FORECASTING PLANNING AND PROCUREMENT STRATEGY OF RAW MATERIAL USING MATERIAL REQUIREMENTS PLANNING METHODE

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Abstract: The research was conducted in the building material manufacturing industry. Research focus on planning and controlling raw fiber roof fiber cement raw material using the Material Requirement Planning method. Problems that occur because of fluctuations in stock. By evaluating the planning process, calculating raw material requirements and then reviewing the most efficient Lotsizing techniques between Fixed Order Quantity, Economic Order Quantity, Lot for Lot, Period Order Quantity. Besides that, a strategy is also studied so that MRP can be applied. From the application of the lot sizing technique, the most efficient lotting method is obtained from the Lot for Lot method at a cost of Rp. 5.29 billion. The application of MRP also has an impact on improving inventory performance, changes in minimum and maximum stock changes that are adjusted to production activities. Efficient purchase costs from total raw material needs with an average value of Rp 8.33 billion.

Keywords: Material Requirements Planning, Forecasting, Lot Size, Bill of Material, Inventory

INTRODUCTION
Every company strives to continue to grow. Improvement of business processes on each line will grow the company and increase business profits. Research conducted in the building materials manufacturing industry with a focus on raw material planning and inventory management. Products with the main raw material in the form of a mixture of chrysotile fiber cement, cellulose fibers and some additives. From the data obtained by the inventory of raw materials is very volatile, high stock results in inefficient supplies, and lack of inventory can be the cause of companies unable to meet market demand.
As a basis for problem identification is the fluctuation of raw material stock in the period 2014 to 2019, the condition of raw materials is a prerequisite for the fulfillment of the needs of the product to be sold. The most important raw material to consider is Chrysotile fiber, which is an imported material with few sources. There are only a few countries that produce chrysotile, namely Russia, China, Brazil. The number of needs is quite large and long distances make the lead time quite high ranging from 4 weeks to 8 weeks, so that this chrysotile becomes a material that requires attention. Based on material inventory data, fluctuating availability one time has a very high stock number, but there are also times where stock shortage occurs. From sales data, The standard shows very high fluctuations. Picture 1 Graph of sales, production output and inventory

![Picture 1. Graph of Sales Output and Stock End Inventory conditions for the period 2014 - 2018](source: Departmental PPC data for 2018)

**LITERATURE REVIEW**

Good control of raw materials will ensure the availability of raw materials in optimum conditions, in order to avoid shortage of raw materials and excessive stock. Good control of raw materials will have a direct impact on the financial aspects. Meeting all needs and not accumulating costs only on material purchases that dominate the costs. If there is a shortage of raw materials, the company will face lost of opportunity for market opportunities, and if there is overstock, it will absorb very large cash flow and can disrupt operations for other needs.

Inventory along the supply chain has major implications for a company's financial performance. Many companies have an inventory value of up to 25% of the total value of assets owned (I Nyoman Pujawan, 2017)

Material Requirements Planning is a concept where in production management that discusses the right way in planning the needs of goods in the production process (Eddy Harjanto, 2018). The purpose of the MRP is to control inventory levels, determine priorities for each item by looking at production capacity or based on forecasting that is done. There are several factors that are taken into account for the successful implementation of MRP including ordering and arrival time of raw materials. So in this case it is very important to know the supply capacity of each supplier and leadtime to predict arrival near the expected time. Then the orientation of the application of MRP is the achievement of optimization of material requirements.

The production function or also commonly called the operation function is a function entrusted with the duties and responsibilities to carry out the activity of converting and
processing production resources (assets of input) into outputs, goods or services, according as previously planned (Haming and Mahfud, 2014:4). The illustration as shown Picture 2.

**Picture 2 General Model of Production Function**
(Source: Haming and Mahfud, 2014)

**Forecasting**
Forecasting is an art and science in predicting future events. Forecasting will involve taking historical data and projecting that data into the future with a mathematical model (Heizer and Render, 2014). Forecasting will have an impact on the organization:

1. Scheduling: Efficient use of resources requires
2. Getting resources: Lead time
3. MeneDetermine resource requirements
4. technology

**Forecasting Methods**

**Naive approach**
The simplest forecasting model assumes that observations in the time period that has just passed (last year, last month and so on) are the best forecasting tools for predicting future conditions. These models are:

\[ Y_{t+1} = Y_t \]  

(1)

**Simple Moving Average**
Represents (n) current data for forecasting the period of forecasting methods using averages of future numbers

\[ Mt = Y_t + 1 = \frac{(Y_1 + Y_t - 1 + Y_t - 2 + \ldots + Y_t - n + 1)}{n} \]  

(2)

\[ Mt \quad = \quad \text{Moving average in period t} \]
\[ Y_{t+1} \quad = \quad \text{Forecast value for the next period} \]
\[ Y_t \quad = \quad \text{Actual value in period t} \]
\[ n \quad = \quad \text{Amount of data in a moving average} \]

**Simple Exponential Smoothing**
The simple Exponential Smoothing method is used for approximate short distances, usually only one month in the future

\[ St = \alpha.X_t + (1-\alpha). S_{t-1} \]  

(3)
S_{t-1} = \text{New data or actual } Y \text{ value in period } t
\alpha = \text{Smoothing constant}
S_{t} = \text{Forecast value for the next period}
X_t = \text{Long smoothing value}

**Linear Regression Method**
Regression analysis is one of the causal methods. This approach is stronger than the time series method which only uses historical values for predictable variables (Heizer and Render, 2014).

\[ Y = a + bx \]  
\( Y \) = Dependent Variable
\( a \) = Interception y
\( b \) = Slope of the line
\( x \) = Independent variable

The degree of correlation is expressed by the size of the correlation coefficient (b), which is a number between –1 and +1. Correlation coefficients are generally calculated by the formula:

\[ r = \frac{n\Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{(n\Sigma x^2 - (\Sigma x)^2)(n\Sigma y^2 - (\Sigma y)^2)}} \]  

**Evaluation of Forecasting Methods**
There are several calculations that can be used to calculate total forecasting errors (forecasting cast errors).

**Mean Absolute Deviation (MAD).** An error calculation technique by adding up all absolute error values and then dividing by the number of forecasting periods.

\[ \text{MAD} = \frac{\sum |\text{Actual} - \text{Forecasting}|}{n} \]  

**Mean Squared Error (MSE).** Calculated by adding up the squares of all errors in each period and dividing by the number of forecast periods. Error is the difference between actual data and forecast results.

\[ \text{MSE} = \frac{\sum (\text{Actual} - \text{Forecasting})^2}{n} \]  

**Mean Absolute Percentage Error (MAPE).** Is a relative measure of error, MAPE is generally more meaningful than MAD because MAPE states the percentage of errors resulting from forecasting the actual demand during a certain period.

\[ \text{MAPE} = \frac{\sum_{i=1}^{n} 100\% |\text{Actual } i - \text{Forecasting } i| / \text{Actual } i}{n} \]  

**Material Requirement Planning**
MRP is a logical and easy-to-understand approach to solving problems related to determining the number of parts, components, and materials needed to produce the final product. The MRP also provides a detailed time schedule for when each component, material and part must be ordered or produced, (Nasution and Prasetyawan, 2009).
The purpose and benefits of Material Requirement Planning. That the objectives and benefits of the MRP can be explained as follows:

1. Reducing inventory.
2. Form a minimum requirement for each item.
3. Determine the implementation of the order plan.
4. Determine rescheduling or cancellation of a planned schedule.

Concluded that the implementation of Material Requirement Planning is the right solution to meet customer needs, better efficiency in monitoring production and avoiding excess and lack of inventory (Iasya and Handayati: 2010)

**MRP System Input**

There are 3 inputs for the material requirements planning (MRP):

**Master Production Schedule (MPS)**

Basically the master production schedule is a statement about the final product of a manufacturing industry company that plans to produce output related to the quantity and time period (Gaspersz: 2014).

**Inventory State Records**

The inventory state log illustrates the status of all items in the inventory. Each inventory item must be defined to ensure that planning does not go wrong. The recording must be kept up to date, by always recording the transactions that occur, such as receipts, expenses, failed products and so forth. Inventory records must also contain a timeline, lot size techniques used, reserve inventory and other important notes of all items.

**Inventory control**

Inventories are goods that are stored for use or sale in the future (Ristono, 2009). Inventory is generally one type of current assets which is quite large in a company (Sartono, 2010) inventory held from raw materials to finished goods is useful for:

1. Eliminating the risk of delays in the arrival of goods
2. Eliminating the risk of damaged goods
3. Maintaining the company's operational stability
4. Achieve optimal machine use
5. Provide the best service for consumers

**Inventory Cost**

There are three types of costs in inventory according to Heizer and Render (2014), including:

1. holding cost.
2. ordering cost
3. setup cost

There are 4 (four) types of inventory based on the manufacturing process according to Nasution & Prasetyawan (2008), as follows:

1. raw materials
2) work in process  
3) finished goods  
4) Auxiliary materials  

**Product Structure or Bill of Materials (BOM)**  
Bill of Materials identify the specific material used to make each item and the amount needed that can be arranged in the form of a product structure (product structure tree). There are 2 broad product structures, namely single level and multi level as in Picture 3.  
Single level product structure. The relationship between the final product that only requires 1 level to arrange it  

![Diagram of Product Structure](source:image)

Multi-level product structure. The product structure with its constituent components require other components with a structure underneath.

**MRP processing process steps**  
Some things that must be the basis for the implementation of the MRP are known to be information about lead time, order quantity, safety stock and gross requirements. From this it can be calculated for the MRP stages as follows:  
Netting is a calculation process to determine the amount of net need, the amount of which is the difference between the gross needs and the state of inventory, for the calculation of netting, what is needed is to know the gross needs, revenue plans, inventory levels owned.  
Lotting or Lot Sizing is the process of determining the size of an order to meet the net needs of several periods, there are several types of lotting that are applied:  
1) Fixed Order Quantity (FOQ), a method that uses the concept of a fixed order quantity by using trial and error.  
2) Economic Order Quantity (EOQ), this method uses the concept of minimizing the cost of storing and ordering costs where the lot size remains based on the count of the minimization  
3) Lot For Lot (LFL), this method aims to minimize storage costs per unit to zero, because the lot size is the same as the need  
4) Period Order Quantity (POQ), this method is the development of the EOQ method for non-uniform requests for several periods.  

Research conducted by Jasorman Sinaga (2018) with the title "Analysis of Raw Material Inventory Planning in L-90D Products in Chemical Companies with Material Requirement Planning (MRP) Method" that by applying MRP makes raw material needs met
properly. This study uses a batch reference in calculating the structure of raw materials. With the condition the company has not implemented a raw material inventory planning system and has not been well documented causing difficulties to get data as a reference on the company. Inventory planning and raw inventory control using LFL and POQ lot techniques were selected as the best lot technique out of the five lot techniques compared at the time of the study where 2 lot sizing produced the smallest total cost.

RESEARCH METHODS

This research was conducted at a building material manufacturing company, with one of its products a roof wave of fibersemen which was the object of research. The study uses a quantitative method with a descriptive approach, with a population of all recording results and calculations of raw materials used and samples of raw materials taken purposively are cement, chrysotile fiber, waste paper and scrap for the period 2014 to 2018.

Data analysis used descriptive analysis, through several research variable data in the form of demand for finished products, percentage of product defects, plans for production needs, plans for ordering raw materials, and costs needed for storage, procurement and control of raw materials with the MRP, LFL, and POQ methods. The research process is as shown in Picture 4

Picture 4. Flow Process of Research

FINDINGS AND DISCUSSION

Determining forecasting by using sales data in the previous period, where the resulting sales data for the period 2014 to 2018 is in Table 1
Table 1. Sales Data for 2014 – 2018

<table>
<thead>
<tr>
<th>Month</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>2,513,201</td>
<td>2,582,372</td>
<td>2,058,651</td>
<td>2,338,385</td>
<td>1,804,256</td>
</tr>
<tr>
<td>February</td>
<td>1,747,058</td>
<td>2,257,435</td>
<td>1,706,945</td>
<td>2,300,000</td>
<td>1,450,256</td>
</tr>
<tr>
<td>March</td>
<td>1,743,888</td>
<td>1,423,582</td>
<td>2,224,347</td>
<td>2,800,000</td>
<td>2,005,658</td>
</tr>
<tr>
<td>April</td>
<td>1,753,171</td>
<td>1,666,380</td>
<td>1,808,138</td>
<td>2,800,000</td>
<td>948,789</td>
</tr>
<tr>
<td>May</td>
<td>2,160,812</td>
<td>1,362,674</td>
<td>1,622,231</td>
<td>2,200,000</td>
<td>2,056,345</td>
</tr>
<tr>
<td>June</td>
<td>1,692,843</td>
<td>2,184,948</td>
<td>1,773,353</td>
<td>2,000,000</td>
<td>1,365,216</td>
</tr>
<tr>
<td>July</td>
<td>1,411,131</td>
<td>1,074,631</td>
<td>1,096,450</td>
<td>2,048,658</td>
<td>2,800,000</td>
</tr>
<tr>
<td>August</td>
<td>2,193,478</td>
<td>2,234,098</td>
<td>1,846,362</td>
<td>1,200,000</td>
<td>2,200,000</td>
</tr>
<tr>
<td>September</td>
<td>2,539,749</td>
<td>2,052,322</td>
<td>2,270,268</td>
<td>2,100,000</td>
<td>2,100,000</td>
</tr>
<tr>
<td>October</td>
<td>2,636,488</td>
<td>3,093,838</td>
<td>2,339,386</td>
<td>1,800,000</td>
<td>2,897,897</td>
</tr>
<tr>
<td>November</td>
<td>2,185,423</td>
<td>2,017,136</td>
<td>1,400,789</td>
<td>2,168,250</td>
<td>2,805,654</td>
</tr>
<tr>
<td>December</td>
<td>2,123,958</td>
<td>3,368,520</td>
<td>2,339,676</td>
<td>1,200,000</td>
<td>770,678</td>
</tr>
</tbody>
</table>

From the data in Table 1, it was tested with several forecasting methods and compared to see the smallest deviation values. Qualitative methods that have been used are compared with several forecasting methods, namely moving average of 3 periods and 5 periods, exponential smoothing method with a value of $\alpha$ 0.4 and linear regression, and the results of comparison of these methods the value of the deviation of each method as in Table 2.

Table 2. Error deviations from several forecasting methods

<table>
<thead>
<tr>
<th>Method</th>
<th>MAD</th>
<th>MSE (10^8)</th>
<th>MAPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualitative</td>
<td>494,954.19</td>
<td>336,417,468</td>
<td>28.68</td>
</tr>
<tr>
<td>Exponential Smoothing $\alpha$ 0.4</td>
<td>492,253.30</td>
<td>366,421,901</td>
<td>29.37</td>
</tr>
<tr>
<td>Linear Regression</td>
<td>515,441.34</td>
<td>384,959,492</td>
<td>29.76</td>
</tr>
<tr>
<td>Moving Average 5 MA</td>
<td>513,441.34</td>
<td>384,959,492</td>
<td>30.12</td>
</tr>
<tr>
<td>Linear Regression</td>
<td>487,118.11</td>
<td>347,923,996</td>
<td>28.89</td>
</tr>
</tbody>
</table>

From the comparison of forecasting methods the linear regression method has the smallest deviation value with a MAPE value of 25.08%, so that the linear regression equation is used to determine the forecast at MPS 2019. The intercept of the regression is $y = 2,042,088 + (-1,218 \times x)$. By calculating the setup factor and the percentage of damage, the total output amount is added by 2%. Total output becomes a reference for the calculation of bill of materials (BoM). Next is calculating the bill of material in the manufacture of products by basing on the mix composition of raw materials as shown in Picture 5.

Picture 5. Product Structure and Material composition

From the composition of raw materials in Figure 5, the needs of each material for each period are as in Table 3.
As a preliminary data reference for MRP, some data is needed, namely the price of raw materials, costs incurred as a basis for the calculation of Lot Sizing, Initial stock for the calculation of Netting, and Lead Time to determine the scheduling of arrival of raw materials, the data can be seen in Table 4

From the calculation of forecasting and the final stock available, the net requirement of each raw material for each period is calculated and in the MRP process this is stated as netting as in Table 5

For the next process is the offsetting process, which is a calculation to determine the right time to make an order plan, where the order plan is obtained by reducing the initial availability of desired net needs with lead time. In Table 6 Offsetting for CHR-G4 material
Table 6. Ofsetting Process

<table>
<thead>
<tr>
<th>PERIODE</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit (Kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Requirement</td>
<td>566,010</td>
<td>565,659</td>
<td>565,309</td>
<td>564,958</td>
<td>564,608</td>
<td>564,258</td>
<td>563,907</td>
<td>563,557</td>
<td>563,206</td>
<td>562,856</td>
<td>562,505</td>
<td>562,155</td>
<td>6,768,988</td>
<td></td>
</tr>
<tr>
<td>Inventory on Hand</td>
<td>130,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Requirement</td>
<td>436,010</td>
<td>565,659</td>
<td>565,309</td>
<td>564,958</td>
<td>564,608</td>
<td>564,258</td>
<td>563,907</td>
<td>563,557</td>
<td>563,206</td>
<td>562,856</td>
<td>562,505</td>
<td>562,155</td>
<td>6,768,988</td>
<td></td>
</tr>
<tr>
<td>Order Released</td>
<td>5,345</td>
<td>1,504,413</td>
<td>1,503,481</td>
<td>1,502,549</td>
<td>1,501,617</td>
<td>1,500,685</td>
<td>1,499,753</td>
<td>1,498,821</td>
<td>1,497,889</td>
<td>1,496,957</td>
<td>1,495,025</td>
<td>1,493,093</td>
<td>16,502,627</td>
<td></td>
</tr>
</tbody>
</table>

In addition to the Offsetting process for determining release orders related to leadtime is determining lots for an order or referred to as lot sizing, some lotting techniques are carried out as follows:

**Fixed Order Quantity (FOQ) Method**

It is lotting technique with a fixed order quantity for each period, from the material requirements of CHR-G4, the lotting results for FOQ are as shown in Table 7.

**Table 7. Lotting with Fixed Order Quantity Techniques**

<table>
<thead>
<tr>
<th>PERIODE</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit (Kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Requirement</td>
<td>566,010</td>
<td>565,659</td>
<td>565,309</td>
<td>564,958</td>
<td>564,608</td>
<td>564,258</td>
<td>563,907</td>
<td>563,557</td>
<td>563,206</td>
<td>562,856</td>
<td>562,505</td>
<td>562,155</td>
<td>6,768,988</td>
<td></td>
</tr>
<tr>
<td>Inventory</td>
<td>130,000</td>
<td>128,073</td>
<td>126,496</td>
<td>125,269</td>
<td>124,393</td>
<td>123,867</td>
<td>123,692</td>
<td>123,867</td>
<td>124,393</td>
<td>125,269</td>
<td>126,496</td>
<td>128,073</td>
<td>130,000</td>
<td></td>
</tr>
<tr>
<td>Planning Order Released</td>
<td>548,082</td>
<td>564,082</td>
<td>564,082</td>
<td>564,082</td>
<td>564,082</td>
<td>564,082</td>
<td>564,082</td>
<td>564,082</td>
<td>564,082</td>
<td>564,082</td>
<td>564,082</td>
<td>564,082</td>
<td>6,768,988</td>
<td></td>
</tr>
</tbody>
</table>

**Economic Order Quantity (EOQ) Method**

Orders are made if the amount of inventory cannot meet the desired needs.

By using the equation:

\[ Q = \sqrt{\frac{2DS}{H}} \]  

(9)

**Number of needs 1 year**  
\( D = 6,768.98 \) Tons

**Order Fee**  
\( S = IDR \ 400,000 / Order \)

**Save Cost**  
\( H = Rp \ 7,500 / Ton \)

\[ Q_{CHR-G4} = \sqrt{\frac{2DS}{H}} \]

\[ Q_{CHR-G4} = \sqrt{\frac{2 \times 6,768.98 \times 400,000}{7,500}} \]

\[ Q_{CHR-G4} = \sqrt{5,415,190,125} \]

\[ Q_{CHR-G4} = 849.72 \] tons

In the calculation of needs in 1 year is 6,768.98 tons, then the order frequency in 1 year is:

\[ N = \frac{Demand}{Order Quantity} \]

Available Online: [https://dinastipub.org/DIJDBM](https://dinastipub.org/DIJDBM)
N = \frac{3,802}{839.72} = 4.51

N = \text{then the order frequency is } 7.97 \approx 8 \text{ times a message } = 846,123 \text{ Tons}

More details for the sizing lot table for the EOQ Method are as follows as in Table 8

<table>
<thead>
<tr>
<th>EOQ PERIODE</th>
<th>RAW MATERIAL Chr Grade 4</th>
<th>Lead Time 36 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Requirement</td>
<td>566,010 565,659 565,309</td>
<td></td>
</tr>
<tr>
<td>Inventory</td>
<td>130,000</td>
<td></td>
</tr>
<tr>
<td>Net Requirement</td>
<td>436,010 555,546 720,855</td>
<td></td>
</tr>
<tr>
<td>Planning Order Released</td>
<td>846,123</td>
<td></td>
</tr>
</tbody>
</table>

| Period Order Quantity (POQ) Method | 

In the lot-to-lot method, the number of orders (lot size) will always be the same as the number of net requirements required as in Table 9

<table>
<thead>
<tr>
<th>Lot For Lot PERIODE</th>
<th>RAW MATERIAL Chr Grade 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Requirement</td>
<td>566,010 565,659 565,309</td>
</tr>
<tr>
<td>Inventory</td>
<td>130,000</td>
</tr>
<tr>
<td>Net Requirement</td>
<td>436,010 555,546 720,855</td>
</tr>
<tr>
<td>Planning Order Released</td>
<td>846,123</td>
</tr>
</tbody>
</table>

| Period Order Quantity (POQ) Method |

The POQ technique is in principle the same as FPR. The difference is that the POQ ordering interval is determined by a calculation based on the modified classical EOQ logic, so that it can be used on discrete-period requests.

<table>
<thead>
<tr>
<th>POQ PERIODE</th>
<th>RAW MATERIAL Chr Grade 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Requirement</td>
<td>566,010 565,659 565,309</td>
</tr>
<tr>
<td>Inventory</td>
<td>130,000</td>
</tr>
<tr>
<td>Net Requirement</td>
<td>436,010 555,546 720,855</td>
</tr>
<tr>
<td>Planning Order Released</td>
<td>846,123</td>
</tr>
</tbody>
</table>

| From the lotsizing calculations performed using FOQ, EOQ, LFL and POQ techniques, the technique that has the lowest cost is the LFL method as shown in Table 10 |
Table 10. Comparison of the costs of the Lotting Technique

<table>
<thead>
<tr>
<th>No</th>
<th>Material</th>
<th>Quantity (Kg)</th>
<th>Price / Kg (Rp)</th>
<th>Amount (Rp)</th>
<th>Handling Cost (Rp 211.304 / Kg)</th>
<th>EOQ</th>
<th>POQ</th>
<th>FOQ</th>
<th>LFL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CHR G4</td>
<td>0.6,768,988</td>
<td>7,000</td>
<td>47,182,913.592</td>
<td>1,409,154.988</td>
<td>1,463,575.576</td>
<td>1,475,584.791</td>
<td>1,496,438.327</td>
<td>1,496,438.327</td>
</tr>
<tr>
<td>3</td>
<td>Cononi (Kg)</td>
<td>98,148,745</td>
<td>1,200</td>
<td>111,027,401.758</td>
<td>56,057.820</td>
<td>51,583.966</td>
<td>14,972.426</td>
<td>5,785.000</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Krefl (Kg)</td>
<td>5,904,082</td>
<td>6,000</td>
<td>35,424,169.434</td>
<td>50,076.444</td>
<td>44,016.673</td>
<td>26,056.567</td>
<td>6,600.000</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Waste (Kg)</td>
<td>6,768,988</td>
<td>6,000</td>
<td>40,613,025.936</td>
<td>45,702.472</td>
<td>60,004.001</td>
<td>36,748.991</td>
<td>7,500.000</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Dry Scrap (Kg)</td>
<td>5,472,799</td>
<td>500</td>
<td>2,736,395.265</td>
<td>32,062.848</td>
<td>32,693.014</td>
<td>9,335.354</td>
<td>5,250.000</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Wet Scrap (Kg)</td>
<td>6,768,988</td>
<td>450</td>
<td>3,027,530.728</td>
<td>50,494.242</td>
<td>49,310.544</td>
<td>12,378.395</td>
<td>5,520.000</td>
<td></td>
</tr>
</tbody>
</table>

| Total | 144,021,014 | 5,651,869,357 | 5,721,827,993 | 5,489,808,524 | 5,286,736,209 | 5,184,706,209 |

From the lotting system applied where the lot for lot method has the least value in terms of cost for all raw materials, the application of MRP, performance evaluation and analysis are carried out.

Optimization of the minimum maximum stock limit

The maximum and minimum stocks with stable fluctuations indicate the occurrence of a match between demand and demand, from the production data for 2018 and 2019, the maximum minimum stock conditions for CHR G4 material are as follows:

Min Stock \[ = \frac{(D \times LT)+Ss}{30} \] (10)
Max Stock \[ = \frac{(2 \times D \times LT)}{30} \] (11)
Ss \[ = \sigma \times Z \] (13)

For CGR G4 Raw Materials the calculation is as follows:
Average usage \( \bar{D} \) = 533,236.36 kg
Standard Deviation \( \sigma \) = 50,720.11 kg
Z 95% = 1.64
Then,
Safety Stock (Ss) = 50,720.11 kg x 1.64
= 83,427.15 kg
Min Stock \( \text{CHR-G4} \) = \( \frac{533,236.36 \times 36 \times 36 \text{har} + 83,727.15}{30} \)
= 642,767.27 Kg
Max Stock \( \text{CHR-G4} \) = \( \frac{(2 \times 533,236.36 \times 36 \text{har})}{30} \)
= 1,279,767.27 Kg
Middle value \( \text{CHR-G4} \) = \( \frac{\text{Min Stok} + \text{Maks Stok}}{2} \)
= \( \frac{642,767.27 + 1,279,767.27}{2} \)
= 961,245.91 kg

Stability stock of raw materials

With the application of MRP the final stock of raw materials is relatively stable compared to the previous period as shown in Figure 6.
Inventory Turn Over Ratio

In the application of MRP provides, improved performance on TOR, especially on CHR material which is the main raw materials that must be very attention to be controlled.

In this case the calculations for several periods are as follows:

\[
\begin{align*}
\text{TOR jan2019} & = \frac{564,000 \text{ Kg}}{431,600 \text{ Kg}} \\
\text{TOR jan2018} & = \frac{564,000 \text{ Kg}}{721,026 \text{ Kg}} \\
\end{align*}
\]

So the 2019 TOR value is 0.37 times higher than the 2018 TOR. It means that CHR G4 Raw Material is faster to use in 2019.

Time to Storage Raw Materials

Assuming the average number of working days is 30 days, the save time for the January 2019 and 2018 periods is as follows:

\[
\begin{align*}
\text{T_{storage 2019}} & = \frac{30 \text{ days}}{1.31} \\
\text{T_{storage 2019}} & = 22.96 \text{ days} \\
\text{T_{storage 2018}} & = \frac{30 \text{ days}}{0.96} \\
\text{T_{storage 2018}} & = 40.4 \text{ days} \\
\end{align*}
\]

Savings on Purchases for Inventory Decline

With a smaller DOI value, this affects the smaller number of purchases, this has a good impact on the company's cash flow.

As a comparison, the drop in the DOI value in 2019 compared to the 2018 DOI on the CHR-4 material

\[
\begin{align*}
\text{Variance} & = \text{DOI 2019} - \text{DOI 2018} \\
& = 32,5 \text{ days} - 40.60 \text{ days} \\
& = -8,10 \text{ days} \\
\text{Saving} & = \text{Variance} \times \text{Average usage} \times \text{Price} \\
& = 8,10 \text{ Days} \times 23,330 \text{ kg} \times \text{Rp. 7,000 / kg} \\
& = \text{Rp. 1,322,811,000} \\
\end{align*}
\]

The efficiency that occurs with the application of MRP

\[
\begin{align*}
\text{\eta_{Inventory}} & = \frac{\text{DOI 2019} - \text{DOI 2018}}{\text{DOI 2018}} \times 100\% \\
& = \frac{32,50 \text{ days} - 40.60 \text{ days}}{40.60 \text{ hari}} \times 100\% \\
\text{\eta_{Inventory}} & = - 19,951 \\
\end{align*}
\]
Discussion

Forecasting method that has the smallest deviation value is a linear regression technique where the MAPE value is 25.08, and the deviation value of other methods ranges from 28 to 30.12.

Lot for Lot Technique is the most efficient technique seen from the costs incurred in the amount of 5.2 Billion Rupiah while the other Lot Sizing Techniques are 5.4 to 5.7 Billion Rupiah.

The implemented MRP affects the entire inventory performance, improving efficiency. Compared to the period of inventory performance in 2018. On average the performance improvements are as follows

Turn Over Ratio in each CHR G4 raw material rose 0.18 times, CHR G5 0.07 times, kraft Pulp 2.8 times, Waste Paper 1.23 times, dry scrap 2.4 times and wet scrap 0.78 times. With the increase in the TOR, it shortens the shelf life which reduces the risk of damage to raw materials, and reduces the number of Day of Inventory of raw materials and decreases in ending stock in each period.

If efficiency is taken into account, improved inventory performance has resulted in an average efficiency in 1 year for each raw material CHR G4 21.65%, CHR G5 1.95%, kraft Pulp 74%, waste paper 26.11%, dry scrap 29.95% and wet scrap 6.58%.

In Table 11 detailed differences in achievement of Performance Invetory in 2018 and 2019.

Table 11. Comparison of 2019 and 2018 Inventory Performance

<table>
<thead>
<tr>
<th>CHR G4</th>
<th>2018</th>
<th>2019</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOR</td>
<td>0.19</td>
<td>0.30</td>
<td>0.24</td>
</tr>
<tr>
<td>Storage Time (Days)</td>
<td>(9.01)</td>
<td>(26.93)</td>
<td>(6.59)</td>
</tr>
<tr>
<td>Days of Inventory</td>
<td>(8.10)</td>
<td>(6.26)</td>
<td>(9.98)</td>
</tr>
<tr>
<td>Ending Stock Variance (Billion)</td>
<td>1.32</td>
<td>10.02</td>
<td>1.63</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>(19.95)</td>
<td>(17.54)</td>
<td>(23.10)</td>
</tr>
</tbody>
</table>

| TOR    | 0.16 | 0.21 | 0.19 |
| Storage Time (Days) | (7.95) | (16.93) | (1.77) |
| Days of Inventory | (0.13) | (2.42) | (5.63) |
| Ending Stock Variance (Billion) | 0.05 | 0.95 | 2.21 |
| Efficiency (%) | (0.37) | (7.82) | (16.26) |

| SEMEN   | 0.02 | 1.64 | 1.73 |
| Storage Time (Days) | (9.72) | (48.97) | (27.63) |
| Days of Inventory | -0.30 | 0.30 | (1.11) |
| Ending Stock Variance (Billion) | -0.12 | (0.44) | 0.12 |
| Efficiency (%) | -10.42 | 9.65 | 52.61 |

| KRAFT PULP | 0.24 | 0.28 | 0.26 |
| Storage Time (Days) | (9.72) | (48.97) | (27.63) |
| Days of Inventory | 0.25 | (9.66) | (5.46) |
| Ending Stock Variance (Billion) | 2.51 | 1.83 | 10.00 |
| Efficiency (%) | (3.46) | (79.31) | (61.35) |

| WASTE PAPER | 0.30 | 0.28 | 0.39 |
| Storage Time (Days) | (2.15) | (3.03) | 0.25 |
| Days of Inventory | 0.25 | (9.66) | (5.46) |
| Ending Stock Variance (Billion) | 0.03 | 1.38 | 0.78 |
| Efficiency (%) | 3.94 | (79.31) | (61.35) |

| DRY SCRAP | 1.89 | 2.69 | 2.45 |
| Storage Time (Days) | (1.89) | (2.69) | (2.45) |
| Days of Inventory | 0.00 | (0.00) | (2.57) |
| Ending Stock Variance (Billion) | 0.00 | 0.00 | 0.05 |
| Efficiency (%) | 0.00 | (22.72) | (57.60) |

| WET SCRAP | 0.19 | 1.68 | 0.58 |
| Storage Time (Days) | (0.19) | (1.68) | (5.07) |
| Days of Inventory | (1.99) | (1.99) | (2.47) |
| Ending Stock Variance (Billion) | 0.02 | 0.01 | 0.05 |
| Efficiency (%) | (27.75) | (12.22) | (34.30) |

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CONCLUSION AND SUGGESTION

Conclusion

From the results of data processing and analysis it can be concluded that the forecasting technique that has the smallest storage value is to use Linear Regression forecasting techniques with a MAPE storage value of 25.08%. The Lotting that provides the most cost efficient is a lot for Lot with a total cost of 5.3 billion. Impacts on the application of MRP have an impact on improving inventory performance and cost efficiency. For the purchase of raw materials, which can be seen in the final value of the stock, each period ranges from 0.02 billion to 3.63 billion. Inventory Turn Over Ratio increases between 0.18 to 2.8 times, and if calculated for the shelf life of raw materials decreases the shelf life from 1.5 to 35 days.

Maximum and minimum stock as inventory control for each raw material Min - Max stock (tons) CHR G4 642.66-1279.77, CHR G5 1805-35696, Cement 563.5 -1045, Kraft 100.9-196.57, waste paper 115.6-225.34, Dry Scrap 63.03 -121.33, Wet Scrap 79.64 - 153.29

Suggestion

suggestions for evaluations carried out, things need to be done as follows.

So that the application of MRP is more optimum where the appropriate Lotting method greatly affects the final results of the application of the MRP, the stability of the supply of raw materials must be increased, this is based on the fulfillment of the commitment between the two parties, namely the company where the research is conducted on the supplier.

The addition of facilities and technology to optimize the use of recycle materials so as to minimize the import of raw materials that have a higher risk of delays.

The scope of MRP can be developed for all functions in a company, therefore Enterprise Resource Planning (ERP) is the latest system that can be applied in the business world both manufacturing and services.

REFERENCE