

Applying linear programming model to aggregate production planning of coated peanut products

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Abstract. The aim of this study was to set the overall production level for each grade of coated peanut product to meet market demands with a minimum production cost. The linear programming model was applied in this study. The proposed model was used to minimize the total production cost based on the limited demand of coated peanuts. The demand values applied to the method was previously forecasted using time series method and production capacity aimed to plan the aggregate production for the next 6 month period. The results indicated that the production planning using the proposed model has resulted a better fitted pattern to the customer demands compared to that of the company policy. The production capacity of product family A, B, and C was relatively stable for the first 3 months of the planning periods, then began to fluctuate over the next 3 months. While, the production capacity of product family D and E was fluctuated over the 6-month planning periods, with the values in the range of 10,864 - 32,580 kg and 255 – 5,069 kg, respectively. The total production cost for all products was 27.06% lower than the production cost calculated using the company's policy-based method.

1. Introduction

Company X is Snacks & Food manufacturer, producing a coated peanut products. Currently, the company faced some issues in the production process, causing a failure in fulfilling the customer's demand. If such conditions remained, this will negatively influence the customer service performance of the company, as well as will reduce the company's profits [1]. Therefore, an accurate aggregate production planning is necessary to determine production capacity, helping the company to meet the market's demand.

Accurate aggregate production planning is a production planning which covers the amount of goods to be produced in a certain time unit within the overall planning horizon [2,3]. Aggregate production planning can be done using several approaches. The linear programming method introduced by Hanssmann dan Hess (1960) is one of them, which defined as a decision making technique to optimally allocate scarce resources [4]. This method was selected due to its compatibility to tackle the company's issue.

This study aimed to determine the production capacity for each product family and to compare the total production cost before and after applying the proposed aggregate production plan.



2. Materials and Methods

This study was carried out at X Snacks & Food company, Tulungagung, East Java. Data analyses were conducted at System Analysis and Computation Laboratory, Department of Agroindustrial Technology, Universitas Brawijaya. The aggregate production planning of the coated peanut products was carried out in two steps, include the demands predicting and the aggregate production planning.

2.1. Method

Aggregate production planning model formulation was developed based on the company's condition and issues. Below are several programming elements used in this study:

- Decision variable, which is the number of coated peanut product i family produced in period t , notated as X_{it} .

- Issue function, consists of:

- 1) First issue is the maximum production capacity in period t .

$$\sum_{i=1}^5 \sum_{t=1}^6 a_{it} X_{it} \leq K_t \dots\dots\dots (1)$$

- 2) Second issue is the forecast demand for coated peanut product i family in period t .

$$X_{it} \geq D_{it} \dots\dots\dots (2)$$

- 3) Third issue is non-negativity issue.

$$X_{it} \geq 0 \dots\dots\dots (3)$$

- Purpose Function, which is the total production cost minimization.

The calculation of the production cost for coated peanut product i family in period t is as following:

- a) Fixed cost

- Machine depreciation cost

$$D = \frac{P - S}{N} \dots\dots\dots (4)$$

- Machine maintenance cost

$$M = [H + I + J]m \dots\dots\dots (5)$$

- Salary

$$Gj = g \times F \times m \dots\dots\dots (6)$$

- b) Variable Cost

- Main resources cost

$$BB = [(Q \times q) + (R \times r) + (T \times t)]m \dots\dots\dots (7)$$

- Packaging cost

$$BP = W \times w \times m \dots\dots\dots (8)$$

- Wage (Salary)

$$Up = Upg \times o \times l \times m \dots\dots\dots (9)$$

- Utility cost

$$BU = [(E \times e) + (Y \times y) + (Z \times z)]m \dots\dots\dots (10)$$

The production cost of coated peanut product i family in period t is the total production cost divided by production capacity, assuming that the cost is always the same throughout the planning period.

$$C_i = \frac{(D + Gj + M) + (BB + BP + Up + BU)}{K_i} \dots\dots\dots (11)$$

Aggregate production planning model is better described as following:

$$\text{Min}Z = \sum_{i=1}^5 \sum_{t=1}^6 C_{it} X_{it}$$

with issue :

$$\sum_{i=1}^5 \sum_{t=1}^6 a_{it} X_{it} \leq K_t$$

$$X_{it} \geq D_{it}$$

with $X_{it} \geq 0$ for $i=1,2,\dots,5$ (12)
 $t=1,2,\dots,6$

The assumptions used in this study include: production activity runs smoothly; fixed number of employees; main resource, packaging material, and utility are always available; the number of production machine and their capacity are fixed; main resource, packaging material, and utility cost are fixed. There were also several parameters, such as i family in period t demand, period t production capacity, i family in period t production percentage, and family i in period t production cost. Following the optimisation, sensitivity analysis on the changing objective function values and a right-hand-side value were carried out.

3. Results and Discussion

Aggregate production planning in Company X was conventionally arranged without any meticulous calculation but based on the company's policy. The company's policy required that the production capacity for the subsequent period have to be based on the product demand from the previous period with an additional 25 % was added. This addition was needed to anticipate any demand instability in the market. However, this company's policy caused issues of excess and insufficient production of the coated peanut product, resulted in an increase of the total production cost.

As shown in Table 1, the production capacity of the coated peanut product from family A, B, C, and E have relatively similar magnitude in each period. This result indicated that the production planning based on the company's policy was inappropriate. Inadequate aggregate production planning contributes to a failure to fulfill the market's demand, thus lowering both the service performance of and the financial profits of the company [5].

Table 1. Aggregate production planning based on the company's policy.

Period	Production Capacity (kg)				
	A	B	C	D	E
1	1,985	20,747	70,170	19,301	3,420
2	674	11,062	69,911	22,399	4,882
3	869	15,250	67,103	20,752	3,845
4	664	13,133	91,610	12,516	4,579
5	1,346	13,512	76,229	22,485	4,419
6	630	27,592	41,613	45,541	5,410
Total Production	6,168	101,296	416,636	142,994	26,555
Total Production Cost	IDR 4,722,816,262				

3.1. Proposed aggregate production planning

In this study, two steps were arranged in the proposed aggregate production planning. The first step was predicting the demand and followed by the aggregate production planning using the proposed linear programming. Predicting the demand was carried out to estimate the coated peanut product demand for the next period throughout the agreed planning duration. The best predicting method was chosen based on lowest error value [6] and verification process was conducted using moving distribution method [7]. Determining the best prediction method was applied to minimise the demand

uncertainty occurred in the next period, thus the results achieved are able to represent the actual condition [8].

The results from the best prediction method was then multiplied by business factor to obtain the prediction result that has been adapted to the future's actual condition. The demand of the coated peanut product was influenced by several factors, either internal or external factors, particularly a business factor. Therefore, this particular demand was proceeded and used to the next stage of the aggregate production planning for the coated peanut product.

The results of the aggregate production planning using the proposed method can be seen in Table 2. The table shows that the lowest production capacity was found in the product famili A, while the product family C exhibited the highest production capacity. The production capacity escalation of the coated peanut product was occurred on period 5 and 6, possibly due to an increase in demand following and during religious days. This result is in agreement with Buxey [9] who claimed that the seasonal pattern may influence the demand instability of a product. He further added that although this was happening only for a certain period, its effect on the production level is obvious.

Table 2. The results of the proposed aggregate production planning of coated peanut product.

Period	Production Capacity (kg)					Allowance (kg)
	A	B	C	D	E	
1	449	5,594	37,929	10,864	1,779	363,637
2	449	5,594	37,929	21,276	1,416	360,179
3	449	5,594	37,929	14,996	255	362,236
4	449	5,594	37,974	8,981	806	359,587
5	1,589	22,179	73,344	27,675	4,326	343,058
6	1,589	22,179	69,027	32,580	5,069	348,171
Total Production	4,974	66,734	294,132	116,372	13,651	
Total Production Cost						IDR 3,444,804,000

In linear programming method, the model parameter values are assumed as a fixed value due to its uncertainty to obtain a precise measure. Therefore, post-optimisation analysis is needed to review the influence of the model parameter value changes toward the optimal solution [10]. The sensitivity analysis result of changing objective function coefficient showed that the cost parameter value for each family for a certain period was similar, which was in the range of 0 to infinity. A decrease or an increase in the cost parameter value would not influence the optimal solution if the value is still within the tolerated limit, as stated by Wendell [11], but it may affect the Z value of the optimal solution. The sensitivity analysis results of a right-hand-side constants showed the limit values of this coefficient were varied. The right-hand-side coefficient consists of the production capacity value and the demand of the coated peanut product. If any changes occurred on those parameters values were still within the tolerated limit, this will not affect the optimal solution.

3.2. Comparisons between proposed aggregate production planning and company's policy-based method

The best aggregate production planning method was determined by comparing both aggregate production planning method. The difference between the production capacity and the total production cost from both aggregate production planning methods are shown in Table 3. The results indicated that the company policy-based aggregate production planning has a different pattern to that of the market demand. This was evidenced by the over and insufficient production occurred during the planning period. A large scale overproduction may increase both the inventory cost and the product's defect risk. Insufficient production capacity may limit the company to meet the customers demand. If the company failed to properly manage this issue, it will cost them a profit loss.

The above findings demonstrated that the proposed aggregate production planning using linear programming is more suitable to customer demand pattern compared to that of the company-based

policy method. The compatibility between the production capacity and market demand can reduce the inventory cost, as well as can provide an excellent service to satisfy the customers. Based on the average production cost, the proposed aggregate production planning decreased the total production cost with the difference value of IDR 1,278,012,262 (or 27.06 % lower). This result is supported by Fahimnia et al. [2] and Techawiboonwong et al. [3] who reported that the linear programmed-aggregate production planning can minimise total production cost and optimise the production capacity.

Table 3. Difference between production capacity and total production cost of both aggregate production planning method.

Period	Production capacity difference (kg)				
	A	B	C	D	E
1	(+)1,536	(+)15,153	(+)32,241	(+)8,437	(+)1,641
2	(+)225	(+)5,468	(+)31,982	(+)1,123	(+)3,466
3	(+)420	(-)4,069	(+)29,174	(+)5,756	(+)3,590
4	(+)215	(+)7,539	(+)53,636	(+)3,535	(+)3,773
5	(-)243	(-)8,667	(+)2,885	(-)5,190	(+)93
6	(-)959	(+)5,413	(-)27,414	(+)12,961	(+)341
Total Production Difference	(+)1,194	(+)20,837	(+)122,504	(+)26,622	(+)12,904
Total Production Cost Difference	IDR 1,278,012,262				

4. Conclusion

The findings in this study confirmed that the aggregate production planning using linear programming reduces the production cost of the coated peanut product by 27.06% (or IDR 1.278 billion). A similar pattern to the customer demand was obtained when using the proposed method compared to that of by using the company's policy method, suggesting its suitability and feasibility for further application in the company. However, in-depth study is still required to include the inventory parameters into calculation, and how its impact on achieving the optimal production capacity with a low production or inventory cost.

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