

CUTTING STOCK OPTIMIZATION PROBLEM FOR PRODUCTION OF CARTON BOARD BOXES

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RESULTS and DISCUSSION

Two different problem sizes were solved one with 7 orders and the other with 9 orders. This second problem is an extension of the former because two (2) more orders are added to the problem.

7 orders problem

Table 1 shows the main results obtained with the nonlinear non-convex problem which was solved with GAMS/DICOPT, others solvers haven been tried (GAMS/SBB, GAMS/ALPHAECF and GAMS/COINBONMIN) without success. Six (6) of eight (8) possible patterns are employed, in Table 1 can be found the order combinations on each pattern, for example, pattern 2 is composed of 1 board of order1 and 3 boards of order6, the pattern width is 1380 mm and the paper width used to produce it is 1400 mm, having a trim loss of 20 mm (which is the minimum allowed in the corrugator machine). Objective function value is of 191.73, where 131.73 correspond to the trim lost cost. Column “Units Produced” shows to the number of boards produced for each order taking into account all the patterns, this column is compared with the number of boards ordered to evaluate the overproduction which is just 6.8% for order1. Table 2 shows that same results are obtained with the convexified model.

The MINLP model solves faster than the linear-discrete model comparing the corresponding execution times in Tables 1 and 2. Since there is no difference in the solution obtained for this case, the MINLP model proved to be superior to the linear-discrete formulation.

Table 1: 7 orders problem solution - non-linear nonconvex MINLP problem

Solver DICOPT-NLP subsolver CONOPT-MIP subsolver CPLEX

Objective Function: 191.73 - Execution time: 6.25 sec.

Pattern	1	2	3	4	5	6	7	8	Units Produced	Units ordered
	n(i,p)	n(i,p)	n(i,p)	n(i,p)	n(i,p)	n(i,p)	n(i,p)	n(i,p)		
order1	-	1	2	-	-	-	-	-	1068	1000
order2	-	-	2	-	-	-	-	-	1500	1500
order3	-	-	-	1	2	-	-	-	2000	2000
order4	-	-	-	2	-	-	-	-	2000	2000
order5	-	-	-	-	-	-	2	-	1500	1500
order6	-	3	-	-	-	-	-	-	1500	1500
order7	-	-	-	-	-	-	-	4	2500	2500
Pattern width	0	1380	1180	1360	960	0	1422	1200		
Paper width	0	1400	1200	1400	1000	0	1500	1300		
Trim-loss width	0	20	20	40	40	0	78	100		
Pattern length	0	900	562.5	755.00	787.5	0	1496.5	531.25		

Table 2: 7 orders problem solution - linear MILP problem

Solver GAMS/LOGMIP/LMCHULL (CPLEX) - Objective Function: 191.73

Execution time: 19.2 sec.

Pattern	1	2	3	4	5	6	7	8	Units Produced	Units ordered
	n(i,p)	n(i,p)	n(i,p)	n(i,p)	n(i,p)	n(l,p)	n(i,p)	n(i,p)		
order1	-	2	1	-	-	-	-	-	1068	1000
order2	-	2	-	-	-	-	-	-	1500	1500
order3	-	-	-	2	1	-	-	-	2000	2000
order4	-	-	-	-	2	-	-	-	2000	2000
order5	-	-	-	-	-	-	2	-	1500	1500
order6	-	-	3	-	-	-	-	-	1500	1500
order7	-	-	-	-	-	4	-	-	2500	2500
Pattern width	0	1180	1380	960	1360	1200	1422	0		
Paper width	0	1200	1400	1000	1400	1300	1500	0		
Trim-loss width	0	20	20	40	40	100	78	0		
Pattern length	0	562.5	900	787.5	755	531.25	1496.5	0		

9 orders problem

Table 3 shows the main results obtained with the nonlinear non-convex problem which was solved using GAMS/DICOPT. Eight (8) patterns are employed; Table 3 shows the composition of each pattern. Objective function value is 215.36, where just 135.36 correspond to the trim lost cost. Overproduction in this case is 9.4% for order 2 and 9,65% for order 3.

Table 4 shows the results obtained with the disjunctive model which are not the same as the ones in Table 3. Pattern conformation and length are different and also the objective function value which is a bit lower: 215.14. The overproduction for this problem is 29.9 for order1, 50% in order2 and 9.65% in case of order3.

Comparing the execution time the solver GAMS/LOGMIP/LMCHULL with GUROBI solves much faster than using CPLEX as the MILP solver, both needs more execution time than DICOPT to reach the solution.

In conclusion, for this case, the MINLP model gives better results because the objective function values are very close to the optimum but the overproduction (which is not desirable) is lower then the linear discrete formulation.

Table 3: 9 orders problem solution - non-linear nonconvex MINLP problem

Solver DICOPT - NLP subsolver CONOPT - MIP subsolver CPLEX

Objective Function: 215.36 - Execution time: 306.8 sec.

Pattern	1	2	3	4	5	6	7	8	Units Produced	Units ordered
	n(i,p)	n(i,p)	n(i,p)	n(l,p)	n(i,p)	n(l,p)	n(i,p)	n(i,p)		
order1	-	2	1	-	-	-	-	-	1000	1000
order2	-	2	-	-	-	-	-	-	1641	1500
order3	-	-	-	1	1	1	-	-	2193	2000
order4	-	-	-	-	2	-	-	-	2000	2000
order5	-	-	-	-	-	-	-	2	1500	1500
order6	1	-	3	-	-	-	-	-	1500	1500
order7	3	-	-	-	-	-	-	-	2500	2500
order8	-	-	-	2	-	2	-	-	3000	3000
order9	-	-	-	-	-	-	3	-	2000	2000
Pattern width	1380	1180	1250	1360	1380	1380	1350	1422		
Paper width	1400	1200	1300	1400	1400	1400	1400	1500		
Trim-loss width	20	20	50	40	20	20	50	78		
Pattern length	663.89	615.56	708.34	755.00	1300.00	500.00	533.34	1496.25		

Table 4: 9 orders problem solution - linear MILP problem

Solver GAMS/LOGMIP/LMCHULL (CPLEX) - Objective Function: 215.14 -

Execution time: 5506 sec.

Solver GAMS/LOGMIP/LMCHULL (GUROBI)- Objective Function: 215.14 -

Execution time: 606 sec.

Pattern	1	2	3	4	5	6	7	8	Units Produced	Units ordered
	n(i,p)	n(i,p)	n(i,p)	n(l,p)	n(i,p)	n(l,p)	n(i,p)	n(i,p)		
order1	1	2	-	-	-	-	-	-	1299	1000
order2	-	-	3	-	-	-	-	-	2250	1500
order3	-	-	-	1	1	1	-	-	2193	2000
order4	-	-	-	-	-	2	-	-	2000	2000
order5	-	-	-	-	-	-	2	-	1500	1500
order6	3	-	-	-	-	-	-	-	1500	1500
order7	-	2	1	-	-	-	-	-	2500	2500
order8	-	-	-	2	2	-	-	-	3000	3000
order9	-	-	-	-	-	-	-	3	2000	2000
Pattern width	1380	1260	1080	1380	1380	1360	1422	1350		
Paper width	1400	1300	1100	1400	1400	1400	1500	1400		
Trim-loss width	20	40	20	20	20	40	78	50		
Pattern length	900	812.5	500.00	1300.00	500.00	755.00	1496.25	533.33		