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Minimizing Production Costs Through Aggregate Production Planning with Compromise Strategy in the Food Industry

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ABSTRACT

The food industry is required to carry out production efficiency by minimizing production costs and maintaining competitiveness in the market. One approach that has proven effective in optimizing the production process is through the application of aggregate production planning. This research aims to design a compromise production planning strategy by considering various factors that influence production costs in the food industry, achieve efficiency, and reduce production costs significantly. This research uses an aggregate production method through a compromise strategy model approach to order data for a year. The research results showed that there were two production planning alternatives, namely the first alternative is variable constant labour with overtime, required additional production costs of IDR 338,080,241, while the second alternative is workforce variations, required additional production costs of IDR 301,229,167. The second production alternative can be chosen to be implemented in production planning due to it requires lower costs. Through this study, it is expected that it can provide a valuable contribution to practitioners and academics in understanding the important role of aggregate production planning in achieving production cost efficiency goals in the food industry.

Keywords: Aggregate Production Planning, Compromise Production Planning Strategy, Production Cost, Food Industry.

Introduction

The food industry is a vital economic sector in meeting daily human needs. In the era of globalization and increasingly fierce competition, The food industry is required to increase production efficiency in order to minimize production costs and maintain its competitiveness in the market. One approach that has proven effective in optimizing the production process is through the application of aggregate production planning. Aggregate operating plans relate to determining production levels by product group or other broad category for the medium term (3 to 18 months). The main purpose of the aggregate plan is to describe the optimal combination of production levels, labor levels and inventory owned by the company [1]. Aggregate production planning is a strategy that allows production management in the medium term, usually in the range of six to twelve months, by integrating various factors such as market demand, production capacity, raw material inventory and inventory policy. Aggregate

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planning plays a role in allocating all the company's resources related to determining the quantity and production time in the medium term, usually between the next 3 to 18 months [2].

Aggregate planning can be used in determining the best way to meet predicted demand by adjusting production values, labor levels, inventory levels, overtime, subcontracting levels, and other controllable variables [3]. By using this approach, companies can organize production more efficiently by avoiding sharp fluctuations in production activities and raw material availability. Although aggregate production planning has been widely applied in various industries, its implementation in the food industry is still limited, especially in the context of minimizing production costs. Therefore, research that investigates the application of the compromise model to aggregate production planning strategies in an effort to minimize production costs becomes very relevant and important so that customer demands can be met with appropriate production planning. Production planning is an activity to obtain products according to the needs of two parties, namely the company and consumers [4].

Aggregate production planning (APP) is a decision-making process to determine the best way to utilize resources to meet forecasted demand [5]. Aggregate production planning is medium-short term capacity planning to meet customer demand at minimum cost [6]. Aggregate production planning is obtained from the results of processing forecasting, labor and machine data into a production target amount for a year [7].

The goal of aggregate production planning is to develop an overall production plan that is flexible and optimal. Flexible means it can fulfill market demand and match existing capacity. Optimal means using the right amount of resources at minimal cost [8]. Implementing an appropriate production plan is crucial to maximizing profits and minimizing production costs [9]. The most frequently used Aggregate Production Strategies include Level Strategy, Chase Strategy, Compromise Strategy. Level Strategy is an aggregate planning strategy where the level of production in each period has a constant value. Chase strategy is an aggregation planning strategy by adjusting existing demand in line with the actual production amount and the number of workers adjusted to the needs of each period. The Compromise Strategy is a combination of the level method and the chase strategy by taking into account overtime costs, the amount of production adjusted to the average demand [10].

In this context, this research aims to fill the gap between demand fluctuation and production cost by designing a compromise model that considers various factors that influence production costs in the food industry. By utilizing this model, it is hoped that companies can optimize their production processes, increase efficiency and reduce production costs significantly. Through this study, it is expected that it can provide a valuable contribution to practitioners and academics in understanding the important role of aggregate production planning in achieving production cost efficiency goals in the food industry. Apart from that, it is also expected that the results of this research can become a basis for further development in the field of operations planning and production management in general.

Methods

The method category is a quantitative method. The data that will be processed is forecasting and order data one year in 2022. Research flow method according to Figure 1

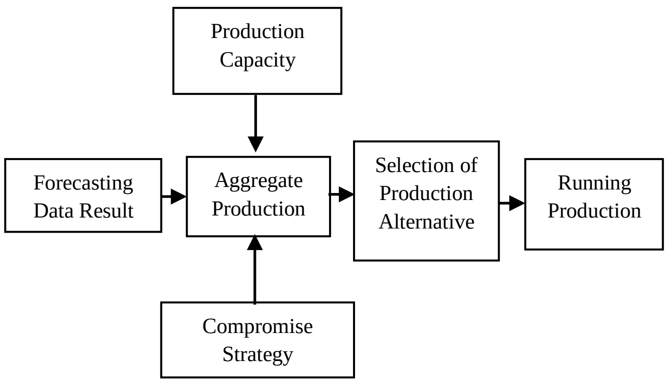

Figure 1. Research Flow Method

Sales data for 52 weeks throughout 2022 is the basis for determining production plans, from the forecasting data it is then compared with available production capacity and safety stock. To calculate safety stock using a formula [11]:

$$\text{Safety stock} = z \ x \ \sqrt{LT} \ x \ RMSE \qquad (1)$$

Description:
Z = Z-score for desired service level
LT = Leadtime periode
RMSE = Root Mean Square Error between actual dan forecas

$$\text{RMSE} = \sqrt{\frac{\sum_{t=1}^{n}(At-Ft)^2}{n}} \qquad (2)$$

Description:
Ft = Forecasting demand
At = Actual demand
n = n Periode

The compromise model production strategy was implemented to maintain production levels and production flexibility by adding additional working time with the main objective being to fulfill sales targets based on forecasting results. Alternative production plans are made with 2 options, namely the first alternative is constant labor and overtime and the second alternative is labor variation.

Results and Discussions

Based on the results of data collection, production capacity can be determined, Production capacity data is known as follows:

Table 1. Production Capacity

Production Line	Machine Capacity/ Hours(carton)	Shift Group	Total Capacity/ Hours(carton)	Production Hours/ Week	Production Capacity/ Weeks (carton)	Manpower Quantity
	a	b	(a x b)	c	(a x b x c)	
Line 1	405.00	2.00	810.00	40.00	32.400	11.00
Line 2	405.00	2.00	810.00	40.00	32,400.00	11.00
Line 3	77.76	1.00	77.76	40.00	3,110.40	8.00
Line 4	77.76	1.00	77.76	40.00	3,110.40	8.00
Line 5	77.76	1.00	77.76	40.00	3,110.40	8.00
Total	**1,043**	**7**	**1,853**	**200**	**74,131**	**46**

Production consists of 5 lines and used 46 manpower with the total production capacity 1853 cartons/hour or 74,131 cartons/week, while the finish good warehouse storage capacity is 219,312 cartons. Forecast and actual sales data for 2022 are known as follows:

Table 2. Forecast, Actual Order and RMSE Value

Periode (Weeks)	Forecast (Carton)	Actual Order (Carton)	Error	Squarred Error	Periode (Weeks)	Forecast (Carton)	Actual Order (Carton)	Error	Squarred Error
1	119.348	119.348	-	-	27	127.536	130.071	2.535	6.424.535
2	61.845	61.845	-	-	28	59.614	56.258	- 3.356	11.264.973
3	57.281	57.281	-	-	29	54.041	50.770	- 3.271	10.699.441
4	75.942	75.942	-	-	30	51.530	64.717	13.187	173.896.969
5	133.006	133.006	-	-	31	125.037	131.907	6.870	47.192.320
6	65.023	82.215	17.192	295.576.325	32	57.248	56.223	- 1.025	1.051.308
7	71.813	59.338	- 12.475	155.617.308	33	57.237	46.525	- 10.712	114.739.803
8	72.498	80.078	7.580	57.451.347	34	55.822	72.294	16.472	271.337.765
9	137.568	137.568	-	-	35	126.455	166.532	40.077	1.606.139.211
10	73.877	96.516	22.639	512.524.321	36	58.347	61.674	3.327	11.066.711
11	78.644	55.273	- 23.371	546.203.641	37	60.164	55.142	- 5.022	25.223.832
12	77.289	64.265	- 13.024	169.624.576	38	63.037	46.928	- 16.109	259.489.142
13	72.018	86.193	14.175	200.930.625	39	54.581	69.208	14.627	213.939.378
14	129.974	127.653	- 2.321	5.387.041	40	142.837	149.266	6.429	41.336.327
15	68.577	72.778	4.201	17.648.401	41	57.093	59.163	2.070	4.286.280
16	74.412	77.214	2.802	7.851.204	42	58.433	51.911	- 6.522	42.536.484
17	69.133	47.562	- 21.571	465.308.041	43	60.094	56.568	- 3.526	12.432.676
18	78.728	75.655	- 3.073	9.445.378	44	149.235	123.396	- 25.839	667.653.921
19	75.216	58.484	- 16.732	279.948.669	45	55.881	57.754	1.873	3.509.378
20	70.451	51.180	- 19.271	371.371.441	46	55.411	54.707	- 704	495.616
21	61.773	70.342	8.569	73.427.761	47	56.343	49.084	- 7.259	52.693.081
22	132.742	117.388	- 15.354	235.755.552	48	146.398	131.790	- 14.608	213.393.664
23	60.002	76.118	16.116	259.725.456	49	53.848	57.864	4.016	16.125.579
24	65.880	72.978	7.098	50.381.604	50	53.885	64.310	10.425	108.680.625
25	73.146	58.303	- 14.843	220.314.649	51	57.086	40.961	- 16.125	260.015.625
26	69.133	47.562	- 21.571	465.308.041	52	54.378	62.637	8.259	68.205.575
Total						4.076.891	4.029.745	(47.146)	8.643.631.602
Average						78.402	77.495	(907)	166.223.685
RMSE									12.893

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This demand data is used as a reference in calculating aggregate production planning. Based on the difference between forecast and actual orders, we can calculate the RMSE value, The RMSE value obtained is 12,893 cartons. After obtaining the RMSE value we continue to calculate the safety stock value, calculation safety stock is carried out as follows:

Table 3. Safety Stock

Z-Score Service	Leadtime (Weeks)	RMSE	Safety Stock
a	b	c	$d = a \; x \sqrt{b} \; x \; c$
2,6	1	12.893	33.210

Based on calculations Table 3, the safety stock value is 33,210 cartons, this value will be used as the minimum stock limit in determining production planning. We use a compromise strategy thus we have to combine the level strategy with the chase strategy therefore we have to maintain the amount of production at the level of production capacity however under certain conditions we need to adjust the amount or hours of production. Production working hours required to meet demand can be seen in the **Table 4**.

Table 4. Order vs Production Capacity

Periode (Weeks)	Production Capacity (carton)	Opening Stock (carton)	Production (carton)	Production Hours	Overtime	Forecast	Order (carton)	Ending Stock (carton)	Safety Stock Standard (carton)	Periode (Weeks)	Production Capacity (carton)	Opening Stock (carton)	Production (carton)	Production Hours	Overtime	Forecast	Order (carton)	Ending Stock (carton)	Safety Stock Standard (carton)
W1	74.131	33.210	119.348	64	24	119.348	119.348	33.210	33.210	W27	74.131	109.809	74.131	40	-	127.536	130.071	53.870	33.210
W2	74.131	33.210	74.131	40	-	61.845	61.845	45.496	33.210	W28	74.131	53.870	74.131	40	-	59.614	56.258	71.743	33.210
W3	74.131	45.496	74.131	40	-	57.281	57.281	62.346	33.210	W29	74.131	71.743	74.131	40	-	54.041	50.770	95.104	33.210
W4	74.131	62.346	74.131	40	-	75.942	75.942	60.535	33.210	W30	74.131	95.104	74.131	40	-	51.530	64.717	104.518	33.210
W5	74.131	60.535	105.680	57	17	133.006	133.006	33.209	33.210	W31	74.131	104.518	74.131	40	-	125.037	131.907	46.742	33.210
W6	74.131	33.209	91.551	49	9	65.023	82.215	42.546	33.210	W32	74.131	46.742	74.131	40	-	57.248	56.223	64.651	33.210
W7	74.131	42.546	74.131	40	-	71.813	59.338	57.339	33.210	W33	74.131	64.651	74.131	40	-	57.237	46.525	92.257	33.210
W8	74.131	57.339	74.131	40	-	72.498	80.078	51.392	33.210	W34	74.131	92.257	74.131	40	-	55.822	72.294	94.094	33.210
W9	74.131	51.392	119.385	64	24	137.568	137.568	33.209	33.210	W35	74.131	94.094	105.647	57	17	126.455	166.532	33.209	33.210
W10	74.131	33.209	105.852	57	17	73.877	96.516	42.545	33.210	W36	74.131	33.209	74.131	40	-	58.347	61.674	45.666	33.210
W11	74.131	42.545	74.131	40	-	78.644	55.273	61.404	33.210	W37	74.131	45.666	74.131	40	-	60.164	55.142	64.656	33.210
W12	74.131	61.404	74.131	40	-	77.289	64.265	71.270	33.210	W38	74.131	64.656	74.131	40	-	63.037	46.928	91.859	33.210
W13	74.131	71.270	74.131	40	-	72.018	86.193	59.208	33.210	W39	74.131	91.859	74.131	40	-	54.581	69.208	96.782	33.210
W14	74.131	59.208	101.654	55	15	129.974	127.653	33.209	33.210	W40	74.131	96.782	85.693	46	6	142.837	149.266	33.209	33.210
W15	74.131	33.209	82.114	44	4	68.577	72.778	42.545	33.210	W41	74.131	33.209	74.131	40	-	57.093	59.163	48.177	33.210
W16	74.131	42.545	77.214	42	2	74.412	77.214	42.546	33.210	W42	74.131	48.177	74.131	40	-	58.433	51.911	70.398	33.210
W17	74.131	42.546	74.131	40	-	69.133	47.562	69.115	33.210	W43	74.131	70.398	74.131	40	-	60.094	56.568	87.961	33.210
W18	74.131	69.115	74.131	40	-	78.728	75.655	67.591	33.210	W44	74.131	87.961	74.131	40	-	149.235	123.396	38.696	33.210
W19	74.131	69.115	74.131	40	-	75.216	58.484	84.762	33.210	W45	74.131	38.696	74.131	40	-	55.881	57.754	55.073	33.210
W20	74.131	84.762	74.131	40	-	70.451	51.180	107.713	33.210	W46	74.131	55.073	74.131	40	-	55.411	54.707	74.497	33.210
W21	74.131	107.713	74.131	40	-	61.773	70.342	111.502	33.210	W47	74.131	74.497	74.131	40	-	56.343	49.084	99.545	33.210
W22	74.131	111.502	74.131	40	-	132.742	117.388	68.246	33.210	W48	74.131	99.545	74.131	40	-	146.398	131.790	41.886	33.210
W23	74.131	68.246	74.131	40	-	60.002	76.118	66.259	33.210	W49	74.131	41.886	74.131	40	-	53.848	57.864	58.153	33.210
W24	74.131	66.259	74.131	40	-	65.880	72.978	67.412	33.210	W50	74.131	58.153	74.131	40	-	53.885	64.310	67.974	33.210
W25	74.131	67.412	74.131	40	-	73.146	58.303	83.240	33.210	W51	74.131	67.974	74.131	40	-	57.086	40.961	101.144	33.210
W26	74.131	83.240	74.131	40	-	69.133	47.562	109.809	33.210	W52	74.131	101.144	74.131	40	-	54.378	62.637	112.639	33.210

Based on order data for 52 weeks, there are 10 weeks where the number of orders was exceed production capacity, namely weeks 1, 5, 6, 9, 10, 14, 15, 16, 35, 40, thus during this period it is necessary to increase production working hours to fulfill incoming orders. Production planning with minimal costs needs to be sought through aggregate production planning using several alternatives, namely the first alternative is constant labour costs with overtime and the second alternative is labour variation.

Table 5. Labour Cost

Variabel	UoM	Salary/ Day	Meal	Transport	BPJS	Labor cost/ day	Hiring cost
		a	b	c	d	f = a + b + c + d	
Labour Cost (1 Employee)	IDR	216.667	17.500	20.000	6.250	260.417	175.000

Daily employee salary costs are obtained from one month's salary data divided by the number of days worked as well as daily BPJS costs. Hiring costs are the costs of the recruitment process. Meanwhile there are no retirement fees. Daily employee costs are obtained by adding up the variables of salary, meal costs and BPJS while hiring costs are only added during the recruitment process or each employee comes to work after a break in production. One of the hiring cost variables is the cost of a medical test.

Table 6. Labour Constant, Overtime Cost

Periode (Weeks)	Salary (IDR)/ Day	Man Power Quantity	Overtime hours / day (Monday to Saturday)	Overtime hours / day (Sunday)	Conversion Overtime Hours	Variabel Value Overtime	Labour Constant, Overtime (IDR)
	a	b			c	d	e=(c / d)*a*b
W1	5.200.000	46	3	6	45	173	62.219.653
W5	5.200.000	46	3	-	31	173	42.309.364
W6	5.200.000	46	2	-	16	173	22.399.075
W9	5.200.000	46	3	6	45	173	62.219.653
W10	5.200.000	46	3	-	32	173	43.968.555
W14	5.200.000	46	2	-	27	173	37.331.792
W15	5.200.000	46	1	-	6	173	8.933.701
W16	5.200.000	46	0	-	2	173	3.450.157
W35	5.200.000	46	3	-	31	173	42.309.364
W40	5.200.000	46	1	-	9	173	12.938.927
Total		**46**	**21**	**12**	**245**		**338.080.241**

Overtime hours are in accordance with government regulations where the maximum number of overtime hours is 4 hours per day or 18 hours a week excluding holidays. The first production alternative with labour constant and overtime requires additional production costs of IDR 338,080,241.

Table 7. Labour Cost Variation

Periode (Weeks)	Man Power Quantity	Additional Working Days	Salary (IDR)/ Day	Meal	Transport	BPJS	Labour Cost/Day	Hiring Cost (IDR)	Labor Cost Variation (IDR)
	a	b	c	d	e	f	g = c + d + e + f	h	I =(a * b * g) + h
W1	46	4	216.667	17.500	20.000	6.250	260.417	175.000	48.091.667
W5	46	3	216.667	17.500	20.000	6.250	260.417	175.000	36.112.500
W6	46	2	216.667	17.500	20.000	6.250	260.417	175.000	24.133.333
W9	46	4	216.667	17.500	20.000	6.250	260.417	175.000	48.091.667
W10	46	3	216.667	17.500	20.000	6.250	260.417	175.000	36.112.500
W14	46	3	216.667	17.500	20.000	6.250	260.417	175.000	36.112.500
W15	46	1	216.667	17.500	20.000	6.250	260.417	175.000	12.154.167
W16	46	1	216.667	17.500	20.000	6.250	260.417	175.000	12.154.167
W35	46	3	216.667	17.500	20.000	6.250	260.417	175.000	36.112.500
W40	46	1	216.667	17.500	20.000	6.250	260.417	175.000	12.154.167
Total	**46**	**25**							**301.229.167**

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The second production alternative with labour variations, where additional labour was added when additional working hours are needed. Additional production of the second alternative requires a cost of IDR 301,229,167.

Conclusions

Based on the results of aggregate production planning simulations for incoming orders using the strategic compromise model, two production planning alternatives were obtained, namely the first alternative is constant variable labour with overtime, requiring additional production costs of IDR 338,080,241, while the second alternative is workforce variation required additional production costs of IDR 301,229,167. Thus, the second production alternative can be chosen to be implemented in production planning because it requires lower costs.

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Author Contribution
Conceptualization, D.M.S and HW; methodology, D.M.S; software, HW; validation, HW; formal analysis, D.M.S; investigation, D.M.S; resources, HW; data curation, D.M.S; writing original draft preparation, D.M.S.; writing review and editing, HW; visualization, HD.; supervision, HW.; project administration, HD; All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest
The Authors declare no conflict of interest

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