Volume 8 Number 3 2009

Production Plan for Wafer Stick Department Using Linear Programming

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Abstract

Wafer Stick Department of a company located in Bekasi, Indonesia, produces 18 kinds of cookies daily to serve both domestic and foreign markets. All these products had the same production processes, namely warehousing of raw materials, mixing, drying, and packing. This department had its own production plan and would like to know whether the existing plan was a good plan or not. The purpose of this paper is to propose linear programming as a technique that can be used to formulate daily production plan for the Wafer Stick Department. In this paper, we compare the maximum profit obtained by the linear programming to that of the existing plan. The comparison was based on a five week schedule.Observations to the plant, especially at the Wafer Stick Department, interviews with the production planner of the Wafer Stick Department as well as the Marketing Department, and the collection of the required data were used to characterize parameters of the linear programming, namely profit contribution of each product, machine capacity, technological coefficients representing resource usage for producing each type of product in each machine, and other necessary requirements. We used WinQSB to solve our linear programming model which resulted in a feasible and optimal solution with a total profit for the five weeks 2.47 billion rupiahs and this is 0.73 billion rupiahs higher than the use of the existing production schedule.

Keywords: production planning, linear programming, wafer stick

1. Pendahuluan

A cookie or biscuit producing company located in Bekasi, Indonesia, produces various kinds of cookies to meet both domestic and foreign markets. One of the departments responsible for the production was the Wafer Stick Department which produced 18 kinds of cookies. All products or cookies had the same production process, starting from warehousing of raw materials, mixing, drying, and packing. The drying process by oven was the major process in that production. The existing method used to schedule forecasted demands was based on historical production schedules. The Production Planner in the Wafer Stick Department would like to have an alternative schedule that could be used as comparison to the existing practice. Therefore, the objective of this paper is to propose the use of linear programming for scheduling in that department. The earlier draft of this paper had been presented in The 11th International Conference on QiR (Quality in Research), Jakarta, 3-6 August, 2009 (Yudoko and Mirzanti, 2009).

The production planning as shown in figure 1 began with demand forecasting by the Marketing Department. The forecasted demand would be given to production planner responsible for production planning and control (PPC). In this regard, the production planner would coordinate with warehousing concerning the available stock or inventory in the warehouse. The implementation of the production and material plan would be done by the production department. The finished goods would be kept in the warehouse.

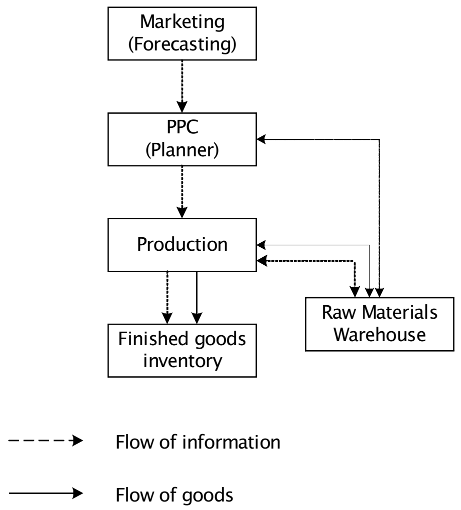

Figure 1. Production planning process

2. Methodology

We propose a linear programming model [2], consisting of decision variables, objective function, and constraints. We conducted direct observations to the plant, interviews with the Production Planner, and collected the required data from the Wafer Stick Department to characterize the linear programming model. In this paper, we only make the model for five weeks as agreed with the Production Planner.

The general form of the linear programming model would use the following notations: Z for total profit, X_{ij} for the number of product i to be produced in week j, d_i for demand of product i in one month, r_j for machine capacity in week j, a_j for maximum work-in-process (WIP) in week j, and b_{ij} for time required to make product i at week j (in minutes).

a. Objective function

The objective function was to maximize total profit (Z) by producing product i at week j (X_{ij}) with each product had its profit contribution of C_{ij}. In this regard, we consider 18 products (i = 1, 2, …, 18) being produced in five weeks (j = 1, 2, 3, 4, 5).

$$Z = \sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij} X_{ij} \quad (1)$$

b. Constraints

* Machine capacity

$$\sum_{i=1}^{n} b_{ij} \sum_{i=1}^{n} X_{ij} \le r_j \quad (2)$$

* Forecasted demand from Marketing

$$\sum_{j=1}^{m} X_{ij} \le d_i \quad (3)$$

* *Secondary process*

$$\sum_{j=1}^{m} X_{ij} \le a_{ij} \quad (4)$$

* Non-negativity

$$X_{ij} \ge 0 \quad (5)$$

3. Results

Based on our agreement with the Production Planner, we would use initials for all products. Table 1 shows profit per cart for each product.

Table 1. Profit for each product

Product initial	Size	Profit/cart (rupiahs)
X1	36 x 60 grams	6,340
X2	120 x 33 grams	8,500
X3	36 x 60 grams	6,500
X4	24 x 60 grams	6,340
X5	24 x 120 grams	4,500
X6	24 x 60 grams	6,000
X7	24 x 120 grams	6,200
X8	6 x 750 grams	15,500
X9	12 x 350 grams	10,800
X10	12 x 350 grams	5,800
X11	12 x 350 grams	16,800
X12	6 x 750 grams	16,800
X13	24 x 150 grams	11,200
X14	24 x 150 grams	9,200
X15	12 x 400 grams	4,100
X16	12 x 400 grams	1,100
X17	12 x 400 grams	12,900
X18	12 x 400 grams	20,500

Total forecasted demands for the overall five weeks provided by the Marketing Department are shown in Table 2. Times required to produce each cart of each product is shown in Table 3. Effective machine capacity for the five weeks is shown in Table 4.

Table 2. Forecasted demands

Product initial	Forecasted demand (carts)
X1	32,916
X2	21,608
X3	2,000
X4	23,972
X5	18,375
X6	550
X7	5,486
X8	7,050
X9	2,625
X10	1,470
X11	4,580
X12	3,790
X13	17,345
X14	6,300
X15	7,924
X16	53,848
X17	81,081
X18	5,940

Table 3. Production time

Product initial	Production time (minutes/cart)
X1	4.03
X2	4.87
X3	3.66
X4	4.03
X5	2.91
X6	4.03
X7	4.03
X8	3.66
X9	3.31
X10	2.91
X11	0.87
X12	0.87
X13	2.01
X14	1.34
X15	8.72
X16	9.26
X17	3.66
X18	4.03

Table 4. Machine capacity

Week	Effective capacity (minutes)
1	263,616
2	331,299
3	318,468
4	281,954
5	188,456

Data about the secondary process related to the capacity of work-in-process (WIP) of a particular product, namely product 16 (X_{16j}) is shown in Table 5. The capacity shown in that table represents a_{ij} in our linear programming model.

Table 5. Capacity of secondary process

Week	Capacity (carts)
1	12.897
2	21.569
3	16.087
4	14.359
5	11.797

Using WinQSB [1] we solve the linear programming (LP) model and the solution is summarized in Table 6. As shown in Table 7, this schedule is able to generate a total profit of 2.474 billion rupiahs. The company's production schedule is shown in Table 8 which generated a total profit of 1.737 billion rupiahs as shown in Table 9. Therefore, the company's schedule had 736.8 million rupiahs less than the proposed schedule using linear programming. This shows that linear programming could be used by the company to optimize its schedules in the future, provided that they would be willing to learn and use it.

Table 6. Proposed production schedule

Product	Week 1	Week 2	Week 3	Week 4	Week 5
X1			32,916		
X2			2,578	19,030	
X3		2,000			
X4		13,523			10,449
X5		18,375			
X6					550
X7					5,486
X8		7,050			
X9	2,625				
X10		1,470			
X11	4,580				
X12	3,790				
X13		17,345			
X14	6,300				
X15				6,458	1,466
X16		10,098	16,087	14,359	11,797
X17	65,356	15,725			
X18			5,940		

Table 7. Optimal profit using LP

Product	LP's schedule	Profit/cart	Total profit
X1	32,916	6,340	208,687,440
X2	21,608	8,500	183,668,000
X3	2,000	6,500	13,000,000
X4	23,972	6,340	151,982,480
X5	18,375	4,500	82,687,500
X6	550	6,000	3,300,000
X7	5,486	6,200	34,013,200
X8	7,050	15,500	109,275,000
X9	2,625	10,800	28,350,000
X10	1,470	5,800	8,526,000
X11	4,580	16,800	76,944,000
X12	3,790	16,800	63,672,000
X13	17,345	11,200	194,264,000
X14	6,300	9,200	57,960,000
X15	7,924	4,100	32,488,400
X16	52,341	1,100	57,575,100
X17	81,081	12,900	1,045,944,900
X18	5,940	20,500	121,770,000
Total			2,474,108,020

Table 8. Company's production schedule

Product	Week 1	Week 2	Week 3	Week 4	Week 5
X1	7,520	10,191	15,184	4,880	
X2		5,457	1,786	7,802	4,173
X3			1,927		
X4	482	2,133	479	2,957	10,444
X5			1,276	690	
X6			35		
X7	2,227	357	2,555		
X8			1,675	4,590	
X9				289	1,906
X10	1,458		236	329	
X11	2,273	3,782	1,781	949	
X12	968				
X13	1,365	2,693	4,507	1,071	
X14	483	164		350	
X15			97	2,386	
X16	14,048	20,718	16,186	13,868	8,807
X17	12,956	11,804	8,993	7,943	8,482
X18	1,192				

Table 9. Total profit of existing schedule

Product	Company's schedule	Profit/cart	Total profit
X1	37,775	6,340	239,493,500
X2	19,218	8,500	163,353,000
X3	1,927	6,500	12,525,500
X4	16,495	6,340	104,578,300
X5	1,966	4,500	8,847,000
X6	35	6,000	210,000
X7	5,139	6,200	31,861,800
X8	6,265	15,500	97,107,500
X9	2,195	10,800	23,706,000
X10	2,023	5,800	11,733,400
X11	8,785	16,800	147,588,000
X12	968	16,800	16,262,400
X13	9,636	11,200	107,923,200
X14	997	9,200	9,172,400
X15	2,483	4,100	10,180,300
X16	73,627	1,100	80,989,700
X17	50,178	12,900	647,296,200
X18	1,192	20,500	24,436,000
Total			1,737,264,200

The use of the existing capacity through the existing production schedule is shown in Table 10 which shows total minutes used in each week. The use of the existing capacity through the use of LP production schedule is shown in Table 11. The comparison of idle or unused capacity for each week by the company's production schedule to LP's schedule is shown in Table 10. It indicates that LP's schedule resulted in greater efficiency of machine capacity use.

Table 10. Comparison of idle machine capacity

Week	Company's schedule	LP's schedule
1	29,561	0
2	9,645	5
3	24,376	1
4	9,912	0
5	7,318	0
Total	80,632	6

4. Discussion

The use of linear programming (LP) resulted in different product mix compared to the product mix of the schedule used by the company. The production planner could see and check that this alternative production schedule provided a higher total profit with less idle machine capacity. He/ she should be interested in using this model for future production scheduling in his/her department.

We were also interested in looking at the sensitivity analysis of the LP solution to see possible changes of certain parameters which do not change the optimal solution that had been obtained. In this regard, we took a look at the values of the decision variables or right-hand-side and machine capacity. From the WinQSB output, we can show the sensitivity of the decision variables indicating minimum and maximum values for each product. This is summarized in Table 11. The notation "M" indicates a very big number. Table 12 shows sensitivity of total machine capacity in each week.

Table 11. Sensitivity of values of decision variables (units)

Product	Minimum	Maximum
X1	29,744	36,032
X2	18,983	30,254
X3	0	27,550
X4	20,510	47,176
X5	13,581	50,510
X6	0	10,999
X7	2,024	15,935
X8	3,238	32,600
X9	0	30,876
X10	0	33,605
X11	0	112,065
X12	0	111,275
X13	10,404	63,868
X14	0	76,085
X15	6,458	12,753
X16	52,341	M
X17	77,269	106,630
X18	2,815	9,010

Table 12. Sensitivity of machine capacity (minutes)

Week	Minimum	Maximum
1	170,104	277,567
2	237,787	345,250
3	305,912	331,250
4	239,846	294,736
5	146,348	202,407

5. Conclusions

We conclude that linear programming (LP) could actually be used by the Production Planner to solve his/her scheduling task since it can help him/her to find the optimal schedule which would generate the maximum profit with respect to constraints. In addition, the optimal schedule would use existing resources, such as machine capacity, efficiently in which idle capacity would be minimized. We believe that through learning and exercises in mathematical formulation and the use of an optimization software, production planner would eventually get used to it. For large problem involving larger variables and constraints, we thought that a more powerful software than WinQSB would be needed.

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