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Original Research Article

Optimization of Production Scheduling System (A Case of Foam Manufacturing Industry)

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Abstract: In manufacturing industries production scheduling is always a key to the company's economic growth and profitability. It defines the appropriate timing system for production. It also establish just-in-time system of the company under study. In this research work, the researcher makes use of 36x75x40 size of foam product which was analyzed using response surface, integer programming and linear programming optimization tools to optimize the production output of the product. The result shows that maximum production output of the product using response surface, integer programming and linear programming were 1854 units, 2160.0 units and 2172.7 units respectively over any given monthly production. The results were recommended to the case company for optimum use in scheduling there monthly production output.

Keywords: Scheduling, response surface, integer programming, linear programming optimization, Production and regression.

INTRODUCTION

Manufacturing is very critical to economic growth, prosperity and a higher standard of living. It is a catalyst for industrial and economic development. Its satisfy economic want of individual, communities and nations by manufacturing things in workshops by utilizing men, materials, machines, money and methods [1].

Essentially, manufacturing can be simply define as value addition processes by which raw materials of low utility and value to its inadequate material properties and poor irregular size, shape and finish are converted into high utility and valued product with definite dimensions, forms, and finish imparting some functional ability by utilizing resources [2]. The resources could be people, machines, computers and/or organized integration of one or more of the above mentioned [3]. To realize higher efficiency, there must be optimal allocation of these resources to activities (scheduling)

Critical areas like cost, time, quality, and flexibility need to be optimize. Optimization is finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones. One of the tools of optimization is scheduling.

Scheduling is the process of arranging, controlling and optimizing work and workloads in a production or manufacturing process. It is used to allocate plant and machinery resources, plan human resources, plan production processes and purchase materials [4].

It is an important tool for production, engineering and in sciences, where it can have a major impact on the productivity of a process. In manufacturing, the purpose of scheduling is to minimize the production time and costs, by telling a production facility when to make, with which staff, and on which equipment. Production scheduling aims to maximize the efficiency of the operation and reduce costs [5].

Wilson [6] provides an overview of manufacturing management and notes how modern manufacturing organizations developed from the mills and workshops and projects of the past. Unfortunately, neither of these excellent sources discusses the scheduling function in detail. Hopp and Spearman, 1996, also provide a general overview of manufacturing in America since the First Industrial Revolution. McKay [7] provides a historical overview of the key concepts behind the practices that manufacturing firms have adopted in modern times, highlighting, for instance, how the ideas of just-in-time (though not the term) were well-known in the early twentieth century.

According to Wight [8], the two key problems in production scheduling are, "priorities" and "capacity." Wight defines scheduling as "establishing the timing for performing a task" and observes that, in manufacturing, there are multiple types of scheduling, including the detailed scheduling of a shop order that shows when each operation must start and complete.

Cox *et al.* [9] also define detailed scheduling as "the actual assignment of starting and/or completion dates to operations or groups of operations to show when these must be done if the manufacturing order is to be completed on time." They note that this is also known as operations scheduling, order scheduling, and shop scheduling which this research is concerned about. The computer based scheduling can help manufacturers improve on time delivery, respond quickly to customer orders and create realistic schedules, but success requires using finite scheduling techniques and integrating them with other manufacturing planning systems [10]. This research investigate the minimization of the makespan via scheduling

The aim of the study is to develop an optimal time scheduling system that will be more suitable in foam manufacturing Industry.

The analysis of the research work were based on the case company data collected over a given period of three years. The data was analyzed and optimized using integer programming model, linear programming model and response surface optimization model. The models were applied to the data in other to obtain the maximum quantity and maximum time scheduling system in the production industry. However, the data collected is a size of foam produced in the case company. Product F is 36X75X40 size of foam produced.

Response surface optimization for scheduling of product F

Response Surface Regression: Yield versus W1, W2, W3, W4, W5, W6, W7, W8

Table 1: Estimated Regression Coefficients for Yield

Term	Coef	SE Coef	T	P
Constant	5163.14	0.000000	*	*
W1	478.94	0.000000	*	*
W2	390.83	0.000000	*	*
W3	615.71	0.000000	*	*
W4	575.61	0.000000	*	*
W5	278.77	0.000000	*	*
W6	345.19	0.000000	*	*
W7	315.31	0.000000	*	*
W8	308.70	0.000000	*	*
W1*W1	0.00	0.000000	*	*
W2*W2	0.00	0.000000	*	*
W3*W3	0.00	0.000000	*	*
W4*W4	-0.00	0.000000	*	*
W5*W5	-0.00	0.000000	*	*
W6*W6	-0.00	0.000000	*	*
W7*W7	-0.00	0.000000	*	*
W8*W8	0.00	0.000000	*	*
W1*W2	-0.00	0.000000	*	*
W1*W3	0.00	0.000000	*	*
W1*W4	-0.00	0.000000	*	*
W1*W5	0.00	0.000000	*	*
W1*W6	-0.00	0.000000	*	*
W1*W7	0.00	0.000000	*	*
W1*W8	-0.00	0.000000	*	*
W2*W3	-0.00	0.000000	*	*
W2*W4	0.00	0.000000	*	*

R-Sq = 100.00%   R-Sq(adj) = 100.00%

Table 2: Analysis of Variance for Yield

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	25	33669948	33669948	1346798	*	*
Linear	8	33669948	2751180	343898	*	*
W1	1	4614041	143	143	*	*
W2	1	15162256	140	140	*	*
W3	1	6978921	84	84	*	*
W4	1	492189	67	67	*	*
W5	1	4722590	17	17	*	*
W6	1	1145438	26	26	*	*
W7	1	465969	31	31	*	*
W8	1	88545	6	6	*	*
Square	8	0	0	0	*	*
W1*W1	1	0	0	0	*	*
W2*W2	1	0	0	0	*	*
W3*W3	1	0	0	0	*	*
W4*W4	1	0	0	0	*	*
W5*W5	1	0	0	0	*	*
W6*W6	1	0	0	0	*	*
W7*W7	1	0	0	0	*	*
W8*W8	1	0	0	0	*	*
Interaction	9	0	0	0	*	*
W1*W2	1	0	0	0	*	*
W1*W3	1	0	0	0	*	*
W1*W4	1	0	0	0	*	*
W1*W5	1	0	0	0	*	*
W1*W6	1	0	0	0	*	*
W1*W7	1	0	0	0	*	*
W1*W8	1	0	0	0	*	*
W2*W3	1	0	0	0	*	*
W2*W4	1	0	0	0	*	*
Residual Error	10	0	0	0		
Pure Error	10	0	0	0		
Total	35	33669948				

Table 3: Residuals in Analysis of Variance

Obs	StdOrder	Yield	Fit	SE Fit	Residual
1	1	6643.290	6643.290	0.000	0.000
2	2	6745.690	6745.690	0.000	0.000
3	3	6061.110	6061.110	0.000	0.000
4	4	4749.040	4749.040	0.000	-0.000
5	5	4900.190	4900.190	0.000	0.000
6	6	3151.770	3151.770	0.000	-0.000
7	7	6164.920	6164.920	0.000	0.000
8	8	6717.970	6717.970	0.000	-0.000
9	9	8350.040	8350.040	0.000	0.000
10	10	6756.480	6756.480	0.000	0.000
11	11	5418.720	5418.720	0.000	0.000
12	12	7336.500	7336.500	0.000	-0.000
13	13	4861.340	4861.340	0.000	0.000
14	14	4850.710	4850.710	0.000	0.000
15	15	6300.980	6300.980	0.000	-0.000
16	16	5565.220	5565.220	0.000	0.000
17	17	5100.540	5100.540	0.000	0.000
18	18	5954.800	5954.800	0.000	0.000
19	19	6616.660	6616.660	0.000	0.000
20	20	6198.640	6198.640	0.000	0.000
21	21	4868.060	4868.060	0.000	0.000
22	22	5129.650	5129.650	0.000	0.000
23	23	6357.060	6357.060	0.000	0.000
24	24	4858.080	4858.080	0.000	-0.000

25	25	4861.340	4861.340	0.000	0.000
26	26	4850.710	4850.710	0.000	0.000
27	27	6300.980	6300.980	0.000	-0.000
28	28	5565.220	5565.220	0.000	0.000
29	29	6057.420	6057.420	0.000	0.000
30	30	4838.560	4838.560	0.000	0.000
31	31	6616.660	6616.660	0.000	0.000
32	32	6198.640	6198.640	0.000	0.000
33	33	4868.060	4868.060	0.000	0.000
34	34	5129.650	5129.650	0.000	0.000
35	35	6357.060	6357.060	0.000	0.000
36	36	4858.080	4858.080	0.000	-0.000

Table 4: Predicted Response for New Design Points Using Model for Yield

Point	Fit	SE Fit	95% CI	95% PI
1	6643.29	0	(6643.29, 6643.29)	(6643.29, 6643.29)
2	6745.69	0	(6745.69, 6745.69)	(6745.69, 6745.69)
3	6061.11	0	(6061.11, 6061.11)	(6061.11, 6061.11)
4	4749.04	0	(4749.04, 4749.04)	(4749.04, 4749.04)
5	4900.19	0	(4900.19, 4900.19)	(4900.19, 4900.19)
6	3151.77	0	(3151.77, 3151.77)	(3151.77, 3151.77)
7	6164.92	0	(6164.92, 6164.92)	(6164.92, 6164.92)
8	6717.97	0	(6717.97, 6717.97)	(6717.97, 6717.97)
9	8350.04	0	(8350.04, 8350.04)	(8350.04, 8350.04)
10	6756.48	0	(6756.48, 6756.48)	(6756.48, 6756.48)
11	5418.72	0	(5418.72, 5418.72)	(5418.72, 5418.72)
12	7336.50	0	(7336.50, 7336.50)	(7336.50, 7336.50)
13	4861.34	0	(4861.34, 4861.34)	(4861.34, 4861.34)
14	4850.71	0	(4850.71, 4850.71)	(4850.71, 4850.71)
15	6300.98	0	(6300.98, 6300.98)	(6300.98, 6300.98)
16	5565.22	0	(5565.22, 5565.22)	(5565.22, 5565.22)
17	5100.54	0	(5100.54, 5100.54)	(5100.54, 5100.54)
18	5954.80	0	(5954.80, 5954.80)	(5954.80, 5954.80)
19	6616.66	0	(6616.66, 6616.66)	(6616.66, 6616.66)
20	6198.64	0	(6198.64, 6198.64)	(6198.64, 6198.64)
21	4868.06	0	(4868.06, 4868.06)	(4868.06, 4868.06)
22	5129.65	0	(5129.65, 5129.65)	(5129.65, 5129.65)
23	6357.06	0	(6357.06, 6357.06)	(6357.06, 6357.06)
24	4858.08	0	(4858.08, 4858.08)	(4858.08, 4858.08)
25	4861.34	0	(4861.34, 4861.34)	(4861.34, 4861.34)
26	4850.71	0	(4850.71, 4850.71)	(4850.71, 4850.71)
27	6300.98	0	(6300.98, 6300.98)	(6300.98, 6300.98)
28	5565.22	0	(5565.22, 5565.22)	(5565.22, 5565.22)
29	6057.42	0	(6057.42, 6057.42)	(6057.42, 6057.42)
30	4838.56	0	(4838.56, 4838.56)	(4838.56, 4838.56)
31	6616.66	0	(6616.66, 6616.66)	(6616.66, 6616.66)
32	6198.64	0	(6198.64, 6198.64)	(6198.64, 6198.64)
33	4868.06	0	(4868.06, 4868.06)	(4868.06, 4868.06)
34	5129.65	0	(5129.65, 5129.65)	(5129.65, 5129.65)
35	6357.06	0	(6357.06, 6357.06)	(6357.06, 6357.06)
36	4858.08	0	(4858.08, 4858.08)	(4858.08, 4858.08)

Response Optimization

```
Parameters

       Goal     Lower  Target  Upper  Weight  Import
Yield  Minimum   3450    3450  10000       1       1


Global Solution

W1   =    20.24
W2   =        0
W3   =    21.08
W4   =    17.64
W5   =   429.52
W6   =   542.81
W7   =   432.18
W8   =    390.6


Predicted Responses

Yield   =   1854.07  ,   desirability =   1.000000


Composite Desirability = 1.000000
```

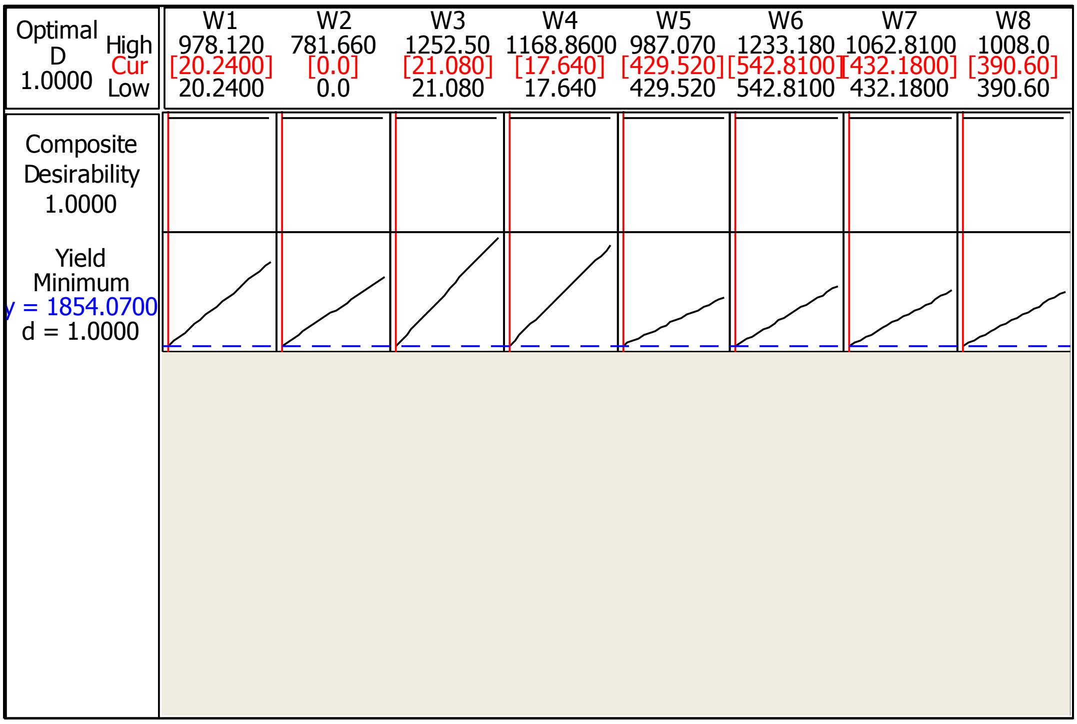

Fig-1: Optimization Plot for Scheduling Product F

INTEGER PROGRAMMING B&B OUTPUT SUMMARY

Title: 36.75.40 Product

FEASIBLE SOLUTION 1:

Objective Value = 1950 Solution found at iteration 12 x1: w1 = 0

x2: w2 = 0 x3: w3 = 0 x4: w4 = 0 x5: w5 = 0 x6: w6 = 1 x7: w7 = 0 x8: w8 = 6

FEASIBLE SOLUTION 2:

Objective Value = 1960 Solution found at iteration 73

x1: w1 = 0

x2: w2 = 0 x3: w3 = 0 x4: w4 = 0 x5: w5 = 0 x6: w6 = 0 x7: w7 = 7 x8: w8 = 0

OPTIMAL SOLUTION:

Objective Value = 2160 (MAX)

solution found at iteration 5277 Result verified at iteration 5287

x1: w1 = 1

x2: w2 = 1 x3: w3 = 1 x4: w4 = 1 x5: w5 = 1 x6: w6 = 1 x7: w7 = 1 x8: w8 = 1

LINEAR PROGRAMMING OUTPUT SUMMARY

Title: 36.75.40 Product

Final Iteration No.: 20
Objective Value = 2172.7

Variable	Value	Obj Coeff	Obj Val Contrib
x1: w1	1.08	280.00	302.68
x2: w2	1.04	280.00	291.16
x3: w3	0.00	250.00	0.00
x4: w4	1.07	260.00	279.39
x5: w5	0.94	260.00	243.30
x6: w6	1.04	270.00	280.47
x7: w7	0.48	280.00	133.79
x8: w8	2.29	280.00	641.92

Constraint	RHS Slack-/Surplus+
1 (<)	1508.000.00
2 (<)	1523.0010.69-
3 (<)	1368.0014.10-
4 (<)	1064.0039.14-
5 (<)	1116.006.27-
6 (<)	1180.000.00
7 (<)	1389.0018.70-
8 (<)	1515.004.38-
9 (<)	1501.0022.12-
10 (<)	1526.003.84-
11 (<)	1511.000.00
12 (<)	1489.0021.52-
13 (<)	1519.0022.33-
14 (<)	1120.0026.81-
15 (<)	1865.0030.48-
16 (<)	1508.005.89-
17 (<)	1273.0023.14-
18 (<)	1049.0033.48-

19 (<)	935.00 58.88-
20 (<)	1312.00109.77-
21 (<)	1147.0075.47-
22 (<)	1102.0064.22-
23 (<)	1363.0021.49-
24 (<)	1040.0019.09-
25 (<)	1140.0058.83-
26 (<)	1096.0043.26-
27 (<)	1423.000.00
28 (<)	1262.0035.76-
29 (<)	1378.0039.12-
30 (<)	1098.0013.39-
31 (<)	1492.0027.49-
32 (<)	1407.000.00
33 (<)	1091.0010.22-
34 (<)	1173.000.00
35 (<)	1433.0030.49-
36 (<)	1094.000.00
UB-x1w1	300.00 298.92-
UB-x2w2	300.00 298.96-
UB-x3w3	300.00 300.00-
UB-x4w4	300.00 298.93-
UB-x5w5	300.00 299.06-
UB-x6w6	300.00 298.96-
UB-x7w7	300.00 299.52-
UB-x8w8	300.00 297.71-

Sensitivity Analysis

Variable	Current Obj Coeff	Min Obj Coeff	Max Obj Coeff	Reduced Cost
x1: w1	280.00	276.95	292.07	0.00
x2: w2	280.00	277.41	283.09	0.00
x3: w3	250.00	-infinity	262.70	12.70
x4: w4	260.00	256.75	264.19	0.00
x5: w5	260.00	258.42	262.43	0.00
x6: w6	270.00	263.21	272.19	0.00
x7: w7	280.00	278.08	281.33	0.00
x8: w8	280.00	278.50	281.33	0.00
Constraint	Current RHS	Min RHS	Max RHS	Dual Price
1 (<)	1508.00	1503.69	1509.93	0.81
2 (<)	1523.00	1512.31	infinity	0.00
3 (<)	1368.00	1353.90	infinity	0.00
4 (<)	1064.00	1024.86	infinity	0.00
5 (<)	1116.00	1109.73	infinity	0.00
6 (<)	1180.00	1166.88	1191.22	0.04
7 (<)	1389.00	1370.30	infinity	0.00
8 (<)	1515.00	1510.62	infinity	0.00
9 (<)	1501.00	1478.88	infinity	0.00
10 (<)	1526.00	1522.16	infinity	0.00
11 (<)	1511.00	1508.76	1514.12	0.24
12 (<)	1489.00	1467.48	infinity	0.00
13 (<)	1519.00	1496.67	infinity	0.00
14 (<)	1120.00	1093.19	infinity	0.00
15 (<)	1865.00	1834.52	infinity	0.00
16 (<)	1508.00	1502.11	infinity	0.00
17 (<)	1273.00	1249.86	infinity	0.00
18 (<)	1049.00	1015.52	infinity	0.00

19 (<)	935.00	876.12	infinity	0.00
20 (<)	1312.00	1202.23	infinity	0.00
21 (<)	1147.00	1071.53	infinity	0.00
22 (<)	1102.00	1037.78	infinity	0.00
23 (<)	1363.00	1341.51	infinity	0.00
24 (<)	1040.00	1020.91	infinity	0.00
25 (<)	1140.00	1081.17	infinity	0.00
26 (<)	1096.00	1052.74	infinity	0.00
27 (<)	1423.00	1415.35	1445.62	0.23
28 (<)	1262.00	1226.24	infinity	0.00
29 (<)	1378.00	1338.88	infinity	0.00
30 (<)	1098.00	1084.61	infinity	0.00
31 (<)	1492.00	1464.51	infinity	0.00
32 (<)	1407.00	1400.56	1412.11	0.06
33 (<)	1091.00	1080.78	infinity	0.00
34 (<)	1173.00	1167.80	1179.58	0.04
35 (<)	1433.00	1402.51	infinity	0.00
36 (<)	1094.00	1087.54	1098.64	0.08
UB-x1	300.00	1.08	infinity	0.00
UB-x2	300.00	1.04	infinity	0.00
UB-x3	300.00	0.00	infinity	0.00
UB-x4	300.00	1.07	infinity	0.00
UB-x5	300.00	0.94	infinity	0.00
UB-x6	300.00	1.04	infinity	0.00

UB-x7300.000.48infinity0.00
UB-x8300.002.29infinity0.00

DISCUSSION

In product two (2), Response surface, integer programming and linear programming optimization tools were employed to optimize the production output of the 36x75x40 size of foam product. From the analysis, it shows the result of the maximum production output of 1854 units, 2160.0 units and 2172.7 units of the product respectively over any given monthly of production. In linear programming algorithm, it shows the slacks in the variables and also it performs the sensitivity analysis of the product. However, the linear programming optimum production was achieved in the seventeenth iterations while the integer programming maximum optimal solution was found at iteration 5277 and also the Result of this iteration was verified at iteration 5287. In linear programming algorithm, it shows the slacks in the variables and also it performs the sensitivity analysis of the product. However, the optimum production was achieved in the fourteenth iterations. Furthermore, the sensitivity analysis in linear programming develops the coefficients of the independent variables and also reduced cost at the optimum iteration.

In response surface model employed to optimize the production time scheduling of the 36x75x40 size of foam product shows the result of the optimum production time scheduling of 1854 units of the product over any given monthly of production. However, response surface method shows the coefficients of the independent variables and the analysis of variance (ANOVA) in the variables. It develops new design points for the variables. The response surface model shows the coefficient of relationship (R^2) to be hundred percent (100%). However, the response optimization shows the composite desirability of achieving the optimum of 1854 units to be 100%. The response optimization also shows the optimization plot which contains the optimum value of the dependent variable (1854units) and the current response values of the independent variables at optimum. The response optimum analysis also reveals that the composite desirability of achieving the predicted optimum result is hundred percent (100%).

CONCLUSION

In conclusion, the research work have really achieved the aim of the study which is to optimize the production time scheduling system in foam industry. The specific size of foam used is 36x75x40. From the discussion of the result, it shows that the optimum production of the foam size at every month runs at the optimal quantity of 1854 units using response surface, 2160 units using integer programme and 2173 units approximately using linear programme model. Having achieved the stated aim of the work, the results were recommended to the aforementioned case Company.

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