Aggregate Planning to Minimize Cost of Production of ABC Company with Forecasting and Master Production Schedule Approach

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Abstract

The rapid growth of the Food and Beverages industry leads to a very fierce competition between the companies in this industry. ABC Company is one of the players in the industry and to gain more competitive advantages to win the competition, The company needs a strategic movement. The company's current condition is that most of the time, the demand is lower than the capacity which leads to an inventory and cost wasting. The objective of this study is to create a complete company's production schedule and meet demand while spending as minimum money as possible on production factors. The data were gathered through literature review and secondary data gathered directly from the company itself. The sales data from the past 4 months are used to forecast upcoming 3 months' demand using smooth exponential forecasting and moving average method. Furthermore, the data are also used to calculate the aggregate planning strategies, such as chase strategy, level strategy, and mixed strategy using the POM QM application. Those three strategies then are validated using MPS calculation to find which strategy has the least cost of production. The result of this study is that the mixed strategy has the least cost of production.

Keywords
Aggregate Planning, Cost of Production, Forecast, and Master Production Schedule

1. Introduction

To assure the availability of products that fulfill the needs of customers, effective and efficient production is required. Thus the implementation of the company's operations do not have problems related to the planning of production. More attention was paid to contributor variables such as labor and machinery (the amount of labor and machinery), the production capacity of the machines used, cycle time, and shift scheduling in the process of building an effective and efficient production. When the production division has people and machinery reserves to deal with fluctuations in demand for goods, production can operate on time and the number of requests can be met. When the amount of demand is uncertain, however, a large amount of labor and machinery is usually not utilized (Nasution in Rahmadhani, Rahman and Tantrika 2014) and tends to waste unnecessary cost. The food and beverage companies need to establish the correct strategies in addressing the increase of production complexity.

Indonesia's food and beverage sector is vital to the country's economic development. Despite the COVID-19 pandemic, the Indonesian food and beverage industry is expected to increase by 3% in 2020. (TheInsiderStories,

2020). From 2021 to 2026, the food and beverage sector is predicted to increase at a pace of 10.8% annually, reaching USD 2,517 million. Because the food sector developed so quickly, competition became a major concern. Future planning, which includes short, middle, and long-term planning, was a response to winning the competition. According to Rahmadhani, Rahman, and Tantrika (2014), aggregate planning is a method of balancing supply and demand (for products or services) by appropriately estimating input time, transformation time, output time, and raw material quantity. One of the objectives of strategic planning is to eliminate overall employment concerns (overtime and subcontracting), as well as to use resources and equipment wisely and efficiently to reduce inventory and costs. (Pratanto 2012). Inventory and cost control management are critical for a company's success (Atnafu and Balda 2018). Businesses are expected to keep their inventory under control as much as possible in order to prevent incurring excessive costs. If the Production Scheduling is not addressed effectively, the problem in cost and inventory control can be catastrophic to business continuity. The application of MPS is expected to solve this issue.

ABC Company is engaged in the beverage industry with a focus in Healthy drinks and snacks production. ABC Company uses a franchise system to develop their branches and as of now it has 90+ outlets all around Indonesia. ABC Company uses a make-to-order system to fulfill their customer's demand. The smoothies drink menu series have the biggest contribution for the company's profit. The diagram below shows the demand and the production capacity of the smoothies drink menu for the past 4 months.

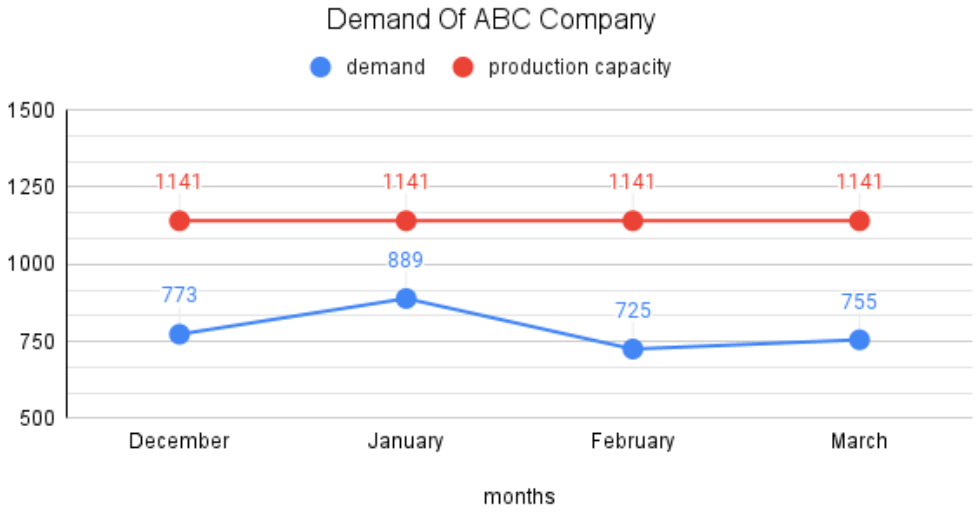

Figure 1. Demand of ABC Company (Dec 2021 - March 2022)

By looking at Figure 1, we can see that there was an increasing demand from December 2021 to January 2022, then starting to decrease from January 2022 to February 2022, and increasing from February 2022 to March 2022. Since most of the time the demand is lower than the capacity, it is important to reduce the materials in production to meet the demand. Reducing non-used materials will reduce the cost of the inventory because if the inventory is excessive, there will be a lot of food or equipment that goes to waste over time.

1.1 Objectives

The objective of production planning is to create a complete production schedule and meet demand while spending as minimum money as possible on production factors. The objective of this research is to forecast the demand on ABC Company from Apr - June 2022 and design an aggregate plan to minimize the cost of production.

2. Literature Review

2.1 Forecasting

In terms of human history, it is not that long since forecasting moved from the religious, the superstitious and even the supernatural (Scott 2015) to the more scientific. Forecasting is retrieving past data (such as sales from the previous year) and using mathematical models to predict the future. Moving averages is one of the forecasting method, this

method used to measure momentum. A moving average is a statistic that captures the average change over time in a set of data. In finance, moving averages are commonly used by technical analysts to track price fluctuations in a particular security. However, in manufacturing companies, it's often used as a forecasting method for production. The other method to forecasting is Exponential smoothing. Exponential smoothing provides a routine method for regularly updating item forecasts and it works well when it faces stable items (Tony Arnold et al. 2008). One of the basic methods is simple exponential smoothing which requires the old forecast value and the actual value from the previous period. Both are then influenced by the alpha value (α) which is used as a weight (Rob J Hyndman et al. 2008).

2.2 Aggregate Planning

Aggregate planning, according to Heizer and Render (2015), is a method for determining the quantity and timing of output in the medium term (usually 3 to 18 months). A variety of accessible options can be used to handle aggregate planning difficulties. Planning decisions are made in line with the expected or predicted Bedwoth in Cahyono (2007) for production manpower, materials, machinery, and other equipment, as well as the capital required to manufacture goods at a specific time in the future. Heizer and Render (2015)'s aggregate planning technique includes five first-choice capacity alternatives, which are designed to absorb demand variations rather than change requests. The following three options are requests that the corporation makes in order to minimize demand pattern changes during the planning phase.

According to Heizer and Render (2015), aggregate planning can be accomplished through the use of one of three strategies: Chase Strategy, Level Scheduling Strategy, or Mixed Strategy. (1) Chase Strategy, a planning strategy with a number of demand equal to the number of expected demand production (production adjusted to demand). This method aims to reach a level of output for each period that corresponds to the period's demand projection. (2) Level Strategy, the aggregate plan in which the rate of production remains constant from period to period (constant output). In the planning horizon, scheduling levels maintain output levels, production levels, or employment levels constant. (3) Mixed strategy entails altering more than one variable that may be controlled (controllable decision variable). A planning approach that best aggregates can be created by controlling a mixture of changing variables.

2.3 Master Production Schedule (MPS)

MPS can be defined as a process that involves developing and establishing plans for a company's sales and production operations. MPS main functions include 1) translating aggregate planning into defined end products; 2) analyzing alternative schedules; 3) determining the production materials required; 4) determining production capacity; 5) facilitating information processing; and 6) effectively utilizing capacity. According to Garpersz (1998), MPS requires five main inputs: 1) total demand data (sales and order forecasts); 2) inventory status (on-hand inventory, allocated stock, released production and purchase orders, and planned orders); 3) production plans; 4) planning data (lot-sizing, shrinkage factor, safety stock, leat time, item master file); and 5) rough cut capacity planning information.

It is typically conducted weekly at the product level, spans a timeframe of a couple of months up to a year, and consists of five activities (Jacobs et al. 2011; Jonsson and Mattsson 2009): forecasting future demand, generating a preliminary market delivery plan, generating a preliminary production plan, adapting plans as necessary by reconciling drafted plans and the conditions for realizing them, and settling on prepared plans. In the process of MPS, particularly when accessing performance, it is important to differentiate the output from the effect of MPS. The output of MPS refers to the production plan indicating what to build and when (i.e., plan feasibility), whereas the effect of MPS, if beneficial, refers to the improved performance of the plant and, in turn, the positive impact on profit and competitiveness (i.e., plant performance).

3. Methods

The research method was a systematic series of stages that must be set before the resolution of the problem being discussed. Type of this paper is descriptive research, i.e..research whose main characteristic is to provide an objective explanation, comparison, and evaluation as a decision for the authorities.

Analyzing production performance on ABC Company, researchers use three alternative strategies (chase, level, and mixed) for aggregate planning. To calculate the alternative strategies and get the optimum cost the company can spend, researchers needed several data such as production capacity and cost of production. Production capacity is the capacity of a company's production process. The production capacity consists of regular time capacity, overtime capacity, and subcontracting policies set by the company. The major determinant of the production capacity is the production

process employed, which in turn defines technology, set of operations, and equipment set. Production process can be represented as a set of time parameters that enter into the production capacity function and are determined exogenously through the inner structure of production process and equipment measures. The cost of production supports an important role in the calculation of aggregate planning is the regular production costs, the production cost of overtime and subcontracting costs, handling costs and the cost of inventory shortages.

The sales data researchers obtain consist of data sales for four months (December 2021 – Mach 2022). ABC Company has a drinks and desserts menu. According to the data researchers obtained, they are also selling seasonal drinks with around 4 variations. Researchers decided to only focus the sales on the smoothies drink menu series.

The sales data for the last four months (December 2021 – Mach 2022) needed to determine predictive forecasting demand for the next three months (April – June 2022). In analyzing the capacity problems that occur in the ABC Company, researchers optimize all the company's resources to minimize all costs incurred to meet customer demand by using POM QM software for Windows.

4. Data Collection

Below are the supporting data taken from the ABC Company from December 2021 until March 2022. The data includes the number of gross sales and items sold. Other information about ABC Company is confidential and can't be mentioned as requested. By using the acquired information on ABC Company as shown on Table 1, researchers will utilize those data to make a forecasting calculation.

Table 1. Data From The ABC Company

Menu	DECEMBER 2021		JANUARY 2022		FEBRUARY 2022		MARCH 2022		TOTAL	
	Items Sold	Gross Sales	Items Sold	Gross Sales	Items Sold	Gross Sales	Items Sold	Gross Sales	Items Sold	Gross Sales
Menu A	160	Rp4,800,000	166	Rp4,980,000	147	Rp4,410,000	116	Rp3,480,000	589	Rp17,670,000
Menu B	88	Rp2,640,000	125	Rp3,750,000	84	Rp2,520,000	101	Rp3,030,000	398	Rp11,940,000
Menu C	50	Rp1,363,000	65	Rp1,772,680	72	Rp1,963,584	55	Rp1,499,960	242	Rp6,599,224
Menu D	0	Rp0	0	Rp0	0	Rp0	2	Rp69,092	2	Rp69,092
Menu E	106	Rp3,180,000	112	Rp3,360,000	96	Rp2,880,000	98	Rp2,940,000	412	Rp12,360,000
Menu F	53	Rp1,590,000	58	Rp1,740,000	55	Rp1,650,000	49	Rp1,470,000	215	Rp6,450,000
Menu G	48	Rp1,309,056	67	Rp1,827,224	60	Rp1,636,320	69	Rp1,881,768	244	Rp6,654,368
Menu H	107	Rp3,307,263	140	Rp4,327,260	87	Rp2,689,083	121	Rp3,739,989	455	Rp14,063,595
Menu I	52	Rp1,560,000	57	Rp1,710,000	42	Rp1,260,000	42	Rp1,260,000	193	Rp5,790,000
Menu J	109	Rp3,270,000	99	Rp2,970,000	82	Rp2,460,000	102	Rp3,060,000	392	Rp11,760,000
Total	773	Rp23,019,319	889	Rp26,437,164	725	Rp21,468,987	755	Rp22,430,809	3142	Rp93,356,279

To make a right forecast, we need more thorough data regarding the gross sales, COGS, working days, regular hours, number and the cost of the worker. On Table 2 below, there is the more detailed data taken from the company's

inventory data and literature review. The data includes the demand units, gross sales, cost of goods sold, working hours, number of workers, and cost of workers.

Table 2. Detailed Data of ABC Company

Demand Unit - Total Production	December 2021		January 2022		February 2022		March 2022	
	773		889		725		755	
Gross Sales	Rp23,019,319		Rp26,437,164		Rp21,468,987		Rp22,430,809	
COGS (45%)	Rp10,358,694		Rp11,896,724		Rp9,661,044		Rp10,093,864	
Working Days	23	day	21	day	20	day	23	day
Regular Hours	8	hour(s)	8	hour(s)	8	hour(s)	8	hour(s)
Number of Worker	2	worker(s)	2	worker(s)	2	worker(s)	2	worker(s)
Cost of Worker	Rp2,500,000		Rp2,500,000		Rp2,500,000		Rp2,500,000	

Table 3 shows the exact data of the company's cost per unit. The data includes the worker cost, raw material cost, machinery and building cost, other cost, and total cost.

Table 3. Cost per Unit of ABC Company's Expenses

Worker Cost	Rp6,468	per unit
Raw Material Cost	Rp13,401	per unit
Machinery and Building Cost	Rp6,468	per unit
Other Cost	Rp647	per unit
Total Cost	**Rp26,984**	**per unit**

5. Results and Discussion

5.1 Exponential Smoothing

According to Siregar, et al (2017), the availability of information on actual output from the prior period is critical for meeting the production target. Only if the previous period's production data is accessible and of good quality can target production be projected in the future. For univariate time series data, exponential smoothing is a forecasting strategy. This method generates projections based on weighted averages of previous observations, with the weights of older observations decreasing exponentially. Exponential smoothing techniques broaden the scope of the research to include data with trends and seasonal components. Analysts can modify how quickly older observations lose their significance in computations by adjusting parameter values. As a result, analysts can adjust the relative importance of new observations vs older observations to match the needs of their subject area.

For each observation, this procedure updates the level component. It only has one weighting parameter, alpha (α), because it only models one component. By modifying how rapidly the level component adjusts to the most current data, this variable controls the degree of smoothing. Alpha in the exponential smoothing context has no relationship to alpha in hypothesis testing. The calculation follows this formula,

$$F_{t+1} = \alpha A_t + (1 - \alpha) F_t$$

where A_t is actual data at time t, F_t is level forecasting at time t, α is the weighting parameter, and on the calculation, researchers use 0.2 as the alpha (α). The equation results shown in Table 4 below.

Table 4. Exponential Smoothing of ABC Company

Month	Sales	Forecast	Error	Error²
December 2021	773	773	x	x
January 2022	889	773	116	13,456
February 2022	725	796	-71	5,069
March 2022	755	782	-27	727

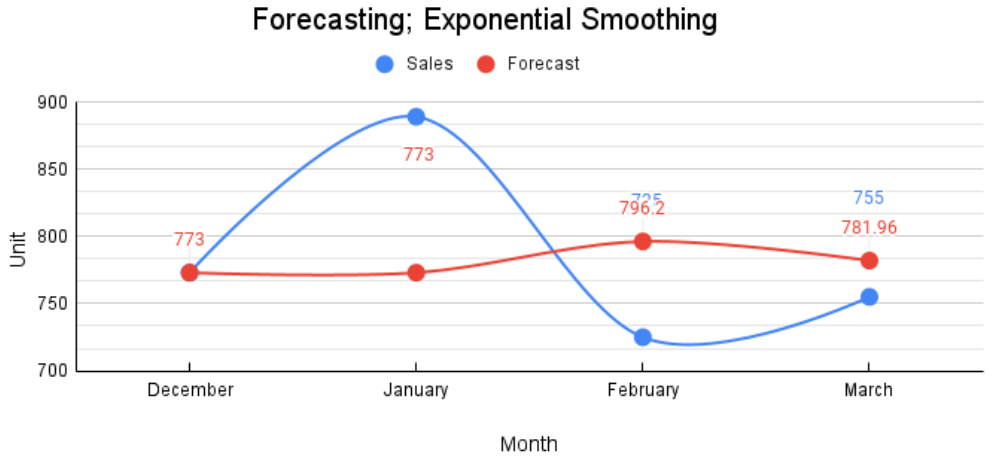

Figure 2. Exponential Smoothing of ABC Company (Dec 2021 - March 2022)

The results of exponential smoothing can be seen as a graphical representation in figure 2. It shows the difference of sales and forecast data in linear regression.

To begin, the cost of regular production (regular time cost) per wrapping is calculated by adding the costs of raw materials, personnel, machinery, and buildings, as well as additional factors such as energy and water. From data shown in table 3 the total regular time cost is Rp26,984. The overtime cost at ABC Company is Rp0, because as a make-to-order company, there is no overtime work hour for the worker. Third, the cost of subcontracting is Rp0 as the company didn't have temporary capacity by subcontracting their workers during high demand periods. The holding/carrying cost in the form of retention of capital costs, taxes, insurance, material damage, and the cost of renting a warehouse, is Rp1,404 per unit.

Backorder costs are the expenses experienced by a company when it is unable to satisfy an order right away but assures the customer that it will be fulfilled at a later date, but this company is an F&B company that makes products by order then Rp0 for backorder cost. The cost of excess production (increase of unit cost), the company policy does not take into account such costs, so the cost is Rp0 per unit. On the decrease unit cost, the company policy does not take into account such costs in this case, so the cost is 0 per unit. The company does not apply an overtime system to the work procedures of the employees so that in this case the value is Rp0 per unit.

The Regular Time Capacity is obtained by dividing the total demand per period of time, so the number of this capacity is 786 units. The Subcontracting Capacity is the number of an exceeding customer demand and forcing the need for a third party to help the company meet the demand. Since The ABC Company doesn't have any third party, the number of this capacity is 0. The Initial Inventory is the number of inventory the company has before the first period, which

is 820 units. The unit from the last period is taken from the number of the previous period's production, which is 755 units.

5.2 Choose Optimum Cost from Different Alternatives on QM for Windows

Program QM for Windows is a set of many computer programs used to solve many quantitative method, science management, and operation research problems. QM, or quantitative method, is software that goes along with operation management textbooks. QM for windows is a mix between last programs, DS and POM for windows. By comparison, modules available on QM for Windows were more than other programs such as POM for windows. One of the modules researchers used is aggregate planning to identify which method from aggregate planning researchers can use that requires the least cost of all the methods.

As stated before, there were three alternatives to analyze the problems for aggregate planning, which are chase, level, and mix. There were several pieces of data needed.

Table 5. Data Needed for QM for Windows

Data needed		Values
Production Cost	Regular time cost	Rp26,984/unit
	Overtime cost	Rp0/unit
	Subcontracting cost	Rp0/unit
Inventory cost	Holding/carrying cost	Rp1,404/unit
	Sorted/backorder cost	Rp0/unit
Increase cost		Rp0/unit
Decrease cost		Rp0/unit
Capacity	Overtime capacity	0 unit
	Regular time capacity	786 unit
	Subcontract capacity	0 unit
Initial Inventory		820 unit
Units Last Period		755 unit

Table 5. shows all the datas needed required by POM QM Windows and also to calculate and analyze the result for chase, level, and mixed strategy. After inputting the data on QM for windows, researchers will choose which alternative gave the least and optimum cost from the company. The first alternative is Chase Strategy. Chase strategy is a planning strategy that sets production equal to the predicted demand (production is adjusted to demand). This

strategy tries to achieve a level of output for each period that satisfies the demand for demand for that period. The second alternative is Level Strategy. Level strategy is an aggregate plan in which the level of production remains the same from period to period (production is constant). Level scheduling maintains a constant level of output, production level, or labor rate on the planning horizon. The last alternative is Mixed strategy. Under mixed strategy, both inventory and work-force levels can change over the planning period. Like its name, the strategy is the combination of the chase and level strategies. This strategy could benefit more if the costs of maintaining inventory and changing workforce levels are relatively high. The data results are listed as below

Table 6. Result from QM for Windows

Alternatives	Method on QM for windows	Total Cost
Level Strategies	Average GROSS demand	Rp65,863,930
Chase Strategies	Chase CURRENT demand	Rp40,356,220
Mixed Strategies	Transportation	Rp17,092,240

On Table 6., the result for all strategies from QM Windows are shown. Based on the comparison of three strategies, the result obtained from Level Strategies has the highest total cost among other alternatives. Using the Chase Strategy has less total cost than level strategies. But it is not the lowest. The Mixed Strategy has the lowest total cost the company could spend between the three strategies.

5.3 Forecasting Using Moving Average Method

A Simple Moving Average model is a time series constructed by taking averages of several sequential values of another time series, Gandesrukma et al. (2021). To support the research, data collection from the firm is needed. Before doing MPS, the forecast demand needs to be determined by taking the average demand of the last three periods and using the result as the forecast for the next period. At the end of the next period, the first-period demand is dropped and the latest-period demand added to determine a new average to be used as a forecast. This forecast would always be based on the average of the actual demand over the specified period.

Table 7. Forecasting Using Moving Average Method

Period	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Forecast	773	773	796	782	790	757	767	2314
Actual Customer Order	773	889	725	755	0	0	0	3142

Table 7. shows the result for forecast and actual custom orde per month and the total using moving average method.

5.4 Validating using Master Production Schedule

According to Lu et al. (2012), The MPS can be used in certain Make-to-Order environments and mixed-mode manufacturing where a business manufactures standard products. In this case, the sales forecast and master production schedule are used to plan the inventory needed for production.

Table 8. MPS Calculation Using Chase Strategy

Period	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Forecast	773	773	796	782	790	757	767	5438
Customer Orders	773	889	725	755	0	0	0	3142

Projected Available Balance	820	47	47	-24	-51	-51	-51	-51	
MPS			842	725	755	790	757	767	4754
Available To Promise			0	0	0	790	757	767	2314

Based on the calculation in table 8, the MPS calculation using Chase Strategy generates inventory levels at the end of the period (June) of -51 units with Available to Promise 767 units. This number is the least compared to other strategies.

Table 9. MPS Calculation Using Level Strategy

Period		Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Forecast		773	773	796	782	790	757	767	5438
Customer Orders		773	889	725	755	0	0	0	3142
Projected Available Balance	820	47	8	62	130	190	283	366	
MPS			850	850	850	850	850	850	5100
Available To Promise			8	125	95	850	850	850	2778

Based on the calculation in table 9, the MPS calculation using Level Strategy generates inventory levels at the end of the period (June) of 366 units with Available to Promise 850 units. This amount is the highest compared to the other strategies.

Table 10. MPS Calculation Using Mixed Strategy

Period		Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Forecast		773	773	796	782	790	757	767	5438
Customer Orders		773	889	725	755	0	0	0	3142
Projected Available Balance	820	47	8	62	130	130	130	130	
MPS			850	850	850	790	757	767	4864
Available To Promise			8	125	95	790	757	767	2542

Based on the calculation in table 10, the MPS calculation using Mixed Strategy generates inventory levels at the end of the period (June) of 130 units with Available to Promise 767 units. The production for months Jan-Mar using the same amount as Level Strategy which is 850 units. After that, for months Apr-Jun is using the same amount as the forecast unit.

5. 5 Proposed Improvement

After calculations using POM QM for Windows and Master Production Schedule (MPS), researchers got the result, which was already summarized in table 11, that it would be better to take the Mixed Strategy according to the results of POM QM and take Chase Strategy from MPS calculation. However, on the other hand, the calculation results that are projected to be available on the Mixed Strategy from the MPS calculation show good results as well that the inventory tends to be constant and does not cost as much as the inventory at the Strategy Level.

From the third strategy that has been analyzed, researchers recommend ABC Company to use the Mixed strategy with an estimated cost of Rp17,092,240 and an inventory level at the end of the period of 130 units and 767 units of ATP.

Table 11. The Comparison of Three Aggregate Planning Strategies

Strategy	Regular Production	Overtime Production	Shortage	Inventory	Sub-contracted	Total Cost (Rp)
Chase Strategy	v	x	v	v	x	Rp40,356,220
Level Strategy	v	x	x	v	x	Rp65,863,930
Mixed Strategy	v	x	x	v	x	Rp17,092,240

6. Conclusion

There are several critical points obtained. The results from POM QM show that it would be much better if ABC company used the Mixed Strategy seen from the lower cost compared to the other two strategies, which was Rp. 17,092,240. To support this argument, the researchers also calculated the Master Production Schedule and found that the order of alternatives from the best to the worst was Chase Strategy, Mixed Strategy, and Level Strategy. In the MPS Chase Strategy calculation, there is a shortage in ABC Company's inventory so in this case it would be much better to take the Mixed Strategy to be implemented in the future. In addition, we found a pattern that did not change significantly for demand and customer orders in the period April 2022 - June 2022.

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Biographies

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