	953	117.0000	Cuts: 121	130505 54.49%
	0	0	44.3797	700	117.0000	Cuts: 134	131078 54.49%
	0	0	44.3822	1144	117.0000	Cuts: 119	131560 54.49%
	0	0	44.3921	967	117.0000	Cuts: 117	132041 46.58%
	0	0	44.4334	993	117.0000	Cuts: 142	132543 46.58%

Detecting symmetries...

0 2 44.6428 880 117.0000 68.6904 134039 41.29%

Elapsed time = 57.56 sec. (99543.96 ticks, tree = 0.02 MB, solutions = 26)

1	3	45.2021	459	117.0000	68.6904	135110	41.29%
6	6	45.6842	433	117.0000	68.6904	135914	41.29%
42	18	100.3880	219	117.0000	68.6904	142491	41.29%
100	43	58.3957	428	117.0000	68.6904	153359	41.29%
172	87	108.0959	182	117.0000	68.6904	165431	41.29%
290	139	84.6917	345	117.0000	68.6904	173061	41.29%
457	247	105.5000	160	117.0000	68.6904	187333	41.29%
624	286	110.0519	317	117.0000	68.6904	196240	41.29%
728	402	110.3995	234	117.0000	68.6904	209365	41.29%

1500 825 114.5383 157 117.0000 68.6904 243267 41.29%

Elapsed time = 59.44 sec. (102679.12 ticks, tree = 5.81 MB, solutions = 26)

1977	1196	112.7143	129	117.0000	85.3632	277766	27.04%
2852	1598	115.0000	127	117.0000	91.4236	309619	21.86%
3488	1795	113.2045	174	117.0000	96.1843	350189	17.79%
4316	2244	110.9415	278	117.0000	100.3923	380514	14.19%
5351	2544	cutoff		117.0000	103.0274	416168	11.94%

Performing restart 1

Repeating presolve.


```

Tried aggregator 4 times.
MIP Presolve eliminated 22495 rows and 11831 columns.
MIP Presolve modified 196 coefficients.
Aggregator did 15 substitutions.
Reduced MIP has 4167 rows, 2531 columns, and 12981 nonzeros.
Reduced MIP has 2416 binaries, 115 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.02 sec. (36.55 ticks)
Tried aggregator 1 time.
Reduced MIP has 4167 rows, 2531 columns, and 12981 nonzeros.
Reduced MIP has 2417 binaries, 114 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.01 sec. (12.09 ticks)
Represolve time = 0.13 sec. (426.87 ticks)
 5458 0      46.6671 586    117.0000      Cuts: 530 433679 11.33%
 5458 0      46.7479 549    117.0000      Cuts: 478 434215 11.33%
 5458 0      46.8309 589    117.0000      Cuts: 544 434976 11.33%
 5458 0      46.9051 553    117.0000      Cuts: 271 435449 11.33%
 5458 0      46.9420 538    117.0000      Cuts: 490 435863 11.33%
 5458 0      47.1574 600    117.0000      Cuts: 474 436633 11.33%
 5458 0      47.3545 563    117.0000      Cuts: 238 437075 11.33%
 5458 0      47.5337 623    117.0000      Cuts: 550 438252 11.33%
 5458 0      47.6616 571    117.0000      Cuts: 169 438748 11.33%
 5458 0      47.7342 531    117.0000      Cuts: 543 439153 11.33%
 5458 0      47.7641 531    117.0000      Cuts: 459 439510 11.33%
 5458 2      47.7641 517    117.0000      103.7392 439510 11.33%
 5468 4      108.0000 227    117.0000      103.7392 442612 11.33%
 5493 4      92.4000 249    117.0000      103.7392 444322 11.33%
 5760 8      49.6370 453    117.0000      103.7392 458093 11.33%
 6192 45     114.3636 121    117.0000      103.7392 499379 11.33%
Elapsed time = 67.04 sec. (115548.12 ticks, tree = 0.07 MB, solutions = 26)
 7193 48     113.2074 254    117.0000      103.7392 557684 11.33%
 9006 77     116.0000 107    117.0000      103.7392 600051 11.33%
11023 209    115.0000 113    117.0000      103.7392 665392 11.33%

Clique cuts applied: 12
Implied bound cuts applied: 47
Flow cuts applied: 73
Mixed integer rounding cuts applied: 136
Zero-half cuts applied: 72
Gomory fractional cuts applied: 13

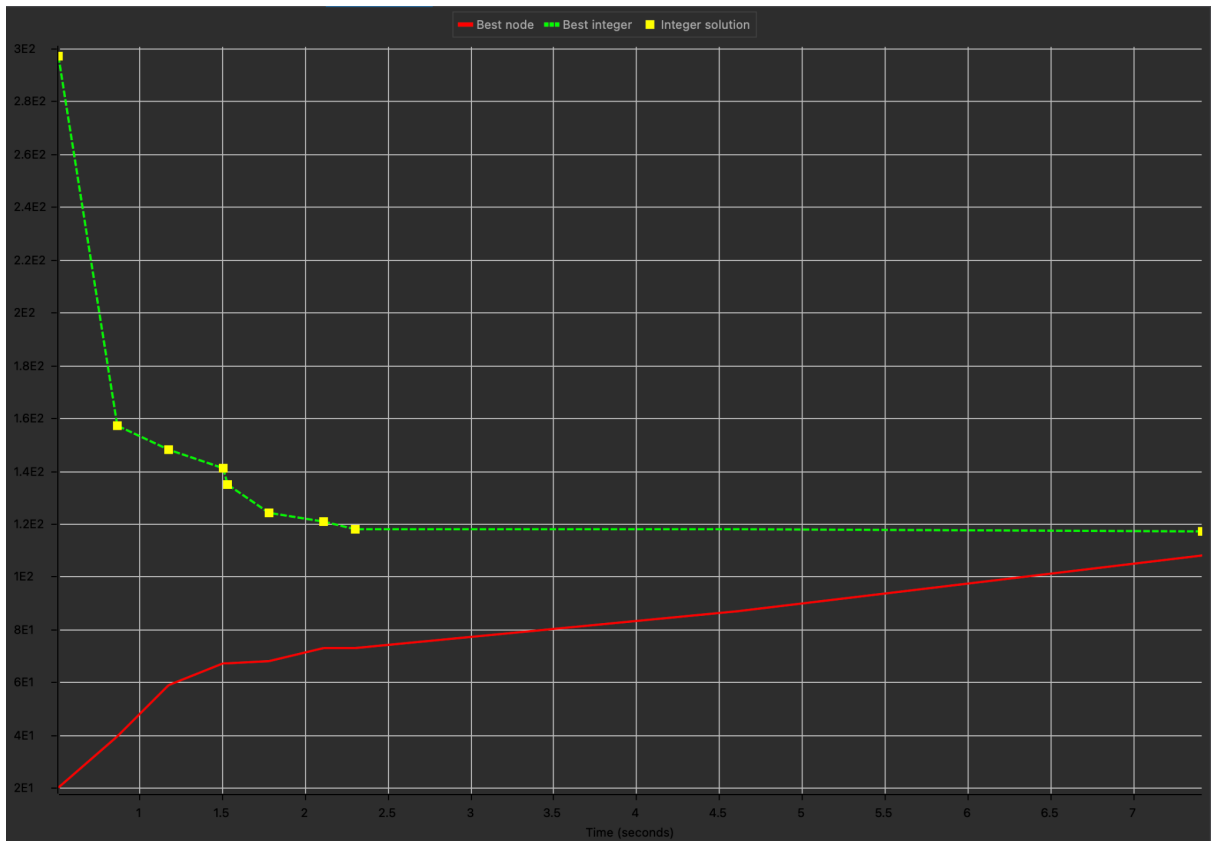
Root node processing (before b&c):
  Real time      = 57.36 sec. (99082.15 ticks)
Parallel b&c, 10 threads:
  Real time      = 12.00 sec. (19903.72 ticks)
  Sync time (average) = 3.43 sec.
  Wait time (average) = 0.00 sec.
-----
Total (root+branch&cut) = 69.36 sec. (118985.87 ticks)

```

5. Máximo 15 lavados con simetría

En menos de 8 segundos llegó al óptimo de 117.

El algoritmo terminó de ejecutarse, mostrando en consola la ejecución de cada nodo.



scripting log

solution: 117 /size: 138 /time: 1718766633.462059021

Nodo 1: 1
Nodo 2: 1
Nodo 3: 1
Nodo 4: 1
Nodo 5: 1
Nodo 6: 1
Nodo 7: 3
Nodo 8: 2
Nodo 9: 1
Nodo 10: 2
Nodo 11: 1
Nodo 12: 2
Nodo 13: 1
Nodo 14: 1
Nodo 15: 1
Nodo 16: 1
Nodo 17: 1
Nodo 18: 4
Nodo 19: 1
Nodo 20: 9
Nodo 21: 3
Nodo 22: 6
Nodo 23: 2
Nodo 24: 1
Nodo 25: 2
Nodo 26: 5
Nodo 27: 2
Nodo 28: 3
Nodo 29: 8
Nodo 30: 1
Nodo 31: 1
Nodo 32: 8

Nodo 33: 2
Nodo 34: 1
Nodo 35: 2
Nodo 36: 8
Nodo 37: 2
Nodo 38: 2
Nodo 39: 1
Nodo 40: 2
Nodo 41: 1
Nodo 42: 1
Nodo 43: 2
Nodo 44: 1
Nodo 45: 10
Nodo 46: 1
Nodo 47: 1
Nodo 48: 1
Nodo 49: 3
Nodo 50: 1
Nodo 51: 1
Nodo 52: 2
Nodo 53: 3
Nodo 54: 8
Nodo 55: 2
Nodo 56: 2
Nodo 57: 6
Nodo 58: 2
Nodo 59: 1
Nodo 60: 3
Nodo 61: 7
Nodo 62: 1
Nodo 63: 1
Nodo 64: 6
Nodo 65: 1
Nodo 66: 1
Nodo 67: 2
Nodo 68: 2
Nodo 69: 7
Nodo 70: 5
Nodo 71: 1
Nodo 72: 7
Nodo 73: 2
Nodo 74: 11
Nodo 75: 1
Nodo 76: 2
Nodo 77: 1
Nodo 78: 8
Nodo 79: 2
Nodo 80: 1
Nodo 81: 10
Nodo 82: 2
Nodo 83: 6
Nodo 84: 2
Nodo 85: 1
Nodo 86: 1
Nodo 87: 1
Nodo 88: 1
Nodo 89: 3
Nodo 90: 1
Nodo 91: 1
Nodo 92: 7
Nodo 93: 1
Nodo 94: 2
Nodo 95: 3
Nodo 96: 2
Nodo 97: 2
Nodo 98: 1

Nodo 99: 6
Nodo 100: 5
Nodo 101: 3
Nodo 102: 1
Nodo 103: 2
Nodo 104: 1
Nodo 105: 1
Nodo 106: 1
Nodo 107: 1
Nodo 108: 6
Nodo 109: 1
Nodo 110: 4
Nodo 111: 1
Nodo 112: 2
Nodo 113: 1
Nodo 114: 2
Nodo 115: 9
Nodo 116: 9
Nodo 117: 1
Nodo 118: 2
Nodo 119: 1
Nodo 120: 1
Nodo 121: 1
Nodo 122: 1
Nodo 123: 1
Nodo 124: 2
Nodo 125: 1
Nodo 126: 7
Nodo 127: 2
Nodo 128: 1
Nodo 129: 1
Nodo 130: 8
Nodo 131: 4
Nodo 132: 1
Nodo 133: 2
Nodo 134: 2
Nodo 135: 7
Nodo 136: 2
Nodo 137: 2
Nodo 138: 5

Engine

Version identifier: 22.1.1.0 | 2022-11-28 | 9160aff4d
Legacy callback pi
Tried aggregator 1 time.
MIP Presolve eliminated 13050 rows and 0 columns.
MIP Presolve modified 1350 coefficients.
Reduced MIP has 3962 rows, 2085 columns, and 13578 nonzeros.
Reduced MIP has 2070 binaries, 15 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.02 sec. (23.33 ticks)
Found incumbent of value 300.000000 after 0.03 sec. (54.96 ticks)
Probing time = 0.01 sec. (4.05 ticks)
Tried aggregator 1 time.
Detecting symmetries...
Reduced MIP has 3962 rows, 2085 columns, and 13578 nonzeros.
Reduced MIP has 2070 binaries, 15 generals, 0 SOSs, and 0 indicators.
Presolve time = 0.01 sec. (12.66 ticks)
Probing time = 0.01 sec. (4.28 ticks)
Clique table members: 1878.
MIP emphasis: balance optimality and feasibility.
MIP search method: dynamic search.
Parallel mode: deterministic, using up to 10 threads.
Root relaxation solution time = 0.26 sec. (140.53 ticks)

	Nodes			Cuts/				
Node	Left	Objective	Inf	Best Integer	Best Bound	ItCnt	Gap	
*	0+	0		300.0000	0.0000	100.00%		
*	0+	0		297.0000	0.0000	100.00%		
	0	0	20.0000	1172	297.0000	20.0000	1823	93.27%
*	0+	0		157.0000	20.0000	87.26%		
	0	0	22.1357	1151	157.0000	Cuts: 1090	5111	74.95%
*	0+	0		148.0000	39.3324	73.42%		
	0	0	25.3340	1020	148.0000	Cuts: 724	8921	60.14%
*	0+	0		141.0000	59.0000	58.16%		
	0	0	27.4166	822	141.0000	Cuts: 662	13313	52.21%
*	0+	0		135.0000	67.3783	50.09%		
	0	0	-1.00000e+75	0	135.0000	67.3783	13313	50.09%
	0	0	27.6012	935	135.0000	Cuts: 516	14007	49.52%
*	0+	0		124.0000	68.1439	45.05%		
	0	0	28.0076	834	124.0000	Cuts: 240	14701	45.05%
	0	0	28.2698	862	124.0000	Cuts: 563	15713	45.05%
*	0+	0		123.0000	68.1439	44.60%		
*	0+	0		122.0000	72.2227	40.80%		
*	0+	0		121.0000	72.2227	40.31%		
	0	2	29.6125	625	121.0000	72.8372	16768	39.80%
Elapsed time = 1.97 sec. (3221.10 ticks, tree = 0.02 MB, solutions = 10)								
*	23+	5		120.0000	72.8372	39.30%		
*	23+	5		118.0000	72.8372	38.27%		
	54	34	101.2159	250	118.0000	72.8372	27228	38.27%
	291	187	85.4398	287	118.0000	72.8372	62963	38.27%
	788	470	113.4360	161	118.0000	72.8372	103231	38.27%
	1238	784	106.8325	222	118.0000	72.8372	130646	38.27%
	1932	1064	114.9295	190	118.0000	74.8248	159634	36.59%
	2673	1553	107.2306	298	118.0000	78.0799	196228	33.83%
	3313	1912	infeasible	118.0000	85.2891	228544	27.72%	

Performing restart 1

Repeating presolve.

Tried aggregator 1 time.

MIP Presolve eliminated 1106 rows and 599 columns.

MIP Presolve modified 122 coefficients.

Reduced MIP has 2856 rows, 1486 columns, and 9492 nonzeros.

Reduced MIP has 1471 binaries, 15 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.01 sec. (9.36 ticks)

Tried aggregator 1 time.

MIP Presolve eliminated 127 rows and 0 columns.

MIP Presolve modified 14 coefficients.

Reduced MIP has 2729 rows, 1486 columns, and 9238 nonzeros.

Reduced MIP has 1471 binaries, 15 generals, 0 SOSs, and 0 indicators.

Presolve time = 0.01 sec. (8.63 ticks)

Represolve time = 0.04 sec. (65.15 ticks)

3819	0	83.3246	328	118.0000	Cuts: 271	260245	26.20%
3819	0	83.4894	392	118.0000	Cuts: 304	261167	26.20%
3819	0	83.8687	406	118.0000	Cuts: 155	261801	26.20%
3819	0	84.4076	394	118.0000	Cuts: 252	262469	26.20%
3819	0	84.5608	374	118.0000	Cuts: 282	263243	26.20%
3819	0	85.1271	409	118.0000	Cuts: 260	263518	26.20%
3819	0	85.1990	404	118.0000	Cuts: 254	263773	26.20%
3819	0	85.2833	403	118.0000	Cuts: 119	264098	26.20%
3819	0	85.3582	408	118.0000	Cuts: 135	264291	26.20%
3819	2	85.3582	385	118.0000	87.0824	264298	26.20%
3822	3	85.5261	388	118.0000	87.0824	266273	26.20%
3841	4	108.8405	258	118.0000	87.0824	272833	26.20%

Elapsed time = 5.02 sec. (8379.92 ticks, tree = 0.04 MB, solutions = 17)

3927	20	105.7667	224	118.0000	87.6872	285295	25.69%
4966	388	116.3093	182	118.0000	92.1365	333280	21.92%
7092	1429	infeasible	118.0000	103.4262	472193	12.35%	

* 8062	1597	integral	0	117.0000	108.0000	535815	7.69%
--------	------	----------	---	----------	----------	--------	-------

Clique cuts applied: 7
Implied bound cuts applied: 3
Flow cuts applied: 37
Mixed integer rounding cuts applied: 113
Zero-half cuts applied: 17
Gomory fractional cuts applied: 16

Root node processing (before b&c):
Real time = 1.94 sec. (3149.65 ticks)
Parallel b&c, 10 threads:
Real time = 5.70 sec. (9082.70 ticks)
Sync time (average) = 1.50 sec.
Wait time (average) = 0.00 sec.

Total (root+branch&cut) = 7.63 sec. (12232.35 ticks)

6.Comparación de paso 3 y 5

En el caso 3 (resultado con cota de 15 lavados), vemos que pese a haber llegado a un buen resultado a los 5.15 segundos, tarda más de 200 segundos en obtener el máximo. Luego en el caso que tiene cota de 15 lavados y además simetría, sólo tarda 5 segundos en llegar a un buen resultado, pero continúa buscándolo hasta los casi 8 segundos.

Podríamos decir que ambos llegaron a un óptimo, pero el segundo caso, que se trataba de un modelo más restrictivo y no estaba obligado a probar tantas combinaciones pudo converger más rápidamente.

Esto sucede con un problema de tan solo 138 prendas, y sus posibles combinaciones, nos damos cuenta que en caso de no contar con el suficiente tiempo, a futuro en problemas de encontrar óptimos, si tenemos información del problema, conviene fijar las restricciones que conozcamos.

7.Comparación heurística y modelo de programación lineal.

La heurística propuesta dio un peor resultado, pero en un tiempo mucho mejor, y no estaba tan alejado del óptimo. Recordemos que la heurística se obtuvo en 26 milisegundos, mientras que el problema de programación lineal continua en el mejor de los casos tardó casi 8 segundos (si miramos el orden de magnitud del tiempo consumido, no es para nada despreciable).

El resultado de la heurística fue de 123, mientras que el del modelo de programación lineal dió 117, es menos del 5%.

La decisión a tomar cuando necesitemos encontrar un óptimo dependerá de los recursos disponibles que tengamos a disposición y de que es más prioritario para nosotros, si encontrar EL ÓPTIMO, a un costo de ejecución alto, o encontrar un muy buen resultado en tiempos mucho menores.