Heuristic Methods on Aggregate Planning Analysis to Minimize Production Cost

Merisha Hastarina [*1)], Muhammad Ikhlasul Amal 2 [2)], Nidya Wisudwati [3)]

*Corresponding author
*ORCHID IDs: https://orcid.org/0000-000X-XXXX-XXXX

[1),2) &3)] Teknik Industri, Universitas Muhammadiyah Palembang, Indonesia
*email: icha3005@gmail.com

Abstract

XYZ is a company engaged in construction, services and cruise ships located in Batam. As the pure Oxygen demand increased, the company then produced pure Oxygen Plant Department. To fulfil the demand for pure oxygen products, the company calculate it in a very simple way. The production only carries out their planning based on previous request. As a result, it caused losses because lack of information and calculation leading to mismatch between supply and demand, and also the company production are reduced. The aim of this study is to optimize available production capabilities by using the analysis of aggregate planning, allowing adjustment to uncertain market demand. The variations in inventory, production level, labour levels, and other controllable variable are considered to minimize production shortfalls. To obtain the best strategy in minimizing costs, the aggregate planning methods used are level strategy, chase strategy, and mixed strategy. From this research it is obtained that the minimum cost is done by mixed strategy method.

Keywords: *aggregate planning, heuristic method, mixed strategy, pure oxygen, costs*

1. Introduction

As the competition in the Indonesian industry becomes increasingly and more competitive, companies need to ensure that their planning has the goal of generating profits. This is not easily achieved because poor planning can lead to losses for the company. Production process is one of the main factors that can affect these losses. Production is a crucial aspect from company's operations, in order to have a smooth and efficient production activities, it needs to be carried out as a series of operational management activities (Efendi, 2019).

XYZ company is located in the Indragiri Hilir Regency, Riau. This company engaged in construction, services, and shipping. The company also ventured into the production of pure oxygen by establishing the Oxygen Plant department in 2018. They produce pure oxygen products at pressures of 1500 Psi and 2000 Psi.

The demand of oxygen is increasing as the infrastructure in Riau. Consequently, the production planning department should be ready to fulfill the demand. Previously, the company plans the production unit only based on historical data. This leads to production shortages and often resulted in unfulfilled demand fluctuations. As a result, consumers turn to

other suppliers to meet their pure oxygen needs, causing financial losses for the company. In response to customer needs, planning must be carried out as efficiently In response to customer needs, planning must be carried out as efficiently and cheaply as feasible.

Aggregate planning can be used to optimize available production capacity for adapting to uncertain market demands (Sari et al., 2022). Aggregate planning is classified as medium-term planning (range from 3 months to 1 year), and its outcome is a production plan (Agustina et al., 2022).

Based on the foregoing, the problem to be addressed in this study is how to apply appropriate aggregate planning techniques, such as the level strategy, chase strategy, and mixed strategy, in the oxygen plant department.

2. Methods

The essence of planning and control includes three aspects: the planning and management of information flow, material flow, and cost flow (Sinulingga, 2009). The planner's job is to integrate the manufacturing department with other departments within the organization in order to guarantee that the production plan appropriately reflects the company's conditions and capabilities. This includes establishing what goods/products will be manufactured, the quantity of goods/products to be manufactured, when production will begin and end, and the amount of labor, raw materials, and equipment required for the manufacturing process (Kusmindari et al., 2018). In a complex and dynamic free market environment, demand forecasting is highly essential as a reference for creating effective and accurate production planning. Therefore, accurate forecasting is a crucial piece of information needed for production planning (Indiyanto, 2008).

Primary data is the research info gathered through interviews with the head of the Oxygen Plant department at PT. XYZ, covering the issues that occur in that department. On the other hand, secondary data is typically collected from official releases or publications, including material utilized as literature within the company includes books and reports. The data collected in this research set includes demand statistics from the previous two years, personnel data, and other relevant information.

If demand and supply or resources are modified simultaneously, this method will be more appropriate for minimizing costs (Wirabhuana et al., 2007). The process of acquiring information in the field to answer research questions is known as data collection. Following that, data processing is performed, with the first step being forecasting utilizing various approaches. The second stage is to compute aggregate planning using a level strategy, a chase strategy, or a mixed strategy.

The following steps are involved in the processing of aggregate planning data:

2.1. Demand Forecasting

Basically, the objective of aggregate planning is to seek an optimal solution to minimize costs during the planning period (Heizer & Render, 2014). Forecasting demand utilizing techniques such as Moving Average (MA), Weighted Moving Average (WMA), and Least Squares. Using data from the two years prior, these mathematical models forecast monthly demand for the future year.

The Simple Moving Average is calculated by averaging the demand over numerous recent previous data points. This MA technique's major purpose is to lessen or eliminate unpredictable variations in demand over time. This goal is met by averaging numerous data

points and using an average to anticipate demand for future periods (Ambarwati & Supardi, 2020).

$$\text{MA} = \frac{\Sigma \text{ (Demand from prior period)}}{\text{n}} \quad (1)$$

Weighted Moving Average is a weighted averaging technique that produces a pattern of averages. Weight is assigned to each period, so the closer the period is to the present, the higher the weight assigned to it.

$$WMA = \frac{\Sigma \text{ (Weighted for n period) (actual demand n period)}}{\Sigma \text{ (Weighted)}} \quad (2)$$

The least squares method is a regression technique that use a linear regression model to identify the best fit for a given set of data that is typically used to predict future data.

This method is frequently used to determine the outcome of experiments since the results are detailed and precise. The least squares method is one of time series, in which data from the previous activity is required to conduct a study of the data from the future/predicted so that the results may be evaluated.

$$a = \frac{\Sigma y}{n} \quad (3)$$

2.2. Aggregate Planning

Aggregate planning is created using predicted demand quantity and predefined relevant criteria. It is then utilized to determine aggregate planning by employing a level strategy, a chase strategy, or both.

This method is separated into two categories: time series methods and cause-and-effect methods. Freehand approaches, half-averaging, moving averages, and exponential smoothing are all time series methods. Meanwhile, cause-effect approaches include both simple and complex regression (Rony et al., 2019).

The accuracy measurement of forecasting results, which is an indicator of forecasting errors, represents the degree of difference between the forecasted results and the actual demand (Kusmindari et al., 2018). There are three common accuracy measurements:

a. Mean Absolute Deviation (MAD)

The Mean Absolute Deviation calculates the average absolute errors over a specific period without considering whether the forecasted values are greater or smaller than the actual values. It is systematically formulated as follows:

$$\text{MAD} = \frac{\Sigma \text{ (Absolut dari forecast error)}}{\text{N}-\text{n}} \quad (4)$$

Where:

n: Number of forecast periods

b. Mean Square Error (MSE)

The Mean Square Error is the average of squared forecast errors. In other words, it represents the mean of the squared forecasting errors. It is formulated as follows:

$$MSE = \frac{\Sigma ei}{n} \quad (5)$$

Where:
n: Number of forecast periods

c. Mean Absolute Percent Error (MAPE)

MAPE expresses the percentage error of the forecasting results compared to the actual demand over a specific period. It provides information about the percentage of errors that are too high or too low. Mathematically, MAPE is expressed as follows:

$$MAPE = \frac{\Sigma \left|\frac{e}{xi}\right| (100)}{n} \quad (6)$$

Where:
e: Error
n: Number of forecast periods
xi: Actual demand in the respective period

Some heuristic methods in aggregate planning (Rosta & Tannady, 2013) are Level Strategy, chase strategy and mixed strategy. These heuristic methods help in making aggregate production planning decisions based on the specific needs and constraints of the organization.

3. Result and Discussion

In the Oxygen Plant department, there are 9 employees responsible for the production process. The production process in the Oxygen Plant includes the liquid pumping process, vaporizer process, and filling oxygen into cylinders. The data to be collected for this research includes demand data, working hours data, and production cost data in the Oxygen Plant department of PT XYZ. Based on observations, the demand data for pure oxygen products in the Oxygen Plant department for the past 2 years, from May 2021 to April 2023, is as follows:

Table 1. Oxygen Demand from Mei 2021 – April 2023

Period	Demand	Period	Demand
Mei-21	741-unit	Mei-22	692-unit
Juni-21	771-unit	Juni-22	749-unit
Juli-21	732-unit	Juli-22	520-unit
Agustus-21	491-unit	Agustus-22	360-unit
September-21	315-unit	September-22	445-unit
Oktober-21	531-unit	Oktober-22	722-unit
November-21	834-unit	November-22	1.015-unit
Desember-21	738-unit	Desember-22	1.392-unit
Januari-22	839-unit	Januari-23	1.238-unit
Febuari-22	616-unit	Febuari-23	1.050-unit
Maret-22	569-unit	Maret-23	1.152-unit
April-22	405-unit	April-23	1.214-unit

According to the observations and interviews with corporate management performed throughout the investigation, the Oxygen Plant department employs 9 people who work non-shifts for 8 hours every day. The following production cost data pertains to the expenses incurred by the Oxygen Plant department for oxygen products.

3.1. Forecasting

During the forecasting stage, three methods are used, including moving average, weighted moving average, and least square. Here are the results of the forecasting calculations:

a. Moving Average (MA) Forecasting

The oxygen moving average forecast is calculated with a 4-period moving average.

Table 2. Moving Average Methods

Month	**Demand**	**4 period of MA**	**Forecast** $Ft = \frac{A1+..An}{n}$	**Error** At - Ft	**Error2** (At – Ft)2	**%Err** $\Sigma \left\lvert \frac{e}{Xi} \right\rvert$ (100
Mei-21	741					
Jun-21	771					
Jul-21	732					
Agu-21	491					
Sep-21	315	(741+771+732+491):4	684	368,75	135976,56	117,06
Okt-21	531	(771+732+491+315):4	577	46,25	2139,06	8,71
Nov-21	834	(732+491+315+531):4	517	316,75	100330,56	37,98
Des-21	738	(491+315+531+834):4	543	195,25	38122,56	26,46
Jan-22	839	(315+531+834+738):4	605	234,5	54990,25	27,95
Feb-22	616	(531+834+738+839):4	736	119,5	14280,25	19,40
Mar-22	569	(834+738+839+616):4	757	187,75	35250,06	33,00
Apr-22	405	(738+839+616+569):4	691	285,5	81510,25	70,49
Mei-22	692	(839+616+569+405):4	607	84,75	7182,56	12,25
Jun-22	749	(616+569+405+692):4	571	178,5	31862,25	23,83
Jul-22	520	(569+405+692+749):4	604	83,75	7014,06	16,11
Agu-22	360	(405+692+749+520):4	592	231,5	53592,25	64,31
Sep-22	445	(692+749+520+360):4	580	135,25	18292,56	30,39
Ok-22	722	(749+520+360+445):4	519	203,5	41412,25	28,19
Nov-22	1.015	(520+360+445+772):4	512	503,25	253260,56	49,58
Des-22	1.392	(360+445+772+1015):4	636	756,5	572292,25	54,35
Jan-23	1.238	(445+772+1015+1392):4	894	344,5	118680,25	27,83
Feb-23	1.050	(772+1015+1392+1238):4	1.092	41,75	1743,06	3,98
Mar-23	1.152	(1015+1392+1238+1050):4	1.174	21,75	473,06	1,89
Apr-23	1.214	(1392+1238+1050+1152):4	1.208	6	36,00	0,49
Mei-23	1.164	(1238+1050+1152+1214):	1.164	1	0,25	0,04

Month	Demand	4 period of MA	Forecast $Ft = \frac{A1+..An}{n}$	Error At - Ft	Error2 (At – Ft)2	%Err $\Sigma \left\lvert \frac{e}{Xi} \right\rvert$ (100
		4				
Jun-23	1.145	(1050+1152+1214+1164): 4	1.145	0	0,00	0,00
Jul-23	1.169	(1152+1214+1164+1145): 4	1.169	0,25	0,06	0,02
Agu-23	1.173	(1214+1164+1145+1169): 4	1.173	0	0,00	0,00
Sep-23	1.163	(1164+1145+1169+1173): 4	1.163	0,25	0,06	0,02
Okt-23	1.163	(1145+1169+1173+1163): 4	1.163	0,5	0,25	0,04
Nov-23	1.167	(1169+1173+1163+1163): 4	1.167	0	0,00	0,00
Des-23	1.167	(1173+1163+1163+1167): 4	1.167	0,5	0,25	0,04
Jan-24	1.165	(1163+1163+1167+1167): 4	1.165	0	0,00	0,00
Feb-24	1.166	(1163+1167+1167+1165): 4	1.166	0,5	0,25	0,04
Mar-24	1.166	(1167+1167+1165+1166): 4	1.166	0,25	0,06	0,02
Apr - 24		(1167+1165+1166+1166): 4	1.166			
Total				4348	1568441, 8	654,46

Forecasting using *moving average* (MA) method resulted MAD, MSE and MAPE as below:

$$\text{MAD} = \frac{\Sigma(\,Absolut\ dari\ error)}{N-n} = \frac{4348}{24-4} = 217{,}40$$

$$\text{MSE} = \frac{\Sigma ei}{N-n} = \frac{1568441}{24-4} = 78422{,}1$$

$$\text{MAPE} = \frac{\Sigma\left|\frac{e}{Xi}\right|(100)}{N-n} = \frac{6{,}54}{20} = 0{,}33$$

b. Weighted Moving Average Forecasting

Weighted moving average (WMA) for the oxygen product MAD, MSE and MAPE sebagai berikut:

$$\text{MAD} = \frac{\Sigma(\,Absolut\ dari\ error)}{N-n} = \frac{4126}{24-4} = 206{,}29$$

$$\text{MSE} = \frac{\Sigma ei}{N-n} = \frac{1288330}{24-4} = 64416{,}5$$

$$\text{MAPE} = \frac{\Sigma\left|\frac{e}{Xi}\right|(100)}{\text{N}-\text{n}} = \frac{6{,}24}{20} = 0{,}31$$

c. Least Square Forecasting

Forecasting by using least square method resulted a, b MAD, MSE and MAPE as below:

$$a = \frac{\Sigma Y}{n}$$

$$a = \frac{18131}{24} = 755{,}46$$

$$b = \frac{\Sigma XY}{\Sigma X^2}$$

$$b = \frac{53193}{4600} = 11{,}564$$

y' = a + bx

y' = 755,46 + 11,564X

Mei-21 = 755,46 + (11,564 x (-23))

= 489

$$\text{MAD} = \frac{\Sigma(\textit{Absolut dari error})}{n} = \frac{4884{,}7}{24} = 203{,}5$$

$$\text{MSE} = \frac{\Sigma ei}{n} = \frac{1363760}{24} = 56823{,}35$$

$$\text{MAPE} = \frac{\Sigma\left|\frac{e}{Xi}\right|(100)}{\text{N}-\text{n}} = \frac{3{,}02}{24} = 0{,}12$$

Three approaches were used to calculate demand forecasts for oxygen products: Moving Average, Weighted Moving Average, and Least Square. The results showed that the error rates for each method varied. Each method's error rates will be compared to the Mean Absolute Percentage Error (MAPE), where a forecasting mistake smaller than zero is indicated as a figure closer to zero. The approach with the lowest MAPE among these three will be used in subsequent computations.

The MAPE value obtained in the Moving Average forecasting method is 0.33. The MAPE value for the Weighted Moving Average technique is 0.31. The MAPE value obtained using the Least Squares approach is 0.12. It is clear from the MAPE numbers that the Least Squares approach has the lowest MAPE when compared to the Moving Average.

Table 3. Forecasting Result for 2023/2024

Period	**Forecast**
Mei-23	1.045-unit
Jun-23	1.068-unit

Jul-23	1.091-unit
Agu-23	1.114-unit
Sep-23	1.137-unit
Okt-23	1.160-unit
Nov-23	1.183-unit
Des-23	1.206-unit
Jan-24	1.230-unit
Feb-24	1.253-unit
Mar-24	1.276-unit
Apr -24	1.299-unit

3.2. Aggregate Planning

In this aggregate planning, calculations are carried out using a heuristic method. This method is the most realistic in terms of its probability of implementation and application to real-world problems. It is divided into three strategies: Level Strategy, Chase Strategy, and Mixed Strategy.

a. Level Strategy Method

There is an initial inventory of 80 units and a fixed production quantity of 1172 units in the Level Strategy calculation. Any excess inventory is utilized to meet demand during designated times. This plan calls for a steady staff of nine workers. Demand predictions and predetermined production costs, computed using the following formulas, are integrated into the planning.

Inventory = 1.172-unit + 80-unit initial inventory – 1045-unit *demand*
= 207 unit
Reguler Time = Rp 3.200.000 x 9 workers
= Rp 28.800.000
Production Cost = 1.172-unit oxygen x Rp. 70.000
= Rp. 82.040.000
Inventory Cost = 207-unit oxygen x Rp. 6.618
= Rp. 1.369.926
Total *Cost* = Rp. 345.600.000 x Rp. 984.480.000 x Rp. 28.311.804

= Rp. 1.358.391.804

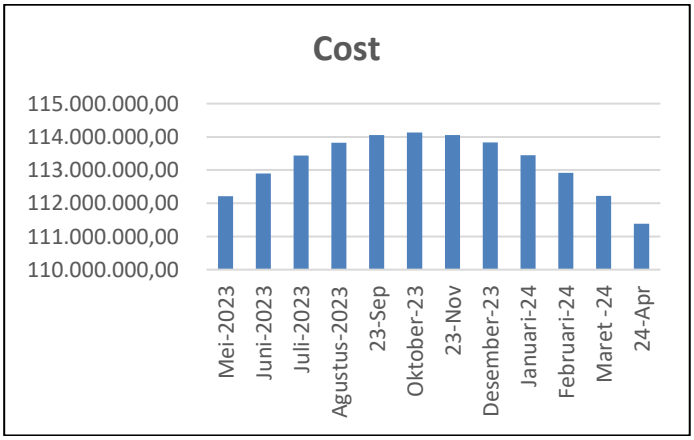

Figure 1. Monthly Cost for Level Strategy Method

b. Chase Strategy Method

In the Chase Strategy calculation, the oxygen production plan is adjusted based on the oxygen demand forecast to meet the demand. Therefore, there is no inventory, and initial inventory is not used in this planning. The required workforce is not fixed; the company can increase or decrease the workforce based on the demand level in each period. Production costs for each period are calculated using the following formulas:

Regular time = Rp 3.200.000 x 8 workers
= Rp 25.600.000

Production Cost = 1.045-unit oxygen x Rp. 70.000
= Rp. 73.150.000

Workforces $= \frac{1.045}{5 \text{ x } 25}$
= 8 people

Hire = No additional worker

Layoff = 1 workforce x Rp. 500.000
= Rp. 500.000

Total *cost* = Rp. 361.600.000 + Rp. 984.340.000 + Rp. 6.000.000 + Rp. 1.500.000
= Rp. 1.353.440.000

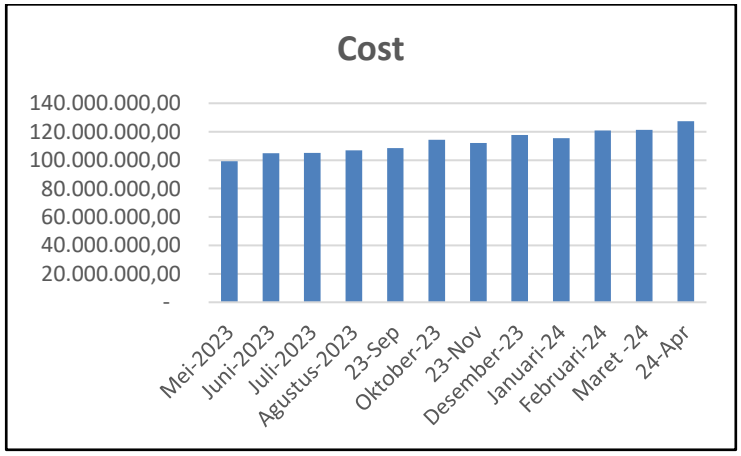

Figure 2. Monthly Cost for Chase Strategy Method

c. Mixed Strategy Method

For the Mixed Strategy calculation, a fixed workforce of 9 employees is required. This planning combines both overtime and inventory. The production quantity is determined based on the smallest demand, which is 1,045 units, with an initial inventory of 80 units. If there is a production shortfall, it will be compensated for with overtime, and if there is an excess production, it will be stored as inventory. Production costs for each period are calculated using the following formulas:

Regular time = Rp 3.200.000 x 9 Workforces
= Rp 28.800.000

Production Cost = 1.045-unit oxygen x Rp. 70.000

= Rp. 73.150.000

Overtime = No *overtime*

Cost overtime = No *overtime*

Inventory = 1.045- production unit + 80-unit initial inventory–1.045-unit *demand*
= 80-unit

Cost Inventory = 80-unit oxygen x Rp. 6.618= Rp. 529.440

Total *cost* = Rp. 979.464 + Rp. 978.740.000 + Rp. 345.600,000 + Rp 4.902.800
= Rp. 1.330.222.264

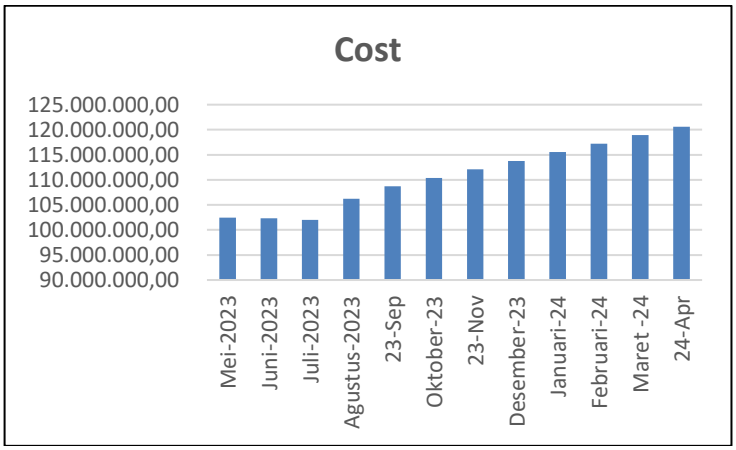

Figure 3. Monthly Cost for Mixed Strategy Method

From the calculation, it is obtained the comparison between three methods. The result as the following can be seen in Table 4 below:

Table 4. Aggregate Planning Result Comparison

Ranking	Method	Result
1	*Mixed Strategy*	Rp. 1.330.222.264
2	*Chase Strategy*	Rp. 1.353.440.000
3	*Level Strategy*	Rp. 1.358.391.804

The Mixed Strategy is the selected approach based on the aggregate planning calculations utilizing heuristic methods, which are separated into three strategies: Level Strategy, Chase Strategy, and Mixed Strategy. Its planning is the most economical and efficient, with oxygen product costs totalling Rp. 1,330,222,264.

4. Conclusions

Based on the data collection and data processing, the forecasting methods yielded the following MAPE values: Moving Average - 0.33, Weighted Moving Average - 0.31, and Least Square - 0.12. The Least Square method, with the lowest MAPE of 0.12, has been selected as the demand forecasting method for May 2023 to April 2024.

In terms of aggregate planning using heuristic methods, the Level Strategy incurs a cost of Rp. 1,358,391,804, the Chase Strategy costs Rp. 1,353,440,000, and the Mixed Strategy costs

Rp. 1,330,222,264. The Mixed Strategy, which results in the minimum cost, is the most suitable for PT. XYZ in the Oxygen Plant department for the period from May 2023 to April 2024. It involves producing 14,062 oxygen cylinders without adding additional labor, resulting in a total minimum cost of Rp. 1,330,222,264.

References

[1] Ambarwati, R., & Supardi. (2020). Buku Ajar Manajemen Operasional Dan Implementasi Dalam Industri. In H. C. Wahyuni & W. Sulistyowati, *Buku Ajar Manajemen Operasional Dan Implementasi Dalam Industri* (1st ed.). UMSIDA Press.

[2] Agustina, M., Apriandani, S., & Anwar, A. (2022). Perencanaan Agregat pada Usaha Pembuat Keranjang Desa Binjai, Kalimantan Barat. *Jurnal LOGIC Logistics & Supply Chain Center*, *01*(01), 18–26.

[3] Heizer, J., & Render, B. (2014). *Manajemen Operasi* (D. A. Halim (ed.); d.). Salemba Empat.

[4] Indiyanto, R. (2008). Perencanaan dan Pengendalian Produksi. In *yayasan Humaniora*. Yayasan Humaniora.

[5] Kusmindari, D., Alfian, A., & Hardini, S. (2018). *Production Planning And Inventory Control*. CV Budi Utama.

[6] Rony, U. E., Nur, J. G. A., & Andry, P. (2019). *Buku Manajemen Operasi* (Issue November). UM Jakarta Press. Buku Manajemen Operasi.

[7] Rosta, J., & Tannady, H. (2013). Perencanaan Agregat Heuristik Untuk Penentuan Sumber Daya Yang Optimal. *Spektrum Industri: Jurnal Ilmiah Pengetahuan Dan Penerapan Teknik Industri, 11*(1), 91–97.

[8] Sari, S., Pitaloka, D. A., Hergiyan, S., Siburian, B., Bagus, I., & Yordan, P. (2022). Analisis Metode Agregat Planning untuk Minimasi Biaya pada UMKM Makmur Jaya-Jakarta Analysis of Agregate Planning Method for Minimizing Costs at UMKM Makmur Jaya-Jakarta. *Jurnal Teknik*, *11*(02), 59–68.

[9] Sinulingga, S. (2009). Perencanaan dan Pengendalian Produksi. In *Book* (1st ed.). Graha ilmu

[10] Wirabhuana, A., Farihah, T., & Agustina, D. (2007). *Sistem Produksi*. info grahailmu.