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Daftar Isi

Selecting the Best Forecasting Method at PT. Indaco Warna Dunia

Maharani Sari M M[1)], Irwan Iftadi[2)]

Department of Industrial Engineering, Sebelas Maret Uiversity,
Jl. Ir. Sutami No. 36 A, Surakarta, 57126, Indonesia[1),2)]
E-Mail : maharanisans99@gmail.com[1)], iftadi@gmail.com[2)]

ABSTRACT

PT. Indaco Warna Dunia is a decorative paint company in Indonesia that produces products under the brands Envi, Belazo, and Top Seal. Preliminary observations revealed that the forecasting method used by the company is ineffective and inaccurate. This inaccurate forecast result company's problem in fulfilling the demand. This study aims to select the best forecasting method to improve forecast effectiveness and accuracy. The research was conducted at the Tarakan depot, and the products understudy were a fast-moving product category, specifically the Envi brand. Several forecasting methods such as Moving Average, Weighted Moving Average, Single Exponential Smoothing, Exponential Smoothing with Trend, and Holt's Double Exponential Smoothing. The accuracy of forecasting is the most important and it can be measured with MAPE (Mean Absolute Percentage Error). The results showed that Holt's Double Exponential Smoothing method is the best for three products, while the Exponential Smoothing with Trend method, and Single Exponential Smoothing method are the best for one of the products, respectively.

Keywords: Moving Average, Weighted Moving Average, Single Exponential Smoothing, Exponential Smoothing with Trend, Holt's Double Exponential Smoothing.

1. Introduction

The development of the business world in Indonesia is growing rapidly with many kinds of competition. Every company must be able to meet consumer needs appropriately and promptly to create and retain customers. In order to fulfill those conditions, it requires inventory control. Forecasting is very important in making decisions for inventory planning. Forecasting is a method that can analyze factors that are known to influence the occurrence of an event over a long period between the need for knowledge of an event in the future with the time that the event has occurred in the future then (Kurniadi, 2018). Forecasting is an important tool in planning effectively and efficiently, especially in economics. Forecasting is part of the decision-support system that can help decision-makers; various methods have been applied in a decision-support system (Chamid & Murti, 2018). In modern organizations knowing the future state is important to see good or bad and aims to prepare to forecast. Several forecasting methods, such as single-moving averages, are often used to support decisions in forecasting historical data. Decision support systems can provide input for decision-makers objectively (Chamid et al., 2015).

PT. Indaco Warna Dunia is a decorative paint company in Indonesia that produces products under the brands Belazo, Envi, and Top Seal. There are various sizes, such as cans, gallons, and pails, and various colors. Each product has a different demand for each period. Sometimes the number of demands has increased drastically and decreased significantly. PT. Indaco Warna Dunia makes production scheduling based on historical sales data for the previous six periods. There is a problem that is often found, that is, the difference between the forecast results and the actual demand. This is an example of the difference between forecasting results and actual demand in the Tarakan depot. Based on the data in Table 1, in July 2019 PT. Indaco Warna Dunia, as the center, sent 260 units of 845G paint to the Tarakan depot and the number of sales for that month was 58 units. There was a surge in demand in August 2019 of 170 units which caused a reduction in the stock of 845G paint products at the Tarakan depot. So, the Tarakan depot requested the center to send products. The unpredictable increase in demand caused the center to be unable to fulfill the demand for the Tarakan depot. Furthermore, sales in September and October were 100 units and 70 units. The center, PT. Indaco Warna Dunia, could not fulfill demand on time. They sent the products in November 2019 and only 32 units which is far from the Tarakan depot's request. The center receives complaints from the depot because they were unable to fulfill demand on time due to an unexpected spike in market demand.

Table 1. Recapitulation of Delivery and Sales at the Tarakan Depot

Period	845G		DBBYCG	
	Delivery	Sale	Delivery	Sale
01/07/2019	260	58		36
02/07/2019		170	40	20
03/07/2019		100		32
04/07/2019		70	60	20
05/07/2019	32	80		13
06/07/2019		94		14
Total	292	572	100	135

Based on the existing problems, a sales strategy is needed, one of which is by predicting or forecasting sales (Margi S & Pendawa, 2015).

A more measured scheme of demand will make the cost lower. It needs a method that can be applied in controlling inventory to reduce costs arising from the fluctuating demand.

This study aims to select the best demand forecasting method to improve forecast effectiveness and accuracy for each product, that is MBYCG, DBBYCG, 845G, 850G, and 870G based on historical demand data.

2. Methodology

This chapter describes the steps in conducting research, starting with the initial identification stage, calculating forecasting using several methods, and the conclusion stage.

At the initial identification stage, observations were done at the Logistics Department of the VMI section. The purpose of this observation is to find a preliminary assumption that the forecasting method used by the company is ineffective and causing forecast errors. This forecasting error failed to fulfill the demand for the depot on time and in the right demand, so the company received complaints from the depot. Therefore, the calculation of the error value is carried out using the company forecasting method as an initial identification to strengthen the assumption obtained at the observation.

The research was conducted at the Tarakan depot and on fast-moving products or PUSH categories (according to the company). The products studied included MBYCG, DBBYCG, 845G, 850G, and 870G.

Forecasting calculations are carried out using the company method, then the tracking signal and MAPE value. The data needed is product demand data and the value of the lead time for sending products from the center to the Tarakan depot, which is 27 days. From this MAPE calculation, it can be seen that the forecasting method used by the company has a high error value. Improvements are needed by looking for a proposed method with a smaller error to improve forecast effectiveness and accuracy.

The next step is to calculate forecasting using various methods including Moving Average, Weighted Moving Average, Single Exponential Smoothing, Exponential Smoothing with Trend, and Holt's Double Exponential Smoothing, and then calculate the MAPE value for each method. The accuracy of forecasting is the most important and it can be measured with MAPE. Selection of the best method based on the smallest MAPE value and tracking signal within the limits (-4 to +4).

And the last stage is conclusions and suggestions. The conclusion contains a summary of this research and suggestions containing suggestions for future research.

3. Results and Discussion

This chapter describes the initial identification, forecasting calculations, and selecting the best method.

3.1. Initial Identification

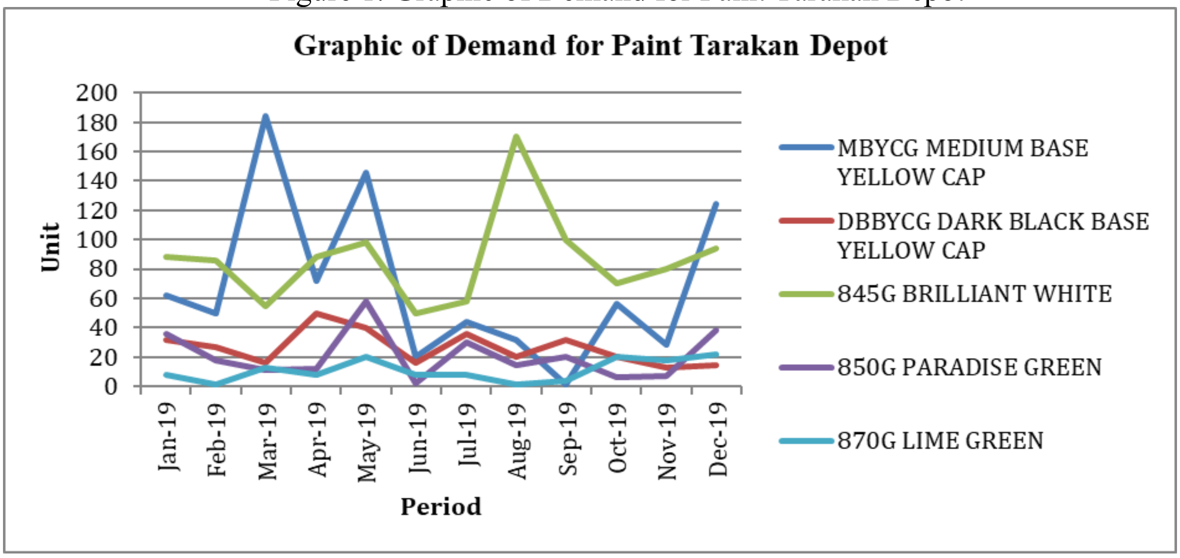
At this stage, data collection is carried out, that is demand data in product sales by the depot and data on the delivery of products to the depot. The result of this stage is that the company forecasting method has a high error value based on MAPE.

From the preliminary observations, it is obtained an assumption that the forecasting method used by the company is ineffective, causing forecast errors. Forecasting calculations used by the company method is using product demand data and the value of the lead time for delivery of products from the center to the Tarakan depot (27 days). Demand data used is for 6 months, from July 2019 to December 2019. Product demand data from January 2019 to December 2019 can be seen in Table 2.

Table 2. Demand for Paint Tarakan Depot

Period	Products				
	MBYCG	DBBYCG	845G	850G	870G
	MEDIUM BASE YELLOW CAP	DARK BLACK BASE YELLOW CAP	BRILLIANT WHITE	PARADISE GREEN	LIME GREEN
Jan-19	62	32	88	36	8
Feb-19	50	27	86	18	1
Mar-19	184	16	55	11	13
Apr-19	72	50	88	12	8
May-19	146	40	98	58	20
Jun-19	20	16	50	2	8
Jul-19	44	36	58	30	8
Aug-19	32	20	170	14	1
Sep-19	1	32	100	20	4
Oct-19	56	20	70	6	20
Nov-19	28	13	80	7	18
Dec-19	124	14	94	38	22

Figure 1. Graphic of Demand for Paint Tarakan Depot



Forecasting calculations with the company method are done by multiplying the median value of demand with the multiplier number that has been determined by the company. If the product is less than the average demand for 6 months, an adjustment is needed to increase the multiplier value without exceeding the maximum adjustment limit. There are three product categories, that is PUSH, PULL, and MIXING. PUSH products are fast-moving products, for forecasting multiplied by the number 1.5, and adjustments can be made up to the number 3. PULL products are medium-moving products, for forecasting multiplied by the number 1, and adjustments can be made up to number 2. MIXING products are paint products. slow-moving whose fulfillment can be done by tinting because of the low demand for that category. Forecasting for the MIXING product category is multiplied by number 1 and adjustments can be made up to 1.5. This research is specifically for PUSH products, the multiplier number is 1.5. Then calculate the error value and get high error results based on MAPE. Recapitulation of the observation results can be seen in Table 3.

Table 3. Recapitulation of Error Value Calculation using Company Method

Produk	*Tracking Signal*	MAPE
MBYCG	-6,00	2109,64%
DBBYCG	-6,00	148,55%
845G	-6,00	141,34%
850G	-6,00	267,08%
870G	-6,00	640,44%

Based on the calculation, it can be seen that the company's forecasting method has a high MAPE value, and the tracking signal is out of limits (-4 to +4). So that improvement is needed in choosing the forecasting method.

3.2. Forecasting Calculations

At this stage, forecasting calculations are carried out using several methods including Moving Average, Weighted Moving Average, Single Exponential Smoothing, Exponential Smoothing with Trend, and Holt's Double Exponential Smoothing then calculating the MAPE value for each method. The data needed is product demand data.

The first method is the Moving Average method. The moving average forecast uses a number of historical actual data values to generate a forecast (Sinaga & Irawati, 2018). The moving average method is used if the past data is data that does not have trend elements or seasonal factors. Moving average forecasting is widely used to determine the trend of a time series (Nurlifa & Kusumadewi, 2017). It is also used as a means for computing short-term forecasts of time series (Perry, 2010).

The Single Moving Average method uses several actual data requests to generate forecast values. The calculation is done by taking a group of values or data and then calculating the average and with the average used to calculate the next period forecast. From the results of the prediction or calculation, product sales can be used to make policies in the production, so that the company gets information for the production in the following month, or in certain months according to the results of predictions of product sales (Dewi & Chamid, 2019).

In this method, data is used at least 3 periods (Gusdian et al., 2016). This method is called a moving average because every time new observation data is available, new average figures are available calculated, and used as a forecast. The Simple Moving Average technique has the characteristic that the causal factors that have occurred in the past are used in the future (Utari et al., 2016). The results of forecasting calculations using the Moving Average Method can be seen in Table 4.

Table 4. Results of Forecasting Calculations using the Moving Average Method

Produk	*Tracking Signal*	MAPE
MBYCG	-1,66	452,61%
DBBYCG	-1,37	51,06%
845G	0,94	34,20%
850G	0,56	220,19%
870G	3,17	166,95%

The concept of the Weighted Moving Average method is similar to the Moving

Average method but provides weighting. The essence of this method is that the company assigns to each value in a year a specific weight (expressed in fractions of one), thereby assessing the significance of the year in question for the value of the predicted parameter, in connection with certain events of those years (Vlasov et al., 2018).

This method is more responsive to changes because data from a new period are usually given greater weight. The results of forecasting calculations using the Weighted Moving Average Method can be seen in Table 5.

Table 5. Results of Forecasting Calculations with the Weighted Moving Average Method

Produk	*Tracking Signal*	MAPE
MBYCG	-0,93	654,67%
DBBYCG	-3,36	51,92%
845G	0,58	32,79%
850G	1,05	251,24%
870G	2,77	166,53%

Single exponential smoothing is also known as simple exponential smoothing. Exponential smoothing methods are the most widely used techniques in forecasting due to their simplicity, robustness, and accuracy as an automatic forecasting procedure (Yapar et al., 2018). Simple smoothing is used for short-range forecasting, usually just one month into the future. The model assumes that the data fluctuates around a reasonably stable mean (no trend or consistent pattern of growth) (Kalekar, 2004). Although exponential smoothing is a common method, there are some shortcomings, for example, there is no consistent rule in the literature about the choice of initial value and smoothing constant. These negatively affect the accuracy of forecasts (Efe et al., 2018).

This method is calculated using weighted averages where the weight decreases exponentially as observations come from further in the past. The smallest weight is associated with the oldest observations. The smoothing parameter α is between 0 and 1. The closer α to 0 then the more weight is given to observations from the more distant past. The closer α to 1 then the more weight is given to recent observations.

The results of forecasting calculations using the Single Exponential Smoothing Method can be seen in Table 6.

Table 6. Results of Forecasting Calculations using the Single Exponential Smoothing Method

Produk	α	*Tracking Signal*	MAPE
MBYCG	0,9	0,99	399,43%
DBBYCG	0,6	-2,46	51,72%
845G	0,2	0,24	28,07%
850G	0,4	-2,06	229,89%
870G	0,8	2,43	173,20%

The trend line analysis model is used when the historical data of actual demand data shows a trend. Selecting optimal α and β values is usually done by trial and error depending on the minimum MAPE value and the tracking signal is between -4 to 4. The results of forecasting calculations using the Exponential Smoothing with Trend Method can be seen in Table 7.

Table 7. Results of Forecasting Calculations using the Exponential Smoothing with Trend Method

Produk	α	β	*Tracking Signal*	MAPE
MBYCG	0,8	0,4	1,25	302,45%
DBBYCG	0,6	0,2	-1,95	50,76%
845G	0,2	0,1	0,28	28,15%
850G	0,3	0,2	-2,14	223,85%
870G	0,7	0,3	2,05	176,89%

The Double Exponential Smoothing method is appropriately used when the data to be forecasted shows a trend. This method is a development of the Single Exponential which adds a trend element to the weight of the calculation so that in Double Exponential Smoothing (Holt's Method) there are two types of weights in the calculation, namely level (α) and trend (β) which are between 0 and 1 (Alfarisi, 2017). Choosing optimal α and β values is usually done in trial and error depending on the minimum MAPE value and the tracking signal is between -4 to 4. The results of forecasting calculations using Holt's Double Exponential Smoothing method can be seen in Table 8.

Table 8. The Results of Forecasting Calculations using Holt's Double Exponential Smoothing Method

Produk	α	β	*Tracking Signal*	MAPE
MBYCG	0,6	0,8	3,55	165,44%
DBBYCG	0,4	0,9	-3,99	59,95%
845G	0,4	0,9	-1,91	43,20%
850G	0,3	0,6	3,77	142,22%
870G	0,7	0,9	1,77	115,16%

3.3. Selection of the Best Forecasting Method

At this stage, the best forecasting method is chosen for each product. The method chosen is the method with the smallest MAPE value. So, the best method for each product is MBYCG, 850G, and 870G using Holt's Double Exponential Smoothing method, DBBYCG using the Exponential Smoothing with Trend method, and 845G using the Single Exponential Smoothing method. The comparison of MAPE values between several methods can be seen in Table 9.

The lowest MAPE value obtained from the calculation is still high. This is probably because other aspects influence demand patterns. Tracking signals also indicate other aspects that affect demand patterns. This aspect produces a fluctuating demand pattern. Things that can influence demand patterns include the presence of competitive products, promos so that sales increase, or other marketing strategies.

4. Conclusion

This study concludes that the forecasting method used by the company has a high error. The forecasting method which is most effective for each product is as follows:

- For MBYCG, 850G, and 870G paint products using Holt's Double Exponential Smoothing method. Furthermore, DBBYCG paints products using the Exponential Smoothing with Trend method. The 845G product uses the Single Exponential Smoothing method.
- For the next research, it is expected to be able to find a forecasting method with a smaller error rate for all products so that forecasting uses the same 1 method. In future work, to further reduce the forecasting error and to find more appropriate forecasting methods, extension or modification of the methods used in this research will be studied, and their performance compared with other forecasting methods. Additionally, forecast prices with longer periods (i.e., more than three months) should be determined.
- Further research can be carried out on aspects that affect demand patterns to determine a more accurate forecasting method. The suggestion for the company is that it can consider the proposed method chosen as an improvement.

Table 9. Comparison of MAPE Value Between Methods

Product	MAPE					
	Company	MA	WMA	SES	EST	Holt's DES
MBYCG	2109,64%	452,61%	654,67%	399,43%	302,45%	165,44%
DBBYCG	148,55%	51,06%	51,92%	51,72%	50,76%	59,95%
845G	141,34%	34,20%	32,79%	28,07%	28,15%	43,20%
850G	267,08%	220,19%	251,24%	229,89%	223,85%	142,22%
870G	640,44%	166,95%	166,53%	173,20%	176,89%	115,16%

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Appendices

Appendix 1. Results of MBYCG Forecasting Calculations using Company Method

MBYCG																
Period	Xt	Mean	Mean (days)	LT	Min	ROP	Dev	Max	Med	Ft	E	|E|	RSFE	MAD	TS	MAPE
Jul-19	44	47,5	2,159	27	58,30	58,30	41,76	100,06	79,18	118,76	-74,76	74,76	-74,76	74,76	-1,00	169,92%
Agu-19	32	47,5	2,159	27	58,30	58,30	41,76	100,06	79,18	118,76	-86,76	86,76	-161,53	80,76	-2,00	271,14%
Sep-19	1	47,5	2,159	27	58,30	58,30	41,76	100,06	79,18	118,76	-117,76	117,76	-279,29	93,10	-3,00	11776,32%
Okt-19	56	47,5	2,159	27	58,30	58,30	41,76	100,06	79,18	118,76	-62,76	62,76	-342,05	85,51	-4,00	112,08%
Nov-19	28	47,5	2,159	27	58,30	58,30	41,76	100,06	79,18	118,76	-90,76	90,76	-432,82	86,56	-5,00	324,15%
Des-19	124	47,5	2,159	27	58,30	58,30	41,76	100,06	79,18	118,76	5,24	5,24	-427,58	73,01	-5,86	4,22%
Jan-20										**119,00**					**MAPE**	**2109,64%**

Appendix 2. Results of MBYCG Forecasting Calculations using Moving Average Method

MBYCG								
Period	Demand	Forecast	Error	|Error|	RSFE	MAD	Tracking Signal	MAPE
Jan-19	62							
Feb-19	50							
Mar-19	184							
Apr-19	72	98,67	-26,67	26,67	-26,67	26,67	-1,00	37,04%
Mei-19	146	102,00	44,00	44,00	17,33	35,33	0,49	30,14%
Jun-19	20	134,00	-114,00	114,00	-96,67	61,56	-1,57	570,00%
Jul-19	44	79,33	-35,33	35,33	-132,00	55,00	-2,40	80,30%
Agu-19	32	70,00	-38,00	38,00	-170,00	51,60	-3,29	118,75%
Sep-19	1	32,00	-31,00	31,00	-201,00	48,17	-4,17	3100,00%
Okt-19	56	25,67	30,33	30,33	-170,67	45,62	-3,74	54,17%
Nov-19	28	29,67	-1,67	1,67	-172,33	40,13	-4,29	5,95%
Des-19	124	28,33	95,67	95,67	-76,67	46,30	-1,66	77,15%
Jan-20		**70,00**					**MAPE**	452,61%

Appendix 3. Results of MBYCG Forecasting Calculations using Weighted Moving Average Method

MBYCG								
Period	Demand	Forecast	Error	|Error|	RSFE	MAD	Tracking Signal	MAPE
Jan-19	62							
Feb-19	50							
Mar-19	184							
Apr-19	72							
Mei-19	146	100,2	45,8	45,8	45,8	45,8	1,00	31,37%
Jun-19	20	121,8	-101,8	101,8	-56,0	73,8	-0,76	509,00%
Jul-19	44	84,6	-40,6	40,6	-96,6	62,7	-1,54	92,27%
Agu-19	32	60,0	-28,0	28,0	-124,6	54,1	-2,31	87,50%
Sep-19	1	44,6	-43,6	43,6	-168,2	52,0	-3,24	4360,00%
Okt-19	56	20,8	35,2	35,2	-133,0	49,2	-2,71	62,86%
Nov-19	28	33,5	-5,5	5,5	-138,5	42,9	-3,23	19,64%
Des-19	124	31,4	92,6	92,6	-45,9	49,1	-0,93	74,68%
Jan-20		**70,0**					**MAPE**	**654,67%**

Appendix 4. Results of MBYCG Forecasting Calculations using Single Exponential Smoothing Method

MBYCG									
Period	Demand	α	Forecast	Error	|Error|	RSFE	MAD	Tracking Signal	MAPE
Jan-19	62	0,9	62,00						
Feb-19	50	0,9	62,00	-12,00	12,00	-12,00	12,00	-1,00	24,00%
Mar-19	184	0,9	51,20	132,80	132,80	120,80	72,40	1,67	72,17%
Apr-19	72	0,9	170,72	-98,72	98,72	22,08	81,17	0,27	137,11%
Mei-19	146	0,9	81,87	64,13	64,13	86,21	76,91	1,12	43,92%
Jun-19	20	0,9	139,59	-119,59	119,59	-33,38	85,45	-0,39	597,94%
Jul-19	44	0,9	31,96	12,04	12,04	-21,34	73,21	-0,29	27,37%
Agu-19	32	0,9	42,80	-10,80	10,80	-32,13	64,30	-0,50	33,74%
Sep-19	1	0,9	33,08	-32,08	32,08	-64,21	60,27	-1,07	3207,96%
Okt-19	56	0,9	4,21	51,79	51,79	-12,42	59,33	-0,21	92,49%
Nov-19	28	0,9	50,82	-22,82	22,82	-35,24	55,68	-0,63	81,50%
Des-19	124	0,9	30,28	93,72	93,72	58,48	59,13	0,99	75,58%
Jan-20			**114,63**					**MAPE**	**399,43%**

Appendix 5. Results of MBYCG Forecasting Calculations using Single Exponential Smoothing with Trend Method

MBYCG												
Period	Demand	α	β	Et	Trend	Forecast	Error	|Error|	RSFE	MAD	TS	MAPE
Jan-19	62	0,8	0,4	62,00	0,00	62,00						
Feb-19	50	0,8	0,4	62,00	0,00	62,00	-12,00	12,00	-12,00	12,00	-1,00	24,00%
Mar-19	184	0,8	0,4	52,40	-3,84	48,56	135,44	135,44	123,44	73,72	1,67	73,61%
Apr-19	72	0,8	0,4	157,68	39,81	197,49	-125,49	125,49	-2,05	90,98	-0,02	174,29%
Mei-19	146	0,8	0,4	89,14	-3,53	85,60	60,40	60,40	58,35	83,33	0,70	41,37%
Jun-19	20	0,8	0,4	134,63	16,08	150,70	-130,70	130,70	-72,36	92,81	-0,78	653,52%
Jul-19	44	0,8	0,4	42,93	-27,03	15,89	28,11	28,11	-44,25	82,02	-0,54	63,88%
Agu-19	32	0,8	0,4	43,79	-15,88	27,91	4,09	4,09	-40,15	70,89	-0,57	12,79%
Sep-19	1	0,8	0,4	34,36	-13,30	21,06	-20,06	20,06	-60,21	64,54	-0,93	2005,96%
Okt-19	56	0,8	0,4	7,67	-18,65	-10,98	66,98	66,98	6,77	64,81	0,10	119,61%
Nov-19	28	0,8	0,4	46,33	4,27	50,61	-22,61	22,61	-15,84	60,59	-0,26	80,74%
Des-19	124	0,8	0,4	31,67	-3,30	28,36	95,64	95,64	79,80	63,77	1,25	77,13%
Jan-20				114,77	31,26	**147,00**					**MAPE**	**302,45%**

Appendix 6. Results of MBYCG Forecasting Calculations using Holt's Double Exponential Smoothing Method

MBYCG												
Period	Demand	α	β	St	Tt	Forecast	Error	|Error|	RSFE	MAD	TS	MAPE
Jan-19	62	0,6	0,8	62,00	-62,00							
Feb-19	50	0,6	0,8	30,00	-38,00	0,00	50,00	50,00	50,00	50,00	1,00	100,00%
Mar-19	184	0,6	0,8	107,20	54,16	-8,00	192,00	192,00	242,00	121,00	2,00	104,35%
Apr-19	72	0,6	0,8	107,74	11,27	161,36	-89,36	89,36	152,64	110,45	1,38	124,11%
Mei-19	146	0,6	0,8	135,20	24,22	119,01	26,99	26,99	179,63	89,59	2,01	18,49%
Jun-19	20	0,6	0,8	75,77	-42,70	159,43	-139,43	139,43	40,20	99,56	0,40	697,13%
Jul-19	44	0,6	0,8	39,63	-37,46	33,07	10,93	10,93	51,13	84,78	0,60	24,85%
Agu-19	32	0,6	0,8	20,07	-23,14	2,17	29,83	29,83	80,96	76,93	1,05	93,21%
Sep-19	1	0,6	0,8	-0,63	-21,18	-3,07	4,07	4,07	85,03	67,83	1,25	406,90%
Okt-19	56	0,6	0,8	24,88	16,17	-21,81	77,81	77,81	162,84	68,94	2,36	138,95%
Nov-19	28	0,6	0,8	33,22	9,91	41,04	-13,04	13,04	149,80	63,35	2,36	46,57%
Des-19	124	0,6	0,8	91,65	48,73	43,12	80,88	80,88	230,68	64,94	3,55	65,22%
Jan-20						**140,38**					**MAPE**	**165,44%**

Enhancing Line Efficiency Performance at Assembly Line using ECRS-Based Line Balancing Concept

Amalia Syaharani Ibnu[1)], Annisa Uswatun Khasanah[2)]

Department of Industrial Engineering, Faculty of Industrial Technology,
Universitas Islam Indonesia, Kaliurang Street km 14.5, Sleman
Daerah Istimewa Yogyakarta, 55584, Indonesia[1),2)]
E-Mail: annisa.uswatun@uii.ac.id[2)]

ABSTRACT

Recently, Indonesian textile and garment manufacturer has experienced a problem with shop floor production. The complexities in the manufacturing process led to many problems, such as inefficiency, and thus prevented the company from achieving its target. Even though the company has established an efficiency target of 80%, the production floor cannot realize it. Thus, this research aims to increase line efficiency to reach the company's target. At the beginning of the analysis, the efficiency of assembly line was only 51,68%. Since this value did not meet the company's target and was not satisfying, the concept of ECRS was applied. This research aims to simplify the method to provide better effect and process flow. Before applying the method, the fishbone diagrams were used. The factors of man, method, machine, and measurement were used to describe the root cause of the losses. Thus, after applying the concept of ECRS, the efficiency level increased to 81,54%, which met the company's target. The assembly line will run better and smoother with less possibility of bottlenecks if all of the workstations have a relatively balanced workload.

Keywords: Assembly Line Balancing (ALB); Line Efficiency; ECRS, Fishbone Diagram

1. Introduction

Industrial activities are inseparable from the global economy. Therefore, companies must create a business strategy to deal with a challenging business climate. Otherwise, the business is at risk of shutting down. Increasing domestic and international competition, coupled with relatively slow growth in Indonesian markets, have forced Indonesian apparel producers and retailers to pay close attention to changes in the market. Recently, Indonesian textile and garment manufacturer, PT XYZ, has confronted several problems related to overcapacity of production, global financial crisis, and multilateral and regional trade agreements. To become more competitive and profitable, PT. XYZ focused on achieving more incredible speed and efficiency. The tool and machinery play an essential role in each segment of textile. In a competitive market, the key determining factors of a company's success are on-time delivery and appropriate distribution. This issue becomes critical especially for the garment industry, which must always keep pace with style and fashion design changes. This is the problem faced by PT. XYZ, where changes must be made by involving complex processes. This condition often causes other problems such as delays in delivery, inefficiency preventing the company from meeting its targets, fewer outputs, and so on.

Australia was the country that placed the biggest order to PT XYZ. This company always tried to build a good relationship with its customers by constantly performing well and giving excellent service and quality, which became its vision and mission. This company maintained to have a solid financial support in order to improve the production technology and product quality. However, PT XYZ faced several problems on the production floor.

Nowadays, PT. XYZ has determined the target efficiency level of the production floor to be 80%. This target was set in order to push the production floor to reach the desired output within an hour and a day. Thus, it can prevent late shipments and maintain quality. However, the production floor mostly cannot meet the daily company target in all garment areas. This problem is mostly due to the sewing process as the last crucial process before finishing and shipping. This problem triggers several effects, such as late shipment that reduces buyers' loyalty or satisfaction. As mentioned in the agreement, in case of order delays, PT. XYZ should send its product using an airplane, which is undoubtedly costly and financially burdensome.

According to the condition mentioned earlier, the challenge for the PT. XYZ was to optimize the whole line production system. The key to improving the assembly line balancing performance is by recognizing the rooting (Nisphaphat & Ratanakuakangwan, 2016). First of all, the fishbone diagram was the appropriate method to analyze problems in the line production system. The root causes of the problem were analyzed based on factors of manpower or operator, methods, machine and measurement since this study was not only focused on the method but also focused on reducing operators. In addition, eliminating, combining, rearranging, and simplifying (ECRS) method was the most practical step to apply since the company integrated the procedure and arrangement of method and machine used. The purpose of the study was to improve the line efficiency of assembly line in the sewing area, and thus it can meet the company target of 80% and increase the output as well. It analyzed the production process based on work study principles and identified the bottleneck in the operation. This approach involved current production system analysis by collecting the cycle time of all operators in the production process, designing the production network, and identifying the bottleneck operation. After that, the ECRS method was proposed and implemented in the actual production line. This study was very important to solve the production shop floor problem and expand the understanding of the assembly line balancing issues that influence the production system.

2. Theoretical Framework

Assembly line balancing Assembly (ALB) lines are often used in the last step of production, in which the product's final assembly from previously manufactured parts is performed. An assembly line typically consists of several workstations, where each workstation is responsible for performing a specific set of tasks. The items move through the line from one workstation to the next according to their order and end up as finished products (Bukchin & Raviv, 2018). To maximize the efficiency of the line, the total assembly time has been divided as equal as possible, among the workstations. Since the assembly of each product consisted of indivisible elements (tasks), the problem of allocating the tasks to the stations became a combinatorial problem called the assembly line balancing problem (Limcharoen et al., 2007). Assembly line needs to be built effectively and efficiently and to distribute the same task among the workers and workstations to ensure that the production process meets the available time and capacity (Hui & Ng, 1999). Meanwhile, according to Nourmohammadi & Eskandari (2017), ALB functions as a design to assign properly the number of operators and machines in every process or work element to meet the desired production rate with zero ideal time. In brief, ALB aims to balance the workstations to reduce bottleneck and total processing by considering the process efficiency and increasing production rate.

Line Efficiency is the ratio of the total work time of the station divided by the cycle multiplied by the number of work stations (Baroto, 2002) or the number of work station efficiency divided by the number of work stations (Nasution, 1999). In this case, the Fishbone diagram (FB) is commonly named as the cause analysis and branches of analysis figure. The term is named after its master named, Kaoru Ishikawa, a Japanese management master who found out the root cause of the problems. It can also show the indicated relationship between the problems and the underlying causes, which are mostly used in qualitative analysis (Luo et al., 2007)(Xing, 2004). Once the problem is identified, the analysts can focus on reducing and eliminating the causes of the problem. Then, those causes are grouped into some key categories to ease the identification of sources and causes for any variations. Those categories included methods, manpower, machines, measurements, environment and materials.

On the other hand, ECRS is a simple approach to quickly and rapidly identify wastes and implement immediate improvements. This tool is impatient for long drawn out projects or long winded Kaizen events – since it is most appropriate for immediate and pointed Kaizen efforts. This tool supports Plan-Do-Check-Action (PDCA) and can be an important element in the PDCA mentoring and coaching process (Ongkunaruk & Wongsatit, 2014). The ECRS steps for continuous improvement consist of the following elements:

i. Elimination (E). In this step, it is important to identify the steps that can be quickly eliminated or reduced where possible to eliminate the details of work.
ii. Combination (C). When work cannot be eliminated, it is necessary to seek to combine them. Sometimes, the process or operation can be eliminated simultaneously by combining the whole processes into a single process.
iii. Rearrangement (R). Work can also be rearranged. Sometimes, it needs the rearrangement of resources, materials, man, or tools to ensure the smooth operation of the production process.
iv. Simplification (S). The simplification could be the combination of the above three steps to ease the manpower or the operator to perform their job. It could be done by combining the movements and operations before eliminating some waste.

Chueprasert & Ongkunaruk (2014) implemented the ECRS concept to increase productivity and efficiency in line process of milk manufactured in Thailand. The result showed that the line efficiency increased from 65.51% to the highest level of 88.33%. Macías-Jiménez et al. (2019) implemented 5W1H and ECRS techniques to improve productivity in food company. Bârsan & Codrea (2019) used the ECRS method to enhance a university's administrative process. Kelendar & Mohammed (2020) implemented ECRS in health sector to improve toolkit and minimize waste. Nisa et al. (2021) applied ECRS to improve the work system on a production line in a data storage manufacturing company in Indonesia. While, Suhardi et al. (2019) tried to minimize waste using lean manufacturing and ERCS principle in a furniture industry.

3. Research Method

3.1. Data Collection Methods

The research required primary and secondary data from interviews and direct observation. The interview involved asking informants open-ended questions. The interview was conducted in the sewing area by involving some managers and supervisors of the PPIC and Engineering department and the sewing operator. The most common problems that frequently occurred in this area were faced by the stakeholders, then lifted up becomes the problem that wants to be solved

For direct observation method, the direct stop-watch time study was used to calculate the cycle time for each element in every workstation in an assembly line. While observing and recording the time, an appraisal of the worker’s performance level is made to obtain the normal time for the task. The data are then used to compute the cycle time for each element in every workstation in assembly line.

3.2. Data Processing

In this study, there were some steps required in processing the data, as written below:

i. Calculating the line efficiency performance
   In this first condition or initial model, the indicators of production system must be

calculated, such as; cycle time, takt time, production capacity, production/head/hour, process time, and line efficiency. The equation for some calculations is as follows;

ii. Fishbone diagram
The result of line efficiency was then compared to the company's target. If it does not meet the company's target, there will be further analysis using fishbone diagram (by considering several factors: the method, man, machine, measurement, material, and environment).

iii. ECRS Method
In this step, some alternatives or solutions are considered by eliminating, combining, rearranging, and simplifying the process or the machine based on the most affected factors resulting from the fishbone diagram.

iv. Re-calculating the line efficiency performance using the updated cycle time. The formula remains the same as the previous indicators and equation. The result is then compared to the company's target.

While assessing the assembly line performance, some indicators were required as written in Table 1.

Table 1. Indicators used in assessing assembly line

	Description	Formula
Cycle time	Used to express the total manual work involved in a process, or part of a process	Production time + Waiting time for Production………(1)
Takt time	The maximum acceptable time to meet customer demand	Maximum cycle time x (100% + allowance)….(2)
Production capacity	The maximum output that can be produced in a business with available resources	Networking time x 60 sec / takt time…………….(3)
Production/ head/hour (PHH)	Production pieces are units business that are generated as an output.	Production capacity x 60 sec /total workstation x networking time ……(4)
Process time	the time used to actually work on the product spent on that workstation	Networking time x total workstation / production capacity……………(5)

4. Results and Discussion

4.1. Calculation of Line Efficiency in Assembly Line Balancing

In the initial system, there were 27 workstations and operators in the assembly line area, which performed special jobs or work elements as showned in Table 2.

Table 2. Cycle Time of Initial Model

No	Work Station	Operator	Process	Work Element	Cycle Time	Total Cycle time in workstation
1	1	1	1	*Blabar + kepras* + *mancing* collar band	36,52	36,52
2	2	2	2	*Balik* collar (manual)	20,1	20,1
3	3	3	3	Stik leaf collar	49,98	49,98
4	4	4	4	Stik hexa s.cuff 5mm k/k	35,97	35,97
5	5	5	5	Put sleeve binding + potong k/k	44,5	44,5
6	6	6	6	Put tape split tempel k/k	14,99	14,99
7	7	7	7	Sort + brand label yoke	47	78
8			8	Sort + size label yoke	31	
9	8	8	9	Inspection	41	41
10	9	9	10	Joint collar	55,07	55,07
11	10	10	11	Stik middle collar	38,82	38,82
12	11	11	12	Joint armhole c.stitch k/k + tape	69,1	69,1
13	12	12	13	Stik armhole JR I + k/k + tape	62,53	62,53
14	13	13	14	sew waist front dart	112,8	112,8
15	14	14	15	sew laid on (kansai model)	90,4	126,64
16			16	sew laid on 2 motif	36,24	
17	15	15	17	Overlock waist dart	47,24	92
18			18	Waist back dart	45	
19	16	16	19	Pasang split	55	105
20			20	Joint cuff k/k	49,79	
21	17	17	21	Button hole (body)	42	42
22	18	18	22	Wrapped button	48,07	48,07
23	19	19	23	*Blabar* + stik back yoke(tape)	57,46	57,46
24	29	29	24	Joint shoulde r+ stik JR I + tape +sortir	50,8	50,8
25	21	21	25	*Blabar*+stik+joint collar+jepit piping	61,8	61,8
26	22	22	26	Put tape on shoder	62,44	62,44
27	23	23	27	*Blabar+kepras* side seam+sortir using tape	57	57
28	24	24	28	Stik side seam l/s + sortir	30,4	30,4
29	25	25	29	Put bottom tape klim	59,21	59,21
30	26	26	30	Bottom tape	64,55	64,55
31	27	27	31	Button sew + Wrapped button II	57,17	57,17
TOTAL CYCLE TIME					**1573,95**	**1573,95**

Thus, each workstation could accommodate more than one work element that also had a cycle time. The total cycle time was 1573,95 second accumulated from 27 workstations (with 27 operators), with 31 processes assembly to complete. Table 3 presents the calculation result to get line efficiency for the initial model.

Table 3. Line efficiency in initial model and company's target

	Initial Model	Company's target
Manpower/shift	27 operators	27 operators
Takt time	124,08 sec	82,5 sec
Total cycle time	1573,95 sec	1500 sec
Working hour/shift	460 minutes	460 minutes
Production capacity/shift	222,44 pieces	334 pieces
Production/head/hour	1,07 piece (s)	1,61 pieces
Process time Line efficiency	55,84 minutes 51,68%	37,2 minutes 80 %

Table 3 demonstrates that takt time was 124 sec from assembly line, which produced shirt. The upper limit of takt time had given a 10 % allowance, which showed the maximum time to produce a product (in unit) for each workstation. Then, the production capacity per shift was 222,44 pieces, meaning that Assembly Line could produce 222 pieces of shirt each day. This resulted in the production capacity calculation to know the PHH or production/head/hour, which was 1,07 pieces. It showed that the ability of one operator to finish the product within an hour was only one piece of shirt. The calculation of process time was derived from the production capacity of 55,84 minutes. This fact indicated that the assembly of 1-unit product (1 piece of shirt) needed for about 55,84 minutes. Thus, based on all calculation results, the line efficiency was 51,68 %. In other words, the efficiency in Assembly Line on output productivity was 51,68 %. Then, all results were compared to the company target of 80%, which means that the line efficiency did not meet the company's target.

4.2. Analysis of Fishbone Diagram

Knowing that the line efficiency failed to meet the company's target, the researcher conducted the next step of making the fishbone diagram to know the factors that caused the problems (Figure 1).

Each branch of the fishbone diagram represented the factors that contribute to line efficiency problem. In short, the categories of manpower, machine, and method were the most significant factor of failure of inefficiency of assembly line. This fishbone diagram can be further used to make decision about selecting the most appropriate method by considering those factors.

4.3. ECRS Concept

After mapping the root cause of the problem using the fishbone diagram, we can see that most of the problems were caused by technical activities such as the wrong method and the insufficient skill of the operator. Thus, the method will be improved using ECRS technique for building the proposed refinement. ECRS had four principles to reduce production time and optimize the whole process. It can be seen that the total reduction of cycle time was up to 165 second, resulting from the re-designing and applying the ECRS concept (elimination, combination, rearrangement, and simplification). The details of above proposed layout are summed up in Table 4.

4.4. Calculation of New Line Efficiency

Based on the new cycle time above, the takt time, production capacity, PHH, process time and assembly line efficiency must be recalculated. The result is depicted in Table 5.

Table 5 shows the performance of each model; initial and proposed model. The number of operators can be reduced to 24 operators in each workstation. It is a good result because the company can save the labor cost. The takt time was also reduced to 79,2 sec, meaning that the maximum acceptable time to meet the daily production target was reduced until 45 second. Then, the production capacity per shift was 348,48 pieces, meaning

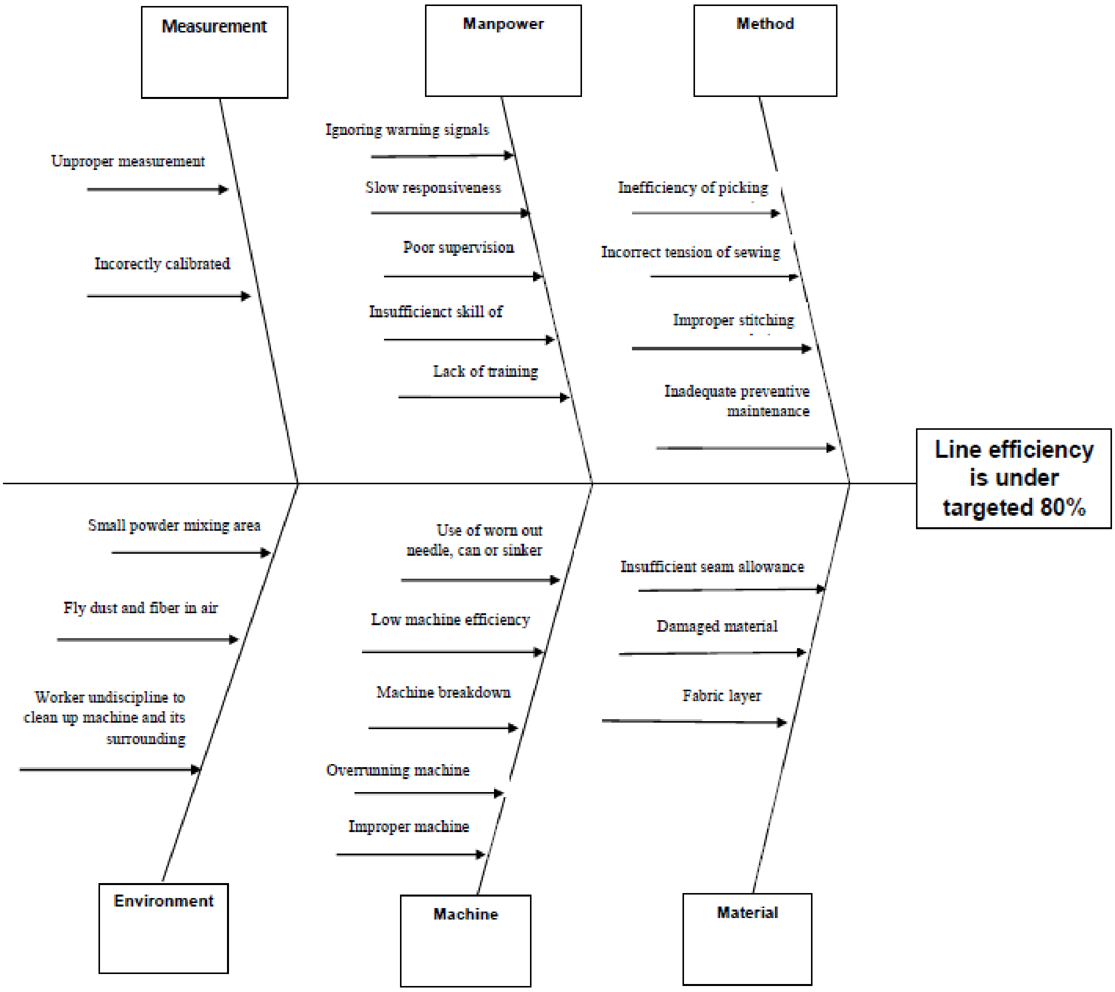

Figure 1: Fishbone Diagram

that Assembly Line could produce as many as 348,48 pieces or nearly 349 pieces of shirts each day. This production capacity was higher than the initial model, so the company could produce more products. Then, the PHH or production/head/hour was 1,89 pieces. It showed that the ability of one operator to finish the product within an hour was nearly 2 pieces of shirt. Production capacity was also derived from calculating process time and obtained 31,68 minutes. It showed that the assembly of 1-unit product (1 piece of shirt) took about 31,68 minutes. The time reduced from the initial model was up to 24 minutes. It means that the company can assemble 1 unit product earlier. These results led to the decreasing cycle time to 1408 second from 1573, which significantly impacted the efficiency, since it reduced up to 165 second.

These also affected the takt time and process time. Both were strongly correlated, since the closer the processing time to takt time, the more efficient the assembly line. The assembly line will run better and smoother with the smaller possibility of bottlenecks if all of the work stations have a relatively balanced work load. In conclusion, it is possible to apply the ECRS method in the real production system since this method does not need a complex tool, has a more straightforward method (easy to operate), and has been proven effective in increasing the efficiency, as revealed by this study (Shirt style).

Table 4. Result of proposed action using ECRS method

ECRS Concept	Workstation	Process	Description	Proposed Refinement	Result
Eliminating and combining	8	9	Inspection	The operator did not check and inspect the result. Inspection and joint collar was done simultaneously in one workstation with the same operator. The new cycle time became 71,6 sec.	Workstation and process were reduced.
	9	10	Joint collar		Cycle time was reduced to 24,47 sec.
	7	7	Sorting and branding with label yoke	The operator sorted, selected and picked the brand label + size, and labelled items simultaneously in one mini-compartment. The new cycle time became 68 sec.	Process reduced
		8	Sorting and giving size label yoke		Cycle time was reduced to 10 sec
	17	21	Button hole (body)	The operator made buttonhole and wrapped the button in one workstation within one machine. The new cycle time became 70,07 sec.	Workstation and process were reduced.
	18	22	Wrapped button		Cycle time was reduced to 20 sec.
	23	27	Side seam and sorting using tape	The operator did side seam and sorting using tape and sticking it with side seam of long sleeve simultaneously in one machine. The new cycle time became 72 sec.	Workstation and process were reduced.
	24	28	Stick side seam l/s + sorting		Cycle time was reduced to 15,4 sec.
Rearrangement	14	15	Laid on sewing (kansai model)	The operator re-adjusting the clamping hole to become 9 cm. The new cycle time became 92,64 sec. Precise and match sewing-pattern. Cycle time was reduced to 34 sec.	
	22	26	Attaching tape to the shoulder	The press machine was set to a higher temperature and tape was easily sticked to fabric. Cycle time was reduced to 14,04 sec.	
Simplification	13	14	Front waits dart sewing	The operator sewed and followed the pattern sprightly using cartoon ruler. Cycle time was reduced to 41,1 sec.	
	20	24	Joint shoulder	The operator selected mode of reverse stitch lever in the machine, and the machine would sew in the reverse while the lever was pushed. Cycle time was reduced to 6 sec.	
Total reduction of cycle time					165 sec

Table 5. Comparison of line efficiency for both initial and proposed model.

	Proposed model	Initial model
Manpower/shift	24 operators	27 operators
Takt time	79,2 sec	124,08 sec
Total cycle time	1408,94 sec	1573,95 sec
Working hour/shift	460 minutes	460 minutes
Production capacity/shift	348,48 pieces	222,44 pieces
Production/head/hour	1,89 piece (s)	1,07 piece (s)
Process time Line efficiency	31,68 minutes 81,54 %	55,84 minutes 51,68%

5. Conclusion

Based on the above calculation and analysis in accordance to the research objective and formulation, it is possible to draw the following conclusions:

i. The value of line efficiency Assembly Line 11 Sewing-K2C in production line increased up to 81,54% from 51,68% after applying the ECRS method. This value was derived from the reduction of takt time, total cycle time, and process time. Thus, the performance of assembly line will run better and smoother with the smaller possibility of bottleneck if all of the work stations have relatively balanced work load.

ii. There are 4 strategies that is used in the proposed model based on ECRS concept, as written below:

   a. Eliminating and combining the inspection process with joint collar, sorting and branding label yoke with

sorting and giving size of label yoke, button hole sewing with wrapped button, and side seam using tape with side seam of long sleeve.
b. Rearrangement of the process of laid on sewing (Kansai model) by re-adjusting the height of clamping hole and attaching tape to the shoulder by re-adjusting the higher temperature when ironing.
c. Simplifying the process of front waist dart sewing using cartoon-ruler and joint shoulder by selecting the mode of reverse stitch lever in the machine.

iii. This research is limited to the objective of only attaining efficiency of 80% by neglecting the external factors such as the economic aspects. This research results in some suggestions for the company after revealing the root cause behind the inefficiency of assembly line. On this basis, it is recommended for further research, that the company applies other methods of assembly line for balancing the condition of the production floor to gain the optimum output and tighter regulation. The company also needs to conduct preventive maintenance plan system against machine failure or breakdown.

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Work Accident Reduction Strategies With Job Safety Analysis at the Gum Rosin and Turpentine Factory

Zati Hulwani Mindandi[1)], Irwan Iftadi[2)]

Department of Industrial Engineering, Faculty of Engineering, Sebelas Maret University
Jl. Ir. Sutami No. 36 A, Surakarta, 57126, Indonesia[1),2)]
E-Mail : zatimindandi45@gmail.com[1)], iftadi@gmail.com[2)]

ABSTRACT

The production methods at the Gum Rosin and Turpentine XYZ Factory involve several types of machinery and chemicals that might result in workplace accidents. Although the most recent Job Safety Analysis (JSA) was completed in 2018, various changes in work responsibilities have resulted in complaints from melting station workers in the case of eye irritation caused by turpentine vapor exposure and PGT waste workers as having the possibility of splashes from industrial waste. The purpose of this research is to assemble the most recent JSA document to eliminate potential dangers. This research was organized into four parts. The first stage involves conducting firsthand observations to describe the workers' responsibilities at each station. The second step includes interviewing the HSE staff and supervisors to determine the possible dangers of each operation. The third stage involves consulting with the HSE supervisor to decide on precautions to minimize possible dangers. The fourth stage consists of collecting JSA papers for each station. A total of 18 job descriptions with four categories of hazards were discovered based on the assembled JSA, including physical, chemical, mechanical, and ergonomic risks. Workplace safety recommendations here include the placement of safety signs, the installation of guardrails for waste tanks, and the application of personal protective equipment. A risk assessment to classify the risk level of each type of hazard and implementation of the JSA can be applied for future research.

Keywords: Job safety analysis, occupational health and safety, gum rosin and turpentine factory, potential hazard.

1. Introduction

The Gum Rosin and Turpentine XYZ Factory is a chemical industry which produces gum rosin and turpentine from raw materials in the form of pine resin. The specialty of pine trees is that they produce pine resin which is can further processed and has a high economic value (Suwaji et al., 2017). Muliani (2014) stated that the pine resin produced by pine, namely gum rosin and turpentine are used in the batik industry, plastics, soap, printing ink, varnish materials, and so on, while turpentine is used as a paint solvent (Suwaji et al., 2017).

During the operation of the Gum Rosin and Turpentine XYZ Factory, occupational safety and health (K3) is implemented to protect the workers. One of the efforts to maintain the safety and health of workers is to conduct safety briefings every time they start shift work. According to the ILO/WHO, OSH is an effort to maintain and improve the highest degree of physical, mental and social well-being for workers in all occupations, prevent health deviations among workers caused by working conditions, protect workers at work from the consequences of environmental factors. which is detrimental to the health, placement and maintenance of workers in a work environment that is adapted to physiological and psychological capabilities, as well as adjustments to human work and each human position (Irzal, 2016). According to the ILO and WHO in 1995, the objectives of OSH are the promotion and maintenance of physical, mental and social health of workers, prevention of health problems caused by working conditions, protection of workers from the risk of factors that interfere with health, placement and maintenance of workers in the environment. work in accordance with their physical and psychological abilities, and the adjustment of each person to his work (Widodo, 2021).

The pine resin processing carried out by The Gum Rosin and Turpentine XYZ Factory involves many machines and chemicals that have the potential to cause work accidents. Referring to the ILO press release on 17 September 2021, the ILO and WHO estimate that almost two million people die from occupational diseases and accidents, this can reduce productivity, burden the health system, and have an impact on work income (Biro Humas Kemnaker, 2021). According to the ILO in 1996, work accidents are events arising from or in the course of work that result in fatal work-related injuries and non-fatal work injuries (Sultan, 2019). Meanwhile, according to Permenaker No. 11 of 2016, work accidents are accidents that occur in work relationships, including accidents that occur on the way from home to work or vice versa and diseases caused by the work environment (Sultan, 2019). Work accidents can be caused by hazards that have the potential to occur in the work being carried out. A hazard is something that can cause injury to people or damage to equipment or the environment. Several types of hazards that can be identified in the workplace are chemical hazards, physical hazards, ergonomic hazards, biological hazards and psychological hazards (Sumarna et al, 2018).

The Gum rosin and Turpentine XYZ factory conducted the latest work safety analysis in 2018 using Job Safety Analysis (JSA) and has not focused on the work of workers in the gum rosin and turpentine production process at each work station. Until now, there has been a change in the operator's duties, but no work safety analysis has been updated. This has led to the emergence of complaints submitted by workers, some of which are sore eyes due to exposure to turpentine vapor at the melter work station and the potential for splashing like factory waste at the PGT waste work station. Job Safety Analysis (JSA) helps to ensure that all members of the organization can recognize and understand actual or potential hazards, associated risks, appropriate actions, and controls needed to reduce potential injury or loss and protect themselves (Crutchfield & Roughton, 2016).

There have been many studies that use JSA and state the benefits of having a JSA document. JSA applied to PT. Geoservices Sangatta has succeeded in reducing the number of work accidents (Selvi Sampe, 2021). PT Pura Barutama experienced a decrease in cases after implementing hazard risk control with JSA (Prasetyo & Mirnayanti, 2017).

Making a JSA involves three steps, namely detailing the work steps from the beginning to the completion of the work, identifying hazards and potential work accidents based on predetermined work steps, and determining control measures based on the hazards in each work step. (Wahyudi, 2018). In addition to health and safety purposes, a JSA can also help product quality improvement program by reducing potential human errors (Ghasemi et al., 2023).

JSA document will be better if implemented directly afterward. this can make it easier for supervisors to provide training and efficient working instructions and warnings of potential hazards in work and can be used to review or re-learn if an accident occurs. With the JSA, operators can work safely and know the hazards that exist in work, how to control measures, and can increase knowledge and awareness of the importance of workplace safety. (Selvi Sampe, 2021).

The aim of this research is construct Job Safety Analysis (JSA) document in order to identify the potential hazard and determine the precautions to minimise the potential hazard happens for each of the six workstations. The workstations are gutter station, melting station, scrubbing station, cooking station, canning station, and PGT waste station.

2. Methodology

There are two types of data used in this study, namely primary and secondary data. The primary data used in this study were obtained through interviews, observations, and consultations with the workers of The Gum Rosin and Turpentine XYZ Factory and the Health Safety Environment (HSE) supervisor. Meanwhile, the secondary data used is the Standard Operating Procedure (SOP) document that applies at The Gum Rosin and Turpentine XYZ Factory, to be precise at all stations, namely gutter station, melting station, scrubbing station, cooking station, canning station, and PGT waste station.

The design of this research is qualitative, namely in the form of a narrative that mentions job descriptions and identification of hazards and control of hazards found at work stations at The Gum Rosin and Turpentine XYZ Factory. The research step begins by describing the work at all stations, identifying the hazards in each job description, and determining preventive measures for each hazard at each station. There are six stations, namely the gutter station, melting station, scrubbing station, cooking station, canning station, and PGT waste station.

Hazard identification is carried out using the Job Safety Analysis (JSA) form. The JSA form contains the company name, date of making, working station, detailed work steps, hazard potential in each step, and its prevention. The work steps were obtained from job description in the Standard Operating Procedure (SOP) at each station and detailed through observation.

Determination of hazard prevention efforts is carried out by identifying PPE that can protect the body parts that face directly to the hazard and checking the Material Safety Data Sheet (MSDS) for hazardous substances that can cause harm and also interviewing workers and the Health Safety Environment (HSE) Supervisor. The Job Safety Analysis (JSA) sheet is the output of the research that has been done.

3. Results and Discussion

3.1. Production Process

The production process carried out at The Gum Rosin and Turpentine XYZ Factory includes six stations, namely the gutter station, melting station, scrubbing station, cooking station, canning station, and PGT waste station.

The production process of gum rosin and turpentine consists of several stages. First, the pine resin that is in the pine resin tub is put into a gum gutter of a maximum of 2,500 liters. After the gutter is filled, oxalic acid is added as much as 0.2% of the amount of pine resin to bind the minerals that contaminate the pine resin. Next, the pine resin from the gutters is put into a melter tank to dilute the pine resin with turpentine as much as 30-40% of the pine resin. In addition to turpentine, this process also requires steam from the boiler to assist the dilution process as well as agitation of the pine resin and turpentine so that it is evenly mixed. In the melter, coarse dirt is also separated from the pine resin called litter. Litter is removed manually after 2-3 times the dilution process.

The liquid pine resin resulting from the melter process is put into the scrubber tank for cleaning the pine resin. In the scrubber, the washing and stirring process is carried out. Hot water as much as 700 kg was added in this process to dissolve the fine impurities that are still bound. After stirring, a deposition process is carried out to form two layers in the form of water and dirt and oil in the form of a mixture of gum and turpentine. Then the water blowdown. Do a test on the soft rosin to get a color less than 4.8.

Soft rosin is flowed into the holding tank before flowing into the cooking tank. After the capacity of the pine resin in the holding tank matches the capacity of the cooking tank, the pine resin is flowed into the cooking tank for cooking. The cooking process produces gum rosin and turpentine. Gum rosin is then put into a can and the turpentine is put into a turpentine storage tank.

Waste from the melter, scrubber, storage tank, and cooking processes is channeled to PGT Waste. The waste generated is water, jonjot, and OPR. Jonjot and OPR produced by Factory 1 are then separated with turpentine. Jonjot that has been separated is processed again by the black gondo cook to become black gondo. The clean wastewater is sent to the WWTP (Wastewater Treatment Plant). Meanwhile, the OPR is put into the OPR holding tank.

3.2. Job Description

Based on the SOP applied and observations at all stations, job descriptions were obtained for all stations.

a. Gutter Station
   In gutter, the operator turns the steering wheel to open the pine resin tub cover so that the pine resin enters the gutters.
b. Melting Station
   1. Push the pine resin into the melter tank.
   2. Turning the steering wheel to open the flow of pine resin from the gutters to the melter, inserting turpentine, stirring and heating processes, and flushing litter.
   3. Open the litter flow cover to remove the litter.
   4. Unloading the litter.
c. Scrubbing Station
   1. Turning the steering wheel to open the flow of pine resin from the melter to the scrubber, stirring, adding hot water, and settling.
   2. Taking samples of soft rosin.
d. Cooking Station
   1. Turn the steering wheel to control the cooking process.
   2. Taking gum rosin samples to be tested in the laboratory.
e. Canning Station
   1. Prepare gum rosin cans and pallets and check and repair cans if they are dented.
   2. Number the cans with spray paint.
   3. Put the can on the pallet.
   4. Put pallets and cans on the scales with a forklift.
   5. Open the gum rosin tap and fill the gum rosin can according to capacity.
   6. Move the cans containing gum rosin to a place that has been prepared with a forklift.
   7. Close the can of gum rosin while waiting for all the cans to be filled.
   8. Move all cans containing gum rosin to the place provided by the forklift.
f. PGT Waste Station
   Pushing waste water, bulge, OPR to enter the next tank with the help of a water push stick.

3.3. Potential Hazard

There are possible risks discovered during the execution of work in all stations by workers in all stations. Table 1 depicts the potential dangers and categories of hazards associated with gutter work. Table 2 depicts the potential dangers and categories of hazards associated with melting work. Table 3 depicts the potential dangers and categories of hazards associated with scrubbing work. Table 4 depicts the potential dangers and categories of hazards associated with cooking work. Table 5 depicts the potential dangers and categories of hazards associated with canning work. Table 6 depicts the potential dangers and categories of hazards associated with PGT waste work.

Table 1. Potential Dangers and Categories of Hazard Associate with Gutter Work

Categories of Hazard	Potential Hazard
Physical Hazard	Falls from a height
Chemical Hazard	Eye irritation caused by steam vapor exposure
	Respiratory burn caused by steam vapor aspiration
	Skin burn caused by steam vapor exposure
Ergonomic Hazard	Wrist injuries or musculoskeletal disorders (MSDs)

Table 2. Potential Dangers and Categories of Hazard Associate with Melting Work

Categories of Hazard	Potential Hazard
Physical Hazard	Falls from a height Stumbled on equipment that was in the foot area Hit the equipment in the head area Blisters or burns due to exposure to hot litter Blisters or burns from touching the hot melter tank
Chemical Hazard	Eye irritation caused by turpentine liquid or turpentine vapor exposure Irritant effects, vertigo, headache, difficulty breathing, and pulmonary edema caused by turpentine vapor exposure Skin irritation and allergy caused by turpentine splash
Ergonomic Hazard	Wrist injuries or musculoskeletal disorders (MSDs) Upper arm pain or musculoskeletal disorders (MSDs)

Table 3. Potential Dangers and Categories of Hazard Associate with Scrubbing Work

Categories of Hazard	Potential Hazard
Physical Hazard	Hit the equipment in the head area Stumbled on equipment that was in the foot area
Ergonomic Hazard	Back pain or musculoskeletal disorders (MSDs) Wrist injuries or musculoskeletal disorders (MSDs)

Table 4. Potential Dangers and Categories of Hazard Associate with Cooking Work

Categories of Hazard	Potential Hazard
Physical Hazard	Falls from a height Hit the equipment in the head area Stumbled on equipment that was in the foot area Exposure to hot liquid gum rosin Cooking noise
Chemical Hazard	Irritating to the respiratory system, lung damage, vertigo, increased heart rate, dizziness, hallucinations, fire and burning sensation on the skin, conjunctivitis, and damage to the body's defense system due to inhaling cooking odors
Ergonomic Hazard	Wrist injuries or musculoskeletal disorders (MSDs) Upper arm pain or musculoskeletal disorders (MSDs) Leg injuries or musculoskeletal disorders Back pain or musculoskeletal disorders (MSDs)

Table 5. Potential Dangers and Categories of Hazard Associate with Canning Work

Categories of Hazard	Potential Hazard
Physical Hazard	Exposure to hot liquid gum rosin Canned lid hook Leg hit by can
Chemical Hazard	Respiratory tract infections from inhaling spray paint Irritation to skin and eyes due to spray paint exposure
Ergonomic Hazard	Leg injuries or musculoskeletal disorders
Mechanical Hazard	Get run over, hit and fall off a forklift

Table 6. Potential Dangers and Categories of Hazard Associate with PGT Waste Work

Categories of Hazard	Potential Hazard
Physical Hazard	Dropped into the tub Slip and fall
Chemical Hazard	Irritant effects, vertigo, headache, difficulty breathing, and pulmonary edema due to the smell of turpentine
Ergonomic Hazard	Upper arm pain or musculoskeletal disorders (MSDs)

3.4. Hazard Prevention Strategies

Hazard prevention strategies that can be done can be in the form of the use of PPE (personal protective equipment) and other things. Table 7 shows the potential hazards and hazard precautions associated with gutter work. Table 8 shows the potential hazards and hazard precautions associated with melting work. Table 9 shows the potential hazards and hazard precautions associated with scrubbing work. Table 10 shows the potential hazards and hazard precautions associated with cooking work. Table 11 shows the potential hazards and hazard precautions associated with canning work. Table 12 shows the potential hazards and hazard precautions associated with PGT waste work.

Table 7. Precautions to Minimize Possible Dangers Associate with Gutter Work

Potential Hazard	Precautions
Falls from a height	Ensure that the floor, stairs, and factory steps are clean and not slippery Use non-slip safety shoes Use a height protection device (body harness) Use head protection (safety helmet)
Eye irritation caused by steam vapor exposure	Use eye protection with side shields (safety glasses with side shields) Use face shields
Respiratory burn caused by steam vapor aspiration	Ensure there is adequate air circulation Use respiratory protective equipment (respirator)
Skin burn caused by steam vapor exposure	Use personal protective equipment (lab coat, protective clothing, or fire-resistant clothing) Use heat-resistant hand protective equipment (asbestos gloves) Use head protection (safety helmet)
Wrist injuries or musculoskeletal disorders (MSDs)	Stretching between work Warm up before doing work Do exercise regularly

Table 8. Precautions to Minimize Possible Dangers Associate with Melting Work

Potential Hazard	Precautions
Hit the equipment in the head area	Ensure that the floor, stairs, and factory steps are clean and not slippery Use non-slip safety shoes Use a height protection device (body harness) Use head protection (safety helmet)
Hit the equipment in the head area	Ensuring adequate lighting in the factory Check the condition of the eyes regularly to be aware of visual disturbances Use head protection (safety helmet)
Stumbled on equipment that was in the foot area	Ensure that the floor, stairs, and factory steps are clean and not slippery Ensuring adequate lighting in the factory Check the eyes condition regularly to be aware of visual disturbances Use non-slip safety shoes Use head protection

Table 8. (continued)

Potential Hazard	Precautions
Blisters or burns due to exposure to hot litter	Use heat-resistant hand protective equipment (asbestos gloves) Use head protection (safety helmet)
Blisters or burns from touching the hot melter tank	Use heat-resistant hand protective equipment (asbestos gloves) Use head protection (safety helmet)
Eye irritation caused by turpentine liquid or turpentine vapor exposure	Use eye protection with side shields (safety glasses with side shields)
Irritant effects, vertigo, headache, difficulty breathing, and pulmonary edema caused by turpentine vapor exposure	Ensure there is adequate air circulation Use respiratory protection (respirator)
Skin irritation and allergy caused by turpentine splash	Use chemically resistant hand protection equipment (0.3 mm nitrile rubber gloves) Using barrier creams/ointments
Wrist injuries or musculoskeletal disorders (MSDs)	Stretching between work Warm up before doing work Do exercise regularly
Upper arm pain or musculoskeletal disorders (MSDs)	Stretching between work Warm up before doing work Do exercise regularly

Table 9. Precautions to Minimize Possible Dangers Associate with Scrubbing Work

Potential Hazard	Precautions
Hit the equipment in the head area	Ensuring adequate lighting in the factory Check the condition of the eyes regularly to be aware of visual disturbances Use head protection (safety helmet)
Stumbled on equipment that was in the foot area	Ensure that the floor, stairs, and factory steps are clean and not slippery Ensuring adequate lighting in the factory Check the condition of the eyes regularly to be aware of visual disturbances Use non-slip safety shoes Use head protection (safety helmet)
Wrist injuries or musculoskeletal disorders (MSDs)	Stretching between work Warm up before doing work Do exercise regularly
Back pain or musculoskeletal disorders (MSDs)	Stretching between work Warm up before doing work Do exercise regularly

Table 10. Precautions to Minimize Possible Dangers Associate with Cooking Work

Potential Hazard	Precautions
Falls from a height	Ensure that the floor, stairs, and factory steps are clean and not slippery Use non-slip safety shoes Use a height protection device (body harness) Use head protection (safety helmet)

Table 10. (continued)

Potential Hazard	Precautions
Stumbled on equipment that was in the foot area	Ensure that the floor, stairs, and factory steps are clean and not slippery Ensuring adequate lighting in the factory Check the condition of the eyes regularly to be aware of visual disturbances Use non-slip safety shoes Use head protection (safety helmet)
Hit the equipment in the head area	Ensuring adequate lighting in the factory Check the condition of the eyes regularly to be aware of visual disturbances Use head protection (safety helmet)
Exposure to hot liquid gum rosin	Use of foot protective equipment (safety shoes) Use heat-resistant hand protective equipment (asbestos gloves) Use head protection (safety helmet) Installing a hot safety sign
Cooking noise	Use ear protection (ear plugs)
Irritating to the respiratory system, lung damage, vertigo, increased heart rate, dizziness, hallucinations, fire and burning sensation on the skin, conjunctivitis, and damage to the body's defense system due to inhaling cooking odors	Ensure there is adequate air circulation Minimizing contact time with cooking places Use respiratory protective equipment (respirator)
Wrist injuries or musculoskeletal disorders (MSDs)	Stretching between work Warm up before doing work Do exercise regularly
Upper arm pain or musculoskeletal disorders (MSDs)	Stretching between work Warm up before doing work Do exercise regularly
Leg injuries or musculoskeletal disorders (MSDs)	Stretching between work Warm up before doing work Do exercise regularly
Back pain or musculoskeletal disorders (MSDs)	Stretching between work Warm up before doing work Do exercise regularly

Table 11. Precautions to Minimize Possible Dangers Associate with Canning Work

Potential Hazard	Precautions
Exposure to hot liquid gum rosin	Use of foot protective equipment (safety shoes) Use heat-resistant hand protective equipment (asbestos gloves) Use head protection (safety helmet)
Canned lid hook	Use sharp-resistant hand protection (leather gloves) Pay close attention to the can lid when closing
Leg hit by can	Use of foot protective equipment (safety shoes)
Respiratory tract infections from inhaling spray paint	Use respiratory protective equipment (mask)
Irritation to skin and eyes due to exposure to spray paint	Use face shields Use eye protection (safety goggles) Use chemical resistant hand protection (rubber gloves)

Table 11. (continued)

Potential Hazard	Precautions
Leg injuries or musculoskeletal disorders (MSDs)	Stretching between work Warm up before doing work Do exercise regularly
Get run over, hit and fall off a forklift	Don't cross the forklift path Give a sign when passing through the forklift lane Make sure there is no work in the forklift path Do not use HP when in the forklift area Disturbing the concentration of the forklift operator Ensure the footing is clean and dry Using a seat belt when in a forklift Rests on 3 points of contact when getting on and off the forklift Use protective footwear (safety shoes) and head protective equipment (safety helmet)

Table 12. Precautions to Minimize Possible Dangers Associate with PGT Waste Work

Potential Hazard	Precautions
Dropped into the tub	Installing the tub guardrail with worker steps Installing the tub depth safety sign Use of foot protective equipment (safety shoes) Use protective gloves (rubber gloves)
Slip and fall	Ensure that the floor and footing of PGT Waste are clean and not slippery Check the condition of the eyes regularly to be aware of visual disturbances Use non-slip safety shoes Use head protection (safety helmet)
Irritant effects, vertigo, headache, difficulty breathing, and pulmonary edema due to the smell of turpentine	Ensure there is adequate air circulation Use respiratory protective equipment (respirator)
Upper arm pain or musculoskeletal disorders (MSDs)	Stretching between work Warm up before doing work Do exercise regularly

3.4. Job Safety Analysis (JSA)

Job safety analysis consists of the work order, possible hazard and precautions, as well as the company name, date of manufacturing, and station site. This research resulted six Job Sheet Analysis (JSA) sheets. The JSA provided for each stations composed of work detailed activity, potential hazard and precautions.

4. Conclusion

Each of the six workstations at the Gum Rosin and Turpentine XYZ factory has a unique set of possible dangers and mitigation measures. There were four sorts of possible dangers discovered: physical hazards, ergonomic hazards, chemical hazards, and mechanical hazards. A total of six Job Safety Analysis (JSA) sheets were created for each station. This sheet includes the work order, possible dangers, and hazard precautions, as well as the company name, date of manufacturing, and station site.

The company's suggestions for improvement include giving strict sanctions to the workers who violate health and safety regulations and always advising workers related to health and safety, to construct a perimeter fence at the PGT waste station as several chemicals may cause harmful effects if it splashed and to consider adding PPE such as safety glasses with side shields, respirators, 0.3 mm nitrile rubber gloves, body harness, and earplugs as an effort to protect workers.

Further research can do a risk assessment to classify the risk level of each hazard. Furthermore, it is necessary to validate the JSA by implementing the JSA within a certain time.

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Analisis Beban Kerja Mental pada Marketing Menggunakan Metode NASA-TLX (Studi Kasus di Perusahaan XSMK)

Elanjati Worldailmi[1)], Atyanti Prabaswari[2)], Rojab Bagus Widianto[3)]

Jurusan Teknik Industri, Fakultas Teknologi Industri, Universitas Islam Indonesia,
Jl. Kaliurang km 14,5, Umbulmartani, Sleman, Daerah Istimewa Yogyakarta, 55584, Indonesia[1),2),3)]
E-Mail : elanjati.worldailmi@uii.ac.id[1)]

ABSTRACT

XSMK is a company engaged in the production of furniture. The Marketing Department plays an important role in increasing product sales at this company. The Marketing Department at the time Imposition of Restrictions on Community Activities or PPKM was required to do work from home is now required to return to work actively in the office coupled with the demand that they have to meet sales targets at the company, namely they must earn a higher profit than the previous year. Therefore, researchers conducted research using the NASA-TLX method in order to be able to measure the mental workload of employees in the marketing department so that recommendations related to mental workload can be given in order to increase employee work effectiveness. The results showed that all operators had a level of mental workload with a fairly high to high classification caused by various factors including Temporal Demand (TD) for operator 1, Effort (EF) for operator 2, and Mental Demand (MD) for operator 3. and 4. Recommendations for work improvement, including adjusting the mental workload to the work capacity and abilities of the operator concerned, adjusting working hours to meet daily target demands because there are also many demands outside work, providing opportunities for operators to develop their abilities. The results of this study can be used for further research related to recommendations for improving workload sharing in companies.

Keywords: *Mental Workload, NASA-TLX, Productivity*

1. Pendahuluan

Di era globalisasi ini industri berkembang semakin pesat, perkembangan industri di era globalisasi ini membuat banyak perusahaan yang bergerak di bidang produksi menjadi lebih kompetitif. Perusahaan mendapat tantangan untuk berperan dengan baik agar dapat mencapai tujuan dan melakukan peningkatan kinerja.

Perusahaan XSMK adalah perusahaan yang memproduksi furnitur. Perusahaan XSMK memiliki target khusus dalam penjualan produk yaitu penjualan furniture dan berbagai macam rak. Sejak tahun 2020 hingga tahun 2021 Perusahaan XSMK mengalami penurunan akibat adanya pandemi covid-19 yang melanda dan mengakibatkan adanya peraturan Pemberlakukan Pembatasan Kegiatan Masyarakat (PPKM). Hal tersebut mengakibatkan terjadinya penurunan ekonomi di seluruh perusahaan. Oleh karena itu, pada tahun 2022 ini dimana sudah tidak diberlakukannya peraturan PPKM dan perekonomian masyarakat sudah mulai naik kembali, Perusahaan XSMK menaikkan target penjualan produk mereka.

Departemen Marketing Perusahaan XSMK berperan penting dalam peningkatan penjualan produk pada perusahaan ini. Dimana departemen marketing yang semula pada saat PPKM diwajibkan untuk melakukan pekerjaan dari rumah kini diharuskan untuk kembali aktif bekerja melalui kantor ditambah dengan tuntutan harus memenuhi target penjualan di perusahaan dimana perusahaan harus mendapatkan keuntungan lebih tinggi dari tahun sebelumnya.

Perusahaan XSMK memiliki departemen marketing dengan jumlah karyawan 4 orang yang bekerja selama 8 jam perhari nya, dengan waktu istirahat selama 30 menit, dan bekerja selama 6 hari dalam 1 minggu. Setiap pekerjaan yang dilakukan memiliki tingkatan kesulitan yang dirasakan oleh pekerja dan kemampuan yang dimiliki oleh setiap pekerja juga berbeda satu sama lain, sehingga beban kerja yang dirasakan oleh pekerja berbeda-beda. Beban kerja menggambarkan bagaimana karyawan menjalankan tanggung jawab dalam pekerjaannya serta mengelola tugas yang telah diberikan (Maharani & Budianto, 2019).

Beban kerja muncul dari adanya tuntutan tugas, keterampilan, perilaku dan persepsi, serta pengaruh faktor lingkungan kerja. Beban kerja dapat bersifat fisik dan mental. Semestinya beban kerja yang diterima seimbang antara kemampuan kognitif dan kemampuan fisik karyawan. Secara umum, aktivitas seseorang dibagi menjadi kerja fisik (otot) dan kerja mental (otak). Keduanya tidak dapat dipisahkan tetapi masih dapat diketahui bagian mana yang mendominasi (Sari, 2017).

Tingkat pembebanan setiap orang berbeda-beda. Pembebanan yang diterima seseorang diupayakan diterima secara optimum. Pembebanan dengan tingkat yang terlalu tinggi menyebabkan tingginya energi seseorang yang dikeluarkan, baik untuk kerja fisik maupun kerja mental sehingga menimbulkan kelelahan dan stress (Zetli, 2019).

Perbandingan antara tuntutan kerja mental dengan kemampuan mental seseorang diketahui dengan mengukur beban kerja mental (Yasmin et al, 2023). Beban kerja mental juga dapat berarti selisih antara tuntutan pekerjaan yang diberikan perusahaan kepada seorang karyawan terhadap kapasitas beban mental maksimal dalam keadaan termotivasi (Yudhistira et al, 2020). Oleh karena itu, dibutuhkan untuk dilakukannya suatu pengukuran Beban Kerja Mental seseorang agar dapat dilakukan perbaikan dengan rekomendasi berdasarkan hasil analisis pengukuran yang telah dilakukan.

Pengukuran beban kerja menggunakan metode NASA-TLX dilakukan secara subjektif terhadap beban kerja operator. Pengembangan metode ini didasarkan pada pengukuran yang terdiri dari Sembilan faktor, yaitu tekanan waktu, kesulitan tugas, usaha fisik, jenis aktivitas, performansi, usaha mental, frustasi, stres, dan kelelahan (Zen dan Adrian, 2019).

NASA-TLX adalah sebuah prosedur penilaian multidimensional yang mendapatkan nilai atau skor beban kerja secara keseluruhan dari bobot rata-rata dari enam sub skala yang terdiri dari kebutuhan waktu (*temporal demand*), kebutuhan fisik (*physical demand*), performansi (*own performance*), kebutuhan mental (mental demand), usaha (*effort*) dan tingkat stres (*frustration*) (Ramadhania & Parwati, 2015)

Oleh karena itu, peneliti melakukan penelitian dengan menggunakan metode NASA-TLX agar dapat melakukan pengukuran beban kerja mental pada karyawan bagian departemen marketing di Perusahaan XSMK. Dengan tujuan mengetahui beban kerja mental pada operator. Sejauh ini, perusahaan XSMK belum pernah melakukan pengukuran beban kerja mental karyawan. Sehingga nantinya dapat diberikan rekomendasi yang berkaitan dengan beban kerja mental agar dapat meningkat efektivitas kerja karyawan pada bagian departemen marketing di Perusahaan XSMK.

2. Studi Literatur

Ergonomi merupakan berbagai pendekatan atau multi disiplin ilmu yang memiliki tujuan untuk memperoleh sistem manusia-pekerjaan yang optimal agar cara, alat, dan lingkungan kerja dalam kondisi yang aman, sehat, nyaman, dan efisien (Hutabarat, 2017). Beban kerja mental menggambarkan beban kerja yang merupakan selisih antara tuntutan beban kerja dari suatu tugas dengan kapasitas maksimum beban kerja seseorang dalam kondisi termotivasi. Indikator untuk menentukan tingkat beban kerja mental diperoleh dari skor hasil unweighted method. Makin tinggi nilai yang dihasilkan, maka makin tinggi pula beban kerja mental yang dirasakan.

Beban kerja faktor eksternal dan faktor internal (Tarwaka, 2010). Faktor eksternal adalah beban yang berasal dari luar tubuh pekerja. Contoh faktor eksternal antara lain tugas-tugas yang bersifat fisik, seperti stasiun kerja, tata ruang, tempat kerja, alat dan sarana kerja, kondisi kerja, sikap kerja, dan tugas-tugas yang bersifat psikologis. Faktor internal adalah faktor yang berasal dari dalam tubuh. Faktor internal muncul karena adanya reaksi beban kerja eksternal. Contoh faktor internal antara lain faktor somatis (ukuran tubuh, status gizi, jenis kelamin, umur, dan kondisi kesehatan) dan faktor psikis (persepsi, kepercayaan, motivasi, keinginan dan kepuasan).

Beberapa gejala yang menjadi dampak dari kelebihan beban mental yang tinggi, antara lain gejala fisik, gejala mental, dan gejala social atau perilaku (Hancock dan & Meshkati, 1988). Contoh gejala fisik antara lain gangguan pola tidur, lesu, kaku leher belakang sampai punggung, sakit kepala, sakit perut, mudah terkejut, nafsu makan menurun, dan lain-lain. Contoh gejala mental antara lain mudah lupa, cemas, was-was, mudah marah, mudah tersinggung, gelisah, sulit konsentrasi, dan putus asa. Contoh gejala social atau perilaku yaitu banyak merokok, minum alkohol, menarik diri, dan menghindar.

NASA-TLX menggunakan enam dimensi untuk menilai beban mental yaitu, *Own Performance, Mental Demand, Temporal Demand, Physical Demand, Effort*, dan *Frustration*. Prosedur pembobotan digunakan untuk menggabungkan enam peringkat skala individu menjadi skor akhir. Diperlukan adanya perbandingan berpasangan antara dua dimensi sebelum penilaian beban kerja yang diisi oleh responden (operator). Responden memilih dimensi yang lebih relevan terkait beban kerja pada keenam dimensi tersebut. Setiap skor dimensi diberi nilai antara 0 sampai dengan 100 dengan mengalikan berat dengan skor skala dimensi (rating), menjumlahkan seluruh dimensi, dan membaginya dengan 15 (jumlah total perbandingan berpasangan) (Rubio, 2004).

3. Metodologi

Subjek dari penelitian ini adalah karyawan bagian departemen marketing di Perusahaan XSMK. Jumlah karyawan pada departemen marketing adalah sebanyak empat orang. Karyawan tersebut bekerja selama 8 jam perhari, dengan waktu istirahat selama 30 menit, serta bekerja 6 hari dalam 1 minggu. Tugas utama dari karyawan ini adalah memasarkan produk yang dimiliki oleh perusahaan, mengenalkan dan menjelaskan produk kepada calon pelanggan, dan membuat iklan yang menarik agar menarik perhatian calon pelanggan. Objek yang diobservasi pada penelitian ini adalah tingkat beban kerja mental pada departemen marketing di Perusahaan XSMK.

Alur penelitian dimulai dari identifikasi masalah, studi literatur, pengumpulan data, wawancara operator NASA-TLX (pembobotan dan *rating indicator*), pengolahan data, perhitungan skor pembobotan, perhitungan rating indicator, perhitungan WWL dan klasifikasi BKM, analisis hasil dan rekomendasi, serta kesimpulan dan saran.

Pengumpulan data dilakukan selama kerja praktik yaitu tanggal 14 Maret 2022 sampai dengan tanggal 27 Mei 2022. Teknik pengumpulan data yang digunakan adalah secara langsung dari objek yang diteliti. Data tersebut berupa perbandingan antara indikator pada metode NASA-TLX dan data demografi operator. Metode pengumpulan data primer yang digunakan adalah dengan memberikan kuesioner NASA-TLX serta melakukan wawancara langsung kepada karyawan bagian departemen marketing di Perusahaan XSMK.

Pengolahan data dilakukan dengan menggunakan metode NASA-TLX dimulai dengan pembobotan, lalu dilakukan pemberian rating, kemudian dilakukan perhitungan nilai produk, dan dilakukan perhitungan nilai *Weighted Workload* (WWL)

Langkah selanjutnya adalah membuat analisis berdasarkan hasil data yang telah dihitung dan mengklasifikasikan hasil rata-

rata WWL tersebut kedalam klasifikasi beban kerja mental sehingga dapat diketahui tingkat beban kerja mental karyawan bagian departemen marketing di Perusahaan XSMK sesuai dengan tujuan penelitian dan dapat memberikan rekomendasi yang dapat operator implementasikan berikutnya terkait hasil beban kerja mental yang didapatkan dari masing – masing operator.

4. Hasil dan Pembahasan

Untuk mengetahui tingkat nilai beban kerja mental, maka dilakukan beberapa tahapan perhitungan SKOR NASA-TLX, yaitu pembobotan, pemberian rating, menghitung nilai produk, menghitung *Weighted Workload* (WWL), menghitung rata-rata WWL, serta mengklasifikasikan beban mental.

Setelah mendapatkan data dari empat operator yang berada di departemen *marketing* serta memiliki *job description* yang serupa, selanjutnya dilakukan wawancara dan pengisian kuesioner berupa perbandingan antar beberapa indikator yang berkaitan dengan pekerjaan yang mereka lakukan. Rekapitulasi data pembobotan seluruh kuesioner dari keempat operator diperlihatkan pada Tabel 1.

Tabel 1. Pembobotan Operator

Operator	Indikator						Total
	MD	PD	TD	OP	EF	FR	
1	1	2	3	3	4	2	15
2	0	4	3	3	2	3	15
3	4	0	2	1	3	5	15
4	5	2	2	3	1	2	15

Empat operator melakukan pemberian *rating* melalui lembar pengamatan. Operator melakukan wawancara dengan peneliti kemudian operator diminta memberikan rating terhadap indikator beban mental. Operator memberikan rating secara subjektif sesuai dengan beban mental yang dirasakan. Kemudian, didapatkan hasil dari pemberian rating yang ditunjukkan oleh Tabel 2.

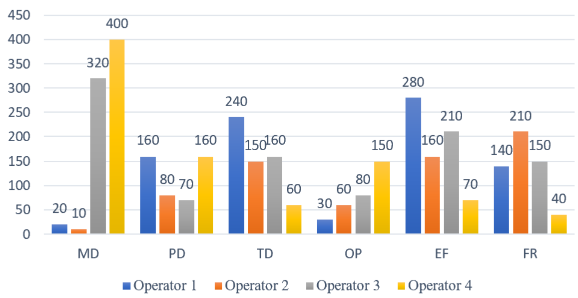
Tabel 2. Pemberian Rating

Operator	Indikator					
	MD	PD	TD	OP	EF	FR
1	20	80	80	10	70	70
2	10	20	50	20	80	70
3	80	70	80	80	70	30
4	80	80	30	50	70	20

Nilai produk diperoleh dari hasil perkalian antara rating dengan jumlah total bobot faktor dengan demikian akan dihasilkan enam nilai produk untuk enam indikator yaitu *Mental Demand* (MD), *Physical Demand* (PD), *Temporal Demand* (TD), *Own Performance* (OP), *Effort* (EF), dan *Frustration* (FR). Hasil perhitungan nilai produk dapat dilihat pada Tabel 3.

Tabel 3. Hasil Perhitungan Nilai Produk

Operator	Indikator					
	MD	PD	TD	OP	EF	FR
1	20	160	240	30	280	140
2	10	80	150	60	160	210
3	320	70	160	80	210	150
4	400	160	60	150	70	40



Gambar 1. Grafik Perbandingan Indikator

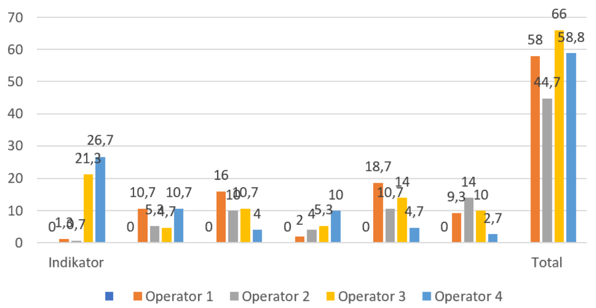
Dari data tersebut kemudian dibuat grafik perbandingan nilai dari masing-masing indikator untuk masing-masing operator. Grafik tersebut ditunjukkan pada Gambar 1. *Weighted Workload* (WWL) dapat diperoleh dengan menjumlahkan keenam nilai produk dalam masing-masing operator, sehingga didapatkan hasil yang ditunjukkan oleh Tabel 4.

Tabel 4. Hasil Perhitungan WWL

Operator	Indikator						Total
	MD	PD	TD	OP	EF	FR	
1	20	160	240	30	280	140	870
2	10	80	150	60	160	210	670
3	320	70	160	80	210	150	990
4	400	160	60	150	70	40	880

Tabel 5. Rata-Rata WWL

Operator	Indikator						Total
	MD	PD	TD	OP	EF	FR	
1	1,3	11	16	2	19	9,3	58
2	0,7	5,3	10	4	11	14	44,7
3	21	4,7	11	5,3	14	10	66
4	27	11	4	10	4,7	2,7	58,8



Gambar 2. Perbandingan Rata-Rata WWL

Nilai rata-rata *Weighted Workload* (WWL) diperoleh dengan membagi nilai WWL dengan jumlah bobot indikator yaitu sebanyak 15, sehingga didapatkan hasil seperti pada Tabel 5. Selanjutnya dibuat grafik perbandingan nilai pada setiap indikator dari keempat operator yang ditampilkan pada Gambar 2.

Berdasarkan hasil total rata-rata WWL yang didapatkan kemudian dapat diketahui klasifikasi beban kerja yang ditunjukkan oleh Tabel 6.

Tabel 6. Klasifikasi Beban Mental Operator

Operator	Nilai Mental	Kategori
1	58	Tinggi
2	44,7	Agak Tinggi
3	66	Tinggi
4	58,8	Tinggi

Berdasarkan hasil kuesioner dan setelah dilakukan perhitungan dengan menggunakan metode NASA-TLX dapat diketahui bahwa seluruh karyawan bagian departemen marketing memiliki beban kerja mental dengan klasifikasi yang agak tinggi hingga tinggi. Stres kerja merupakan kejadian–kejadian disekitar kerja yang berupa bahaya atau ancaman seperti cemas, rasa bersalah, marah sedih, rasa takut, putus asa, dan bosan. Stres kerja disebabkan oleh adanya beban kerja di luar batas kemampuan pekerja yang diterima dalam waktu yang relatif lama pada situasi dan kondisi tertentu (Rusdiana & Ramdhani, 2019).

Tingginya beban kerja mental disebabkan oleh descriptor yang paling besar (Mahmud, 2022). Berdasarkan hasil pengolahan data, pada operator 1 skor tertinggi terdapat indikator *Temporal Demand* (TD) yaitu sebesar 16 hal ini dikarenakan operator merasa lebih mengeluarkan tenaga fisik yang cukup banyak dalam menyelesaikan pekerjaannya, dengan nilai rata-rata WWL sebesar 58 yaitu masuk dalam klasifikasi tinggi hal ini membuktikan bahwa operator 1 memiliki perbedaan antara tuntutan beban kerja dari suatu tugas dengan kapasitas maksimum beban kerja mental, sehingga mengakibatkan operator 1 memiliki beban kerja mental yang tinggi. Kemudian pada operator 2 skor tertinggi terdapat indikator *Effort* (EF) yaitu sebesar 10,7 hal ini dikarenakan operator merasa dalam penyelesaian tugasnya operator memiliki usaha secara general yang cukup besar dalam menyelesaikan tanggung jawabnya pada pekerjaan tersebut, dengan nilai rata-rata WWL sebesar 44,7 yaitu masuk dalam klarifikasi cukup tinggi, hal ini membuktikan bahwa dibutuhkannya rekomendasi perbaikan agar beban kerja mental pada operator 2 tidak meningkat. Untuk operator 3 skor tertinggi terdapat pada indikator *Mental Demand* (MD) yaitu sebesar 21,3 hal ini dikarenakan operator merasa tertekan pada mental saat menjalankan pekerjaannya, dengan nilai rata-rata WWL sebesar 66 yaitu masuk dalam klasifikasi tinggi hal ini membuktikan bahwa operator 3 memiliki perbedaan antara tuntutan beban kerja dari suatu tugas dengan kapasitas maksimum beban kerja mental, sehingga mengakibatkan operator 3 memiliki beban kerja mental yang tinggi dan membutuhkan rekomendasi perbaikan. Pada operator 4 skor tertinggi terdapat pada indikator yang sama seperti pada operator 3 yaitu *Mental Demand* (MD) dengan skor sebesar 26,7 hal ini dikarenakan operator 4 juga mengalami adanya tekanan pada mental saat menjalankan pekerjaannya, dengan nilai rata-rata WWL sebesar 58,8 yaitu masuk dalam klasifikasi tinggi hal ini membuktikan bahwa operator 4 membutuhkan rekomendasi perbaikan segera agar dapat meningkatkan efektivitas kerja.

Dari hasil perhitungan data dan pada Tabel 6, dapat diketahui bahwa dari keempat operator memiliki nilai beban kerja mental dengan kategori agak tinggi hingga tinggi. Untuk itu, dapat dilakukan rekomendasi seperti beban Kerja Mental harus disesuaikan oleh kapasitas kerja dan kemampuan operator yang bersangkutan dengan menghindari adanya kesalahan saat bekerja atau beban berlebih yang terjadi pada operator; jam kerja harus disesuaikan terhadap tuntutan target harian karena menimbang mungkin banyak juga tuntutan diluar pekerjaan, sehingga memungkinkan adanya beban mental yang memberatkan pekerjaan; memberikan kesempatan pada operator untuk mengembangkan kemampuannya. Namun jika memang memungkinkan, bisa diberikan bonus tambahan untuk karyawan.

Apabila perusahaan melakukan pengukuran beban mental karyawan, perusahaan dapat mengetahui dan mengukur pemerataan deskripsi kerja sehingga karyawan yang berada di dalamnya akan merasa nyaman sehingga dapat meningkatkan kinerja dan mengurangi *turnover.* Hasil penelitian ini dapat digunakan untuk penelitian lebih lanjut terkait rekomendasi perbaikan pembagian beban kerja di Perusahaan XSMK.

5. Kesimpulan

Kondisi beban kerja mental karyawan bagian departemen marketing di Perusahaan XSMK dengan menggunakan lembar pengamatan NASA-TLX dan setelah dilakukan perhitungan didapatkan hasil yaitu seluruh operator memiliki tingkat beban kerja mental dengan klasifikasi cukup tinggi hingga tinggi. Penyebab dari tingginya beban kerja mental yang dirasakan cukup beragam dari masing-masing operator, penilaian yang telah dilakukan secara subjektif sehingga hal yang dirasakan oleh masing-masing operator tentunya berbeda. Dimana pada operator 1 memiliki faktor utama yang mengakibatkan tingginya beban kerja mental yang dialami adalah *Temporal Demand* (TD), untuk operator 2 faktor utamanya adalah *Effort* (EF), untuk operator 3 dan 4 memiliki kesamaan dalam faktor utamanya yaitu *Mental Demand* (MD).

Dari hasil perhitungan data diatas maka dapat diberikan rekomendasi perbaikan pekerjaan seperti menyesuaikan beban kerja mental dengan kapasitas kerja dan kemampuan operator yang bersangkutan, menyesuaikan jam kerja terhadap tuntutan target harian karena menimbang banyak juga tuntutan diluar pekerjaan, memberikan kesempatan pada operator untuk mengembangkan kemampuannya. Kesempatan mengembangkan kemampuan operator dapat menjadi nilai positif bagi operator itu sendiri karena ketika operator mampu mengembangkan kemampuannya, maka itu akan berdampak baik pada pekerjaannya dan akan memberikan rasa senang bagi operator sehingga mampu bekerja secara maksimal.

Agar dapat menurunkan beban kerja mental pekerja pada departemen marketing, perusahaan harus memotivasi pekerja untuk melakukan pekerjaannya dengan sebaik mungkin tanpa merasa tertekan dengan target yang harus dicapai. Selain itu, perusahaan harus menyediakan tempat kerja yang nyaman supaya pekerja merasa nyaman dalam melaksanakan pekerjaannya serta bisa bekerja secara optimal. Yang terakhir, pemberian SOP yang jelas sangat diperlukan agar pekerja bisa melaksanakan pekerjaan sesuai dengan standar dari perusahaan.

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Pengendalian Persediaan Obat Kelompok V Berbasis Abc Indeks Kritis Menggunakan *Periodic Review System*

Fausa, E.[1)], Parkhan, A.[2)], Widodo, I. D.[3)]
Jurusan Teknik Industri, Fakultas Teknologi Industri, Universitas Islam Indonesia
Jl. Kaliurang Km. 14.5, Ngemplak, Sleman, 55584, Indonesia[1),2),3)]
E-Mail :efausa@uii.ac.id[1)], aliparkhan@uii.ac.id[2)], imamdjati@uii.ac.id[3)]

ABSTRAK

Instalasi Farmasi Rumah Sakit memiliki persediaan obat – obatan dengan berbagai jenis dan fungsinya. Mengingat banyaknya macam obat pada instalasi farmasi, maka perlu ditentukan prioritas obat yang akan dioptimalkan, salah satunya menggunakan metode ABC Indeks Kritis. Berkaitan dengan ketidakpastian pemakaian, perlu dilakukan pengendalian persediaan yang ditujukan untuk menjamin terpenuhinya kebutuhan obat untuk pasien dengan biaya persediaan yang minimal. Metode yang dapat digunakan pada kondisi ketidakpastian adalah metode *Periodic Review System.* Berdasarkan analisis ABC Indeks Kritis, dari 2039 jenis obat 76 jenis diantaranya termasuk kategori A atau Vital, dengan indeks kritis tertinggi adalah ATS 1500 Injeksi dan Fentanyl 0,05 mg/ml 2 ml Injeksi. Kondisi optimal ATS 1500 Injeksi tercapai jika dilakukan pemesanan setiap 8 hari, dengan persediaan maksimum yang diharapkan = 12,69 ≈ 13 ampul, kebijakan ini akan menghasilkan level servis (η) =96,76%, sedangkan kondisi optimal Fentanyl 0,05 mg/ml 2 ml Injeksi tercapai jika dilakukan pemesanan setiap 10 hari, dengan persediaan maksimum yang diharapkan = 24,37 ≈ 25 ampul, kebijakan ini akan menghasilkan level servis (η) = 89,96%.

Kata kunci : ABC Indeks Kritis, *Periodic Review System,* Level Servis

1. Pendahuluan

Rumah sakit merupakan lembaga kesehatan yang menyediakan pelayanan medis, perawatan, dan pengobatan bagi pasien yang mengalami gangguan kesehatan atau cedera. Menurut Undang-undang no 44 tahun 2009 tentang Rumah Sakit, Rumah Sakit dinyatakan sebagai "institusi pelayanan kesehatan yang menyelenggarakan pelayanan kesehatan perorangan secara paripurna yang menyediakan pelayanan rawat inap, rawat jalan, dan gawat darurat". Fungsi utama rumah sakit adalah menyediakan fasilitas dan tim medis yang terlatih untuk mendiagnosis, merawat, dan menyembuhkan pasien. Pada rumah sakit terdapat instalasi farmasi yang bertujuan untuk memastikan penggunaan obat yang aman, efektif, dan tepat. Farmasis bekerja sama dengan tim medis dan pasien untuk memberikan dukungan farmasi yang komprehensif dalam rangka meningkatkan kualitas perawatan pasien.

Agar dapat memenuhi kebutuhan pelayanan kesehatan yang beranekaragam, bagian instalasi farmasi perlu memiliki persediaan berbagai jenis obat. Menurut Kumar dan Chakravarty (2014), lebih dari 30% dari total anggaran tahunan rumah sakit diperlukan untuk membeli bahan dan persediaan termasuk obat–obatan. Persediaan obat perlu penanganan khusus karena apabila memiliki jumlah yang kurang memadai dapat mengakibatkan tidak terlayaninya pasien dengan baik dan rumah sakit akan mengalami potensi kehilangan mendapatkan keuntungan (*opportunity cost*), sebaliknya jika jumlah produk berlebihan dapat menyebabkan banyaknya produk yang kadaluarsa dan dapat menyebabkan biaya simpan yang tinggi (Nafisah et al., 2011).

Instalasi Farmasi Rumah Sakit memiliki persediaan obat – obatan dengan berbagai jenis dan fungsinya. Mengingat banyaknya macam obat pada suatu instalasi farmasi, maka perlu ditentukan prioritas obat yang akan dioptimalkan. Metode yang dapat digunakan sebagai langkah awal melakukan prioritas perencanakan kebutuhan obat adalah analisis ABC Indeks Kritis sebagaimana penelitian Suciati dkk (2006) adalah perlunya pengelompokan berbagai jenis obat dengan mempertimbangkan pemanfaatan, nilai investasi yang akan menghasilkan status yaitu vital, essensial dan nonessensial sebagai dasar menentukan prioritas obat yang akan dianalisis. Beberapa pengembangan model ABC dilakukan dengan penggabungan model dengan VAD (Devnani dkk, 2015) dan pemilihan multi kriteria (Eslaminasab & Dokoohaki, 2006)

Salah satu sistem persedian yang sangat responsif adalah sistem persediaan kontinu. Sistem ini memungkinkan organisasi dapat memperoleh visibilitas yang lebih baik tentang persediaan mereka, mengelola persediaan dengan lebih efisien, dan membuat keputusan yang lebih baik berdasarkan informasi yang akurat dan real-time. Ini adalah beberapa keunggulan utama yang ditawarkan oleh sistem persediaan kontinu. Beberapa penelitian pengendalian persedian bersifat kontinu dengan berbasis pada beberapa kondisi telah dikembangkan antara lain terkait pendekatan Meta Heuristic Algorithms (Fattahi dkk, 2015), backorder (Gozali dkk, 2013), Periodic Review (Park dkk, 2014) dan kuantitas penerimaan tidak pasti (Priyan & Uthayakumar, 2015).

Untuk mengatasi kompleksitas pengelolaan manajemen persedian dalam pemantauan dan menentukan waktu pemesan dalam sistem persediaan kontinu, *Periodic Review System* dapat dipergunakan baik dalam situasi yang bersifat deterministik maupun probabilistik. Berkaitan dengan ketidakpastian pemakaian yang berakibat terjadinya kelebihan atau kekurangan stok obat pada sistem persediaan obat-obatan, instalasi farmasi perlu melakukan pengendalian persediaan berbagai jenis obat, yang ditujukan untuk menjamin adanya persediaan yang optimal, yaitu kebutuhan obat untuk pasien dapat terpenuhi dengan biaya persediaan yang minimal.

2. Dasar Teori

2.1. ABC Indeks Kritis

Persedian menjadi bagian penting dari suatu rantai pasok. Disamping banyaknya barang dan lokasi dalam rantai pasok, persediaan juga akan memiliki efek finansial yang cukup besar terhadap rantai pasok Sehingga perlu dilakukan optimilaisasi manajemen persediaan dengan mempertimbangkan prioritas item barang. Pada obat-obatan, prioritas item yang akan dioptimalkan dapat ditentukan berdasarkan analisis ABC indeks kritis (Febriawati, 2013).

Analisis ABC Indeks Kritis digunakan untuk meningkatkan efisiensi penggunaan dana dengan cara mengelompokkan obat atau perbekalan farmasi, berdasarkan dampaknya terhadap kesehatan. Tahapan analisis ABC Indeks Kritis adalah sebagai berikut:

a. Identifikasi obat
   Susun rekapitulasi daftar obat, satuan obat, jumlah obat dan harga satuan obat yang dipakai selama satu tahun di instalasi farmasi.
b. Membuat nilai pemakaian
   1) Urutkan nilai pemakaian obat dari pemakaian terbesar sampai terkecil.
   2) Berdasarkan persen kumulatif pemakaian obat, tentukan bobot nilai setiap jenis obat, dengan kriteria, nilai 3 : untuk % kumulatif < 70%, nilai 2 : untuk % kumulatif antara 70% - 90%, nilai 1 : untuk % kumulatif > 90%
c. Menghitung nilai investasi obat
   1) Urutkan nilai investasi dari yang investasi terbesar sampai terkecil.
   2) Berdasarkan persentase kumulatif, tentukan bobot nilai setiap jenis obat dengan kriteria, nilai 3 : untuk % kumulatif < 70%, nilai 2 : untuk % kumulatif antara 70% - 90%, nilai 1 : untuk % kumulatif > 90%
d. Menghitung nilai indeks kritis (NIK) obat
   Informasi NIK obat, diperoleh dari dokter atau apoteker berdasarkan data pemakaian obat, dengan kriteria, kelompok X (kelompok vital, bobot 3), kelompok Y (kelompok obat essensial, bobot 2), kelompok Z (kelompok obat nonessensial, bobot 1), kelompok 0: obat atau barang yang tidak di

klasifikasikan kedalam kelompok X, Y dan Z.

NIK = nilai investasi + nilai pemakaian + (2 x nilai kritis)

e. Mengelompokkan jenis obat berdasarkan analisis ABC indeks kritis Mengelompokan setiap jenis obat dengan kriteria sebagai berikut:
   1) Kelompok A atau V (Vital): merupakan kelompok obat sangat essensial atau vital, sehingga obat pada kelompok ini tidak boleh terjadi kekosongan. NIK antara 9,5 – 12
   2) Kelompok B atau E (Essensial): merupakan kelompok obat essensial, kekosongan obat kelompok ini dapat ditolerir kurang dari 48 jam. NIK antara 6,5 – 9,4
   3) Kelompok C atau N (Non essensial): merupakan obat penunjang agar tindakan atau pengobatan menjadi lebih baik, kekosongan obat ini dapat ditolerir lebih dari 48 jam. NIK antara 4 – 6,4

2.2. Biaya Persediaan

Biaya persediaan diklasifikasikan sebagai berikut.

a. Biaya pembelian (*Purchasing cost* = c), jika item berasal dari sumber eksternal, biaya pembelian adalah harga pembelian per unit item, sedangkan jika item berasal dari internal perusahaan merupakan biaya produksi per unit item tersebut.
b. Biaya pengadaan (*Procurement cost*), berdasarkan sumbernya dibedakan menjadi biaya pemesanan (*Ordering cost* = k) yaitu semua pengeluaran yang timbul akibat mendatangkan barang dari luar danb biaya pembuatan (*Setup cost* = k) yaitu semua pengeluaran yang timbul akibat persiapan memproduksi barang.
c. Biaya penyimpanan (*Carrying cost* = h) merupakan biaya yang timbul akibat menyimpan suatu item, yang meliputi biaya memiliki persediaan (biaya modal), biaya gudang, biaya kerusakan dan penyusutan, biaya kadaluarsa, biaya asuransi biaya administrasi dan pemindahan.
d. Biaya kekurangan persediaan (*Shortage cost* = *p*), terjadi jika persediaan tidak mencukupi permintaan produk atau kebutuhan bahan. Biaya ini meliputi: biaya kehilangan penjualan, biaya kehilanggan pelanggan, biaya pemesanan khusus. Biaya kekurangan persediaan dapat diukur berdasarkan: kuantitas yang tidak dapat dipenuhi, waktu pemenuhan, biaya pengadaan darurat.

2.3. Metode Pengendalian Persediaan Probabilistik

Metode Pengendalian Persediaan Probabilistik merupakan model yang umum digunakan jika parameter model tidak diketahui dengan pasti, namun nilai ekspektasi, variansi dan pola distribusi kemungkinannya dapat diprediksi. Dikenal dua macam metode pengendalian persediaan yang bersifat probabilistik, yaitu metode *Q* dan metode *P*. Dikenal 2 macam metode *P* yaitu: 1) Metode *P* dengan *back order* yaitu metode pengendalian persediaan yang memungkinkan terjadinya kekurangan persediaan (backorder) saat permintaan melebihi persediaan yang tersedia dan 2) Metode *P* dengan *lost sales* yaitu metode pengendalian persediaan yang tidak mengizinkan terjadinya backorder atau kekurangan persediaan. *Costumer* akan mencari barang kebutuhan di tempat lain. Nilai *T** dan *R** dapat ditentukan sebagai berikut:

1. Hitung nilai T sebagai berikut :

$$T = \sqrt{\frac{2A}{Dh}} \quad (1)$$

2. Hitung nilai α dan R menggunakan formula berikut:

$$\alpha = \frac{hT}{Cu+hT} \quad (2)$$

Jika kebutuhan selama $T + L$ berdistribusi normal, maka:

R $= DT + D_L + Z\alpha\sqrt{T+L}$ (3)

3. Hitung total biaya persediaan $(Ot)_0$ menggunakan formula berikut:

$$Ot = p + \frac{A}{T} + h\left(R - D_L + \frac{DT}{2} + \int_R^{\infty}(z - R)f(z)dz\right) + \frac{Cu}{T}\int_R^{\infty}(z - R)f(z)dz \quad (4)$$

Ulangi mulai di atas dengan mengubah $T = T + \Delta T$

- Jika nilai Ot baru > dari Ot sebelumnya, hentikan iterasi penambahan T dan lakukan iterasi pengurangan ($T = T - \Delta T$) hingga diperoleh $T^* = T$ yang memberikan nilai Ot^* minimal.
- Jika hasil Ot baru < dari Ot sebelumnya, lanjutkan iterasi penambahan $(T = T + \Delta T)$ dan berhenti jika Ot baru > Ot sebelumnya . Harga T yang memberikan nilai total terkecil $(Ot)^*$ merupakan selang waktu optimal (T^*).

Tingkat pelayanan (η) yang menggambarkan probabilitas terpenuhinya permintaan adalah:

$$\eta = (1 - \int_R^{\infty}(z - R)f(z)dz / D_L) \times 100\% \quad (5)$$

dengan:

η = Level Servis
D_L = Ekspektasi permintaan selama *lead time*
x = Variabel acak permintaan barang selama periode *lead time*
$f(x)$ = Fungsi kepadatan probabilitas variabel acak x
α = Kemungkinan terjadinya kekurangan persediaan
Z_α = Nilai Z pada distribusi normal standar untuk tingkat α
D = Ekspektasi jumlah barang yang dibutuhkan
Op = Biaya pengadaan
A = Biaya untuk setiap kali melakukan pemesanan
T = Periode waktu antar pemesanan
R = Persediaan maksimum yang diharapkan
Os = Biaya simpan
h = Biaya simpan per unit per periode
L = *Lead time*
S = Standar deviasi
S_L = Standar deviasi selama *lead time*
Ok = Biaya kekurangan persediaan
C_u = Biaya kekurangan persediaan setiap unit barang
Ot = Total biaya persediaan

2.4. Titik Pemesanan Kembali (*Reorder Point)*

Reorder Point (ROP) adalah titik persediaan untuk menempatkan pesanan baru agar persediaan mencukupi sebelum kehabisan. Dalam pengendalian persediaan, ROP menentukan kapan pesanan harus ditempatkan berdasarkan tingkat persediaan saat ini, tingkat permintaan, dan waktu pengiriman atau lead time. Batas minimal tersebut dihitung dengan mempertimbangkan probabilitas terjadinya kekurangan stok (Rangkuti, 2000).

3. Metode Penelitian

3.1. Rancangan Penelitian

Obat merupakan barang logistik atau persediaan di Instalasi Farmasi. Agar dapat menyediakan obat dengan jumlah dan waktu yang tepat dengan biaya yang minimal, dibutuhkan pengelolaan persediaan yang efektif dan efisien. Penelitian ini ditujukan untuk mengetahui kelompok jenis obat berdasarkan analisis ABC Indeks Kritis dan menentukan waktu dan jumlah perlunya melakukan pemesanan obat dari kelompok A (Vital) dengan indeks kritis terbesar agar diperoleh biaya minimal.

3.2 Objek Penelitian

Penelitian yang akan dilakukan di Instalasi Farmasi Rumah Sakit pada bagian persediaan obat dengan objek penelitian adalah obat paten dan obat generik.

3.3 Sumber Data dan Alur Penelitian

Data yang digunakan pada penelitian ini diperoleh dari penelitian Anindia Medinah dalam (Anindia Medinah, 2016), dengan alur penelitian sebagai berikut:

1. Identifikasi nama obat, satuan obat, jumlah obat tersedia, harga obat, total pemakaian obat, nilai kritis obat berdasarkan pembobotan dari apoteker
2. Menggunakan tahapan analisis ABC Indeks Kritis, klasifikasikan obat kedalam kelompok A (atau Vital), kelompok B (atau Esensial) dan kelompok C (atau Non Esensial)
3. Pilih dua obat kelompok A (atau Vital) dengan NIK tertinggi
4. Identifikasi dan hitung besarnya biaya pesan, biaya simpan dan biaya kekurangan persediaan, dan total biaya persediaan
5. Tentukan kondisi optimal waktu (kapan), persediaan maksimum yang diharapkan serta service level
6. Pembahasan dan Penutup

4. Hasil Penelitian dan Pembahasan

4.1. Data Penelitian

Dalam penelitian yang dibutuhkan, berkaitan dengan klasifikasi jenis obat berbasis ABC indeks kritis dan pengendalian persediaan kelompok A (atau Vital) yang mempunyai nilai indek kritis tertinggi. Data tersebut meliputi:

4.1.1. Identifikasi Obat

Berdasarkan data pemakaian obat pada bagian Instalasi Farmasi terdapat 2039 jenis obat yang akan ditentukan prioritas obat yang akan dianalisis, menggunakan analisis ABC Indeks Kritis. ABC Indeks Kritis ditujukan untuk mengetahui pengelompokan obat vital, essensial dan nonessensial. Data yang dibutuhkan meliputi nama obat, satuan obat, jumlah obat tersedia, harga obat, total pemakaian obat, nilai kritis obat berdasarkan pendapat ahli, dalam hal ini adalah apoteker dan Manager Farmasi di Instalasi Farmasi. Kelompok A (Vital) adalah obat vital untuk memperpanjang hidup guna mengatasi penyakit penyebab kematian maupun untuk pelayanan pokok kesehatan, sehingga obat pada kelompok ini tidak boleh terjadi kekosongan. Kelompok B (Esensial) adalah obat essensial yang bekerja kausal yaitu obat yang bekerja pada sumber penyakit, logistik farmasi yang banyak digunakan dalam pengobatan penyakit terbanyak, kekosongan obat kelompok ini dapat ditolerir kurang dari 48 jam. Kelompok C (Non Esensial) adalah obat nonessensial yang merupakan obat penunjang agar tindakan atau pengobatan menjadi lebih baik, untuk kenyamanan atau mengatasi keluhan, kekosongan obat ini dapat ditolerir lebih dari 48 jam.

4.1.2. Biaya Persediaan

Data biaya persediaan yang dibutuhkan, berkaitan dengan jenis obat yang masuk kategori A (vital) dengan nilai indeks kritis tertinggi. Biaya persediaan adalah biaya yang terjadi akibat memiliki persediaan yang meliputi:

a. Biaya Pembelian
   Biaya pembelian adalah harga beli obat ke distributor. Harga beli per unit masing – masing obat tidak berbeda untuk pembelian dalam jumlah besar maupun dalam jumlah kecil.
b. Biaya Pemesanan
   Pemesanan obat dilakukan dengan cara pihak instalasi farmasi menelepon distributor untuk memesan obat yang dibutuhkan. Besarnya biaya telepon menggunakan tarif dasar telepon PT Telkom yaitu 250,00/2menit untuk tarif lokal, besarnya biaya administrasi dan pemeriksaan setiap kali melakukan pemesanan adalah Rp 4.500,00.
c. Biaya Penyimpanan
   Biaya penyimpanan meliputi biaya modal (10.93 %/tahun), biaya tenaga kerja bagian Gudang (3 orang (@ Rp 2.750.000,00/bulan) dan biaya listrik Instalasi Farmasi (Rp 1.316.532,00/bulan).
d. Biaya Kekurangan Persediaan
   Biaya kekurangan timbul akibat persediaan obat pada waktu tertentu tidak mencukupi permintaan, sehingga bagian instalasi farmasi perlu melakukan pengadaan/pemesanan darurat dengan biaya 5% × harga obat.

4.1.3. Lead Time

Berdasarkan wawancara dengan Manager Farmasi, diperoleh bahwa lokasi distributor dekat dengan Instalasi Farmasi sehingga hanya membutuhkan waktu 1 hari untuk pengiriman obat yang dipesan.

4.2. Analisis dan Pembahasan

Pengolahan data menggunakan analisis ABC indeks kritis dan pengendalian persediaan untuk obat jenis katagori A atau obat vital dengan nilai indeks kritis tertinggi adalah sebagai berikut:

4.2.1. Klasifikasi Jenis Obat Berbasis ABC Indeks Kritis

- Nilai Pemakaian (NP)
  Berdasarkan persen komulatif pemakaian obat, dari 2039 jenis obat, terdapat 1476 jenis obat dengan bobot nilai 1, 362 jenis obat dengan bobot nilai 2, dan 201 jenis obat dengan bobot nilai 3.
- Nilai Investasi (NI)
  Berdasarkan persen komulatif pemakaian dan harga satuan darin 2039 jenis obat terdapat 1357 jenis obat dengan bobot nilai 1, 439 jenis obat dengan bobot nilai 2, 243 jenis obat dengan bobot nilai 3.
- Nilai Kritis (NK)
  Berdasarkan informasi yang diperoleh dari dokter atau apoteker, dari 2039 jenis obat, terdapat 71 jenis obat dengan bobot nilai 1, 497 jenis obat dengan bobot nilai 1,5, 1293 jenis obat dengan bobot nilai 2, 162 jenis obat dengan bobot nilai 2,5 dan 16 jenis obat dengan bobot nilai 3.
- Nilai indek kritis (NIK) dan Pengelompokkan Obat
  Menggunakan rumus: NIK = NP + NI + (2 x NK), dari 2039 jenis obat, terdapat : 1180 jenis obat memiliki indeks kritis 4 – 6,4 (kelompok C atau non Esensial) ; 783 jenis obat memiliki indeks kritis 6,5 – 9,4 (kelompok B atau Esensial) dan 76 jenis obat memiliki indeks kritis 9,5 – 12 (kelompok A atau Vital). Dari 76 jenis obat kelompok A, diperoleh bahwa obat dengan NIK tertinggi = 11 adalah jenis obat ATS 1500 Injeksi dan Fentanyl 0,05 mg/ml 2 ml Injeksi. Selanjutnya 2 jenis obat ini yang akan dikendalikan waktu pemesanan dan persediaan maksimum yang diharapkan.

Tabel 1 Data Pemakaian Obat (Ampul)

Bulan	ATS 1500 Injeksi	Fentanyl 0,05 mg/ml
Januari	58	50
Februari	60	100
Maret	40	0
April	30	50
Mei	50	100
Juni	60	100
Juli	30	50
Agustus	40	0
September	28	100
Oktober	48	100
November	30	0
Desember	30	150

4.2.2. Pengendalian Persediaan

Berdasarkan obat kelompok A (vital), akan dianalisis 2 jenis obat dengan NIK tertinggi (yaitu ATS 1500 Injeksi dan Fentanyl 0,05 mg/ml 2 ml dengan Injeksi).

a. Pemakaian Obat

Jumlah Pemakaian Obat ATS 1500 Injeksi dan Fentanyl 0,05 mg/ml 2 ml Injeksi Harga per ampul obat ATS 1500 injeksi dan Fentanyl 0.05 mg/ml 2 ml Injeksi, masing-masing Rp 112.125, - dan Rp 44.000, -

a. Biaya Pesan
   Biaya pesan terdiri dari biaya telepon, biaya pemeriksaan dan administrasi sebesar = Rp 5.000, -/sekali pesan.
b. Biaya Simpan
   Biaya simpan terdiri dari biaya modal (bunga bank), biaya tenaga kerja gudang, dan biaya listrik.
   - ATS 1500 Injeksi
     - Biaya Modal
       = Suku bunga /tahun x harga obat
       = 10,93% x Rp 112.125
       = Rp 12.255,26, -/ampul/tahun
     - Biaya tenaga kerja = jumlah pegawai gudang × gaji pegawai gudang/tahun: rata – rata obat di

gudang × bobot penggunaan ATS 1500 injeksi
= (3×2.750.000×12)/50×0,033%
= Rp 653,4, -/ampul/tahun

- Biaya listrik = Biaya listrik Instalasi Farmasi/tahun: rata-rata obat digudang × bobot penggunaan ATS 1500 injeksi
  = $(1.316.532\ x\ 12)/50$ × 0,033%
  = Rp 104,26, -/ampul/tahun

Total biaya simpan (h) = Rp 12.255,26, - + Rp 653,4, - + Rp 104,26, -
= Rp 13.012,92, -/ampul/tahun

- Fentanyl 0,05 mg/ml 2 ml Injeksi
  - Biaya Modal
    = Suku bunga /tahun x harga obat
    = 10,93% x Rp 44.000, -
    = Rp 4.809,26/ampul/tahun
  - Biaya tenaga kerja = jumlah pegawai gudang × gaji pegawai gudang/tahun: rata–rata obat di gudang × bobot penggunaan Fentanyl 0,05 Mg/Ml
    = (3×2.750.000×12)/50×0,052%
    =Rp1.029,60/ampul/tahun
  - Biaya listrik= Biaya listrik Instalasi Farmasi/tahun: rata-rata obat digudang× bobot penggunaan Fentanyl 0,05 Mg/Ml 2 Ml Injeksi
    = (1.316.532×12)/50×0,052%
    = Rp 164,24, -/ampul/tahun

  Total biaya simpan (h)
  = Rp 4.809,26 + Rp 1.029,60 + Rp 164,24
  = Rp 6.003,10/ampul/tahun

c. Biaya Kekurangan Persediaan
   Biaya kekurangan persediaan diukur dari biaya pengadaan darurat.
   - ATS 1500 Injeksi
   Biaya pengadaan darurat
   = 5% x Rp 112.125, - /ampul
   = Rp 5.606,25/ampul
   - Fentanyl 0,05 Mg/Ml 2 Ml Injeksi
   Biaya pengadaan darurat
   = 5% x Rp 44.000, - /ampul
   = Rp 2.200, -/ampul
d. Total Biaya Persediaan

- ATS 1500 Injeksi
Karena tidak terdapat *discount quantity*, maka nilai *Dp* tidak diikutsertakan pada model. Berdasarkan persamaan (1) – (4) dengan A = Rp 5.000, -/pesan; D = 504 ampul/tahun; h = Rp 13.012,92, -/ampul/tahun; C_u= Rp 5.606,25, -/ampul; L = 1 hari; hari kerja = 365 hari/tahun ; S_L = 0,66658 diperoleh nilai *Ot* sebagai berikut:

<u>Iterasi 1.</u>

T = ((2 x 5.000) /(504 x 13.012,92))$^{1/2}$
= 0,03905
α = 13.012,92*0,03905/ (5.606,25, -+ 13.012,92* 0,03905) = 0,08310
$Z\alpha$ = 1,38449
R= 504 (0,03905) + 1,38 + 1,38449 ($\sqrt{0,03905 + 1/365}$) = 21,34397
$\int_R^\infty (z-R)f(z)dz = S_L[f(Z_\alpha) - Z_\alpha \Psi(Z_\alpha)]$; dengan S_L = 0,66658; $f(Z\alpha)$ = 0,152995; $\Psi(Z\alpha)$ = 0,037938
$\int_R^\infty (z-R)f(z)dz$= 0,66658 [0,152995 − 1,38449 (0,037938)] = 0,06697
$Ot = \frac{5.000}{0,03905} + 13.012,92\left(21,34397 - 1,38 + 504\left(\frac{0,0395}{2}\right) + 0,06697\right) + (\frac{5.606,25}{0,03905}(0,06697) = 526.361,525$
Ulangi langkah di atas dengan mengubah $T = T + \Delta T$

<u>Iterasi 2.</u>

T = 0,04110
α = 13.012,92* 0,04110/(5.606,25,-+ 13.012,92* 0,04110) = 0,08708
$Z\alpha$ = 1,35894
R = 504 (0,04110) + 1,38 + 1,35894 ($\sqrt{0,04110 + 1/365}$) = 22,37767
$\int_R^\infty (z-R)f(z)dz = S_L[f(Z_\alpha) - Z_\alpha \Psi(Z_\alpha)]$; dengan S_L = 0,66658; $f(Z\alpha)$ = 0,158453; $\Psi(Z\alpha)$ = 0,040113

$\int_{R}^{\infty}(z-R)f(z)dz$ = 0,66658 [0,158453− 1,35894 (0,040113)]= 0,06929

$Ot = \frac{5.000}{0,04110} + 13012,92(22,37767 - 1,38 + 504\,(0,04110/2 + 0,06929) + (\frac{5.606,25}{0,04110}\,(0,06929) = 540.014,478$

Karena nilai Ot baru > dari Ot sebelumnya, lakukan iterasi pengurangan $(T = T - \Delta T)$

Iterasi 3.

T = 0,02740

α = 13.012,92* 0,02740 / (5.606,25, -+ 13.012,92* 0,02740) = 0,05979

$Z\alpha$ = 1,55653

R = 504 (0,02740) + 1,38 + 1,55653 ($\sqrt{0,02740 + 1/365}$) = 15,45926

$\int_{R}^{\infty}(z-R)f(z)dz = S_L[f(Z_\alpha) - Z_\alpha \Psi(Z_\alpha)]$; dengan S_L = 0,66658; $f(Z\alpha)$ = 0,118797; $\Psi(Z\alpha)$ = 0,025731

$\int_{R}^{\infty}(z-R)f(z)dz$ = 0,66658 [0,118797− 1,55653 (0,025731)]= 0,05249

$Ot = \frac{5.000}{0,02740} + 13012,92(15,45926 - 1,38 + 504\,(0,02740/2 + 0,05249) + (\frac{5.606,25}{0,02740}\,(0,05249) = 466.968,304$

Dengan cara yang sama diperoleh nilai R dan Ot iterasi 1 – 6 sebagai terlihat dalam Tabel 2.

*Ot** = Rp 459.162, - diperoleh pada periode waktu antar pemesanan *T** = 0,02192 tahun atau 8 hari dengan persediaan maksimum yang diharapkan = 12,69 ≈ 13. Pada kondisi ini diperoleh nilai η = (1 – 0,04472/1,38082) × 100% = 96,76%

- Fentanyl 0,05 mg/ml 2 ml Injeksi

Berdasarkan Persamaan (1) – (4) dengan A = Rp 5.000, -/pesan; D = 800 ampul/tahun; h = Rp 6.003,1, -/ampul/tahun; C_u = Rp 2.200, -/ampul; L = 1 hari; hari kerja = 365 hari/tahun; S_L = 49,236596, diperoleh nilai *Ot* seperti terlihat dalam Tabel 3.

*Ot** = Rp 401.012, - diperoleh pada periode waktu antar pemesanan *T** = 0,02192 tahun atau 8 hari dengan persediaan maksimum yang diharapkan = 24,37 ≈ 25. Pada kondisi ini diperoleh nilai η = (1 – 0,22720/2,19178) × 100% = 89,96%.

Tabel 2. Nilai *R* dan *Ot* ATS 1500 Injeksi

Iterasi ke	T (tahun)	R (unit)	Os (Rp)	Op (Rp)	Ok (Rp)	Ot (Rp)
1	0,03905	21,32	128.048	388.698	9.615	526.361
2	0,04110	22,38	121.667	408.896	9.452	540.015
3	0,02740	15,46	182.500	273.727	10.741	466.968
4	0,02466	14,07	202.778	246.668	11.072	460.518
5	0,02192	12,69	228.125	219.597	11.440	459.162
6	0,01918	11,30	260.714	192.422	10.928	464.114

Tabel 3. Nilai *R* dan *Ot* Fentanyl 0,05 mg/ml 2 ml Injeksi

Iterasi ke	T (tahun)	R (unit)	Os (Rp)	Op (Rp)	Ok (Rp)	Ot (Rp)
1	0,04563	38,97	109.573	332.243	15.340	457.156
2	0,04658	39,72	107.353	339.066	15.224	461.643
3	0,03288	28,75	152.083	239.953	17.208	409.424
4	0,03014	26,56	165..909	220.144	17.703	403.726
5	0,02740	24,37	182.500	200.268	18.244	401.012
6	0,02466	22,17	202.778	180.414	18.840	402.032

Nilai *T** mengindikasikan bahwa semakin rendah nilai *T* dari nilai *T**, berakibat pada semakin tingginya biaya persediaan dan rendahnya servise level. Servise level dapat ditingkatkan dengan menaikkan nilai *T* menjadi > 8 hari (untuk ATS 1500 Injeksi) dan *T* menjadi > 10 hari u(ntuk Fentanyl 0,05 mg/ml 2 ml Injeksi), akan tetapi hal ini berakibat pada kenaikan biaya persediaan.

5. Kesimpulan

Berdasarkan hasil analisis di atas, dapat disimpulkan bahwa adalah:

1. Dari 2039 jenis obat yang digunakan di instalasi farmasi, 76 jenis diantaranya termasuk kategori A atau Vital, dengan indeks kritis tertinggi adalah ATS 1500 Injeksi dan Fentanyl 0,05 mg/ml 2 ml Injeksi.
2. Kondisi optimal ATS 1500 Injeksi tercapai jika perusahaan melakukan pemesanan setiap 8 hari, dengan persediaan maksimum yang diharapkan = 12,69 ≈ 13 ampul, kebijakan ini akan menghasilkan level servis (η) = 96,76%, sedangkan kondisi optimal Fentanyl 0,05 mg/ml 2 ml Injeksi tercapai jika perusahaan melakukan pemesanan setiap 10 hari, dengan persediaan maksimum yang diharapkan = 24,37 ≈ 25 ampul, kebijakan ini akan menghasilkan level servis (η) = 89,96%

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