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Control of Inventory of Raw Materials for Wine Products by Form 2 Phase Inventory Using Material Requirement Planning (Case Study at Pt. XYZ)

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EOQ; LFL; Ordering; Storage.

ABSTRACT

This research aims to analyzing the MRP method to obtain the lowest inventory costs of product wine. The raw material planning system carried out by PT XYZ uses sales data from the PPIC division to order all raw materials at one time. Preparing MRP requires input in the form of an ind schedule through the netting, lotting (economic order quantity (EOQ), lot for lot (LFL)), and offsetting. The output of the MRP method is a plan for ordering raw material requirements based on lead time. This MRP method can provide improvements to PT XYZ through the formation of a master production schedule, ordering schedule, and reducing inventory costs. Comparing the company's inventory costs with the MRP method for wine raw materials produces savings of 15% per year, and EOQ is more economical. SiO2 raw material produces savings of 55% per year, and EOQ is more economical. Purifying enzyme raw materials produces savings of 41% per year, and EOQ is more economical. The MRP process is carried out at 28% annually, and EOQ is more economical. Fermented extract raw materials produce savings of 14% per year, and LFL is more economical.

1. INTRODUCTION

Wine is a premium drink that involves (1) vegetable ingredients, (2) distribution of raw materials, and (3) production and sale of alcoholic beverages (Liu et al., 2018). Managing production and distribution in the wine industry is quite challenging because it faces fluctuations in the supply of raw materials, and demand for wine products is influenced by climate variations, seasonal changes, and various social factors. These factors result in an imbalance between supply and demand for products (Jeon et al., 2014). The raw materials for PT X wine are red and white grapes. This material is easily damaged due to the nature of the grape skin. If it is hit, the fruit breaks easily, and over time, the fruit flesh rots quickly, thus affecting the storage of raw materials and supplies in producing wine (Ramos et al., 2010). One good supply of raw materials for fermented products is the 2-phase inventory method.

The 2-phase inventory method has been applied to kimchi products whose raw material is raw cabbage (phase 1), which is processed into salted cabbage (phase 2) to extend the storage period (Shin et al., 2019). The advantage of the fermentation process (2 phases) in making products is that no additional costs are incurred, such as fumigation treatment or other additional storage methods.

Research on inventory management of perishable raw materials in the food industry has been widely conducted (Ahumada & Villalobos, 2009; Amorim, Meyr, Almeder, & Almada-Lobo, 2013). Many researchers examine cost-effectiveness with demand-oriented fluctuations in perishable goods (either deterministic or stochastic (Muriana, 2016). However, inventory in the form of 2 phases aims to minimize the gap between raw material supply and ordering demand for future shortages rather than minimizing costs or maximizing profits.

The importance of raw material inventory with 2 phases means that companies must create an effective and efficient inventory planning and control system. One method of controlling raw material inventory is Material Requirement Planning (MRP). According to Taha (2017), material requirements planning is the logic for determining the number of parts, components, and materials needed to produce a product and providing a schedule determining when the parts, components, and materials needed must be ordered or produced.

The MRP system determines the amount of raw materials to be ordered according to production requirements by considering the costs that will arise due to Inventory (Heizer et al., 2017). Therefore, the MRP system is a series of control mechanisms that are very useful for ensuring the availability of raw materials in the correct quantity and time, supporting the smoothness and accuracy of the production process and time.

Therefore, this paper aims to identify a system for planning and controlling raw material inventory in the form of 2 phases at PT XYZ. Apart from that, analyzing the implementation of raw material inventory planning and control using the MRP method from the cost side at PT XYZ

2. METHODS

The research procedure begins with the concept of thinking. This research begins with identifying the raw material inventory planning and control system in the form of 2 phases at PT XYZ. This is important because the raw materials can influence the company's production activities. The next step is to determine the company's master production schedule, product structure, lead time, and raw material inventory status to analyze it through planning and control using various appropriate MRP methods. The Material Requirement Planning system is in Figure 1.

Material Requirement Planning (MRP) can fulfill scheduled orders at the desired time, so the MRP system can provide indications for rescheduling plans (if possible) by determining realistic order priorities. Suppose this rescheduling still does not work, according to Taha (2017). In that case, the MRP system is a logical procedure using decision rules and computer-based transaction techniques designed to translate the master production schedule into net requirements for all items.

The MRP system was developed to help manufacturing companies address the need for dependent items better and more efficiently. The MRP system is designed to create production and purchase orders to manage the flow of raw materials and Inventory to follow the final

product's production schedule. The MRP system is a system that aims to produce the correct information to take the right action (order cancellation, reorder, and reschedule).
Regarding control over materials or items, the MRP system, as a production planning and control system, balances demand (needs) and capacity (capabilities). The research flow diagram can be seen in Figure 2. The four objectives that are the main characteristics of the MRP system are:

1. Determine needs at the right time.
   Determine precisely when a job must be completed, or material must be available to meet the demand for the final product planned in the master production schedule.
2. Determine the minimum requirements for each item.
   By knowing the final requirements, the MRP system can determine the precise scheduling system (priorities) to meet all minimum requirements for each item.
3. Determine the implementation of the order plan.
   Indicates when a booking or cancellation of a booking should be made. Orders need to be made via purchase or made at the factory itself.
4. Determine the rescheduling or cancellation of a planned schedule
   If the existing capacity does not allow the fulfillment of the order, then a cancellation or an order must be made.

The three inputs required by the MRP system are:

1. Master production schedule
2. Note the state of the Inventory or list of materials
3. Product structure

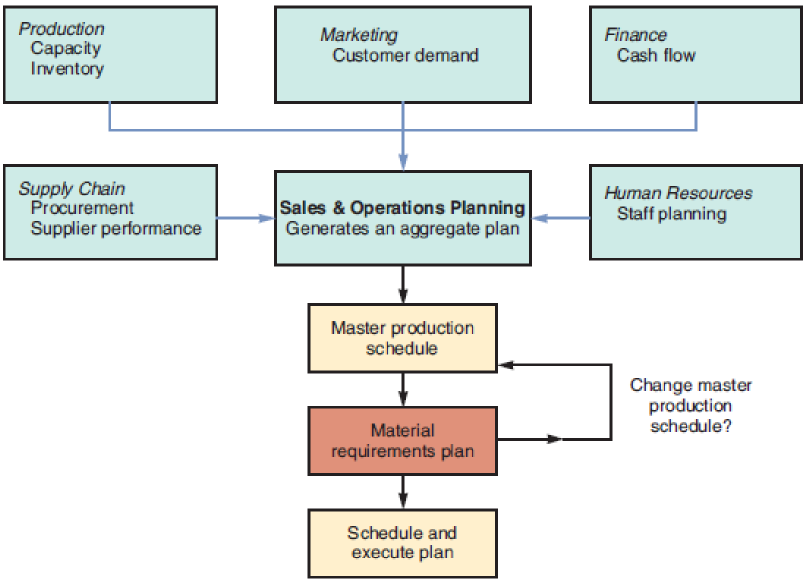

Fig 1. Material requirement planning (Source: Heizer et al. (2017)

1.1 Steps of MRP

The steps in analyzing data using the MRP procedure have four main steps; then, these four steps are applied individually in the planning period and on each item. This procedure can be carried out manually if the number of items seen in production is relatively less. These steps are:

1. Netting is a calculation process to determine the amount of net requirements, which is the difference between gross requirements and the state of Inventory (in stock and being ordered). The data required in the process of calculating net needs is:
   a. Gross requirements for each period
   b. Inventory on hand at the start of planning
   c. Revenue plan for each planning period.

   The definition of gross requirements for independent demand is the amount of final product consumed. Meanwhile, for dependent products, gross requirements are calculated based on the parent item at the top level, usually multiplied by a certain multiple according to what is needed. After the gross requirements are determined, the next step is calculating the net requirements (netting). The calculation of net requirements (netting) is (1):

$$\mathrm{NRi} = \mathrm{GRi} - \mathrm{SRi} - \mathrm{OHi} \text{ with } \mathrm{NR} = 0 \text{ if } \mathrm{GR} - \mathrm{SR} - \mathrm{OH} < 0 \quad (1)$$

   Where:
   NRi = net requirement (NR) for the i period
   GRi = gross requirement or GR for the i period
   OHi = Inventory on hand (on-hand Inventory or OH) for the I period

2. Lotting is a process for determining the optimal order quantity for each item individually based on the results of the net needs calculation that has been carried out. There are many alternative methods for determining lot size. Several techniques are aimed at minimizing total set-up costs and storage costs.

3. Offsetting aims to determine the right time to plan an order to meet net needs. The ordering plan is obtained by subtracting the initial availability of the desired lot size from the lead time. Offsetting is the final step in applying the MRP system to an item.

4. Explosion is calculating gross requirements for lower-level items or components. The calculation of gross requirements is based on the ordering plan for product items at a higher level. To calculate gross requirements, a product structure and information regarding the amount needed for each item are needed for the item to be calculated. In this explosion process, data regarding the product structure must be available accurately. Inaccuracies in product structure data result in calculation errors. It is based on this product structure that the explosion process is created.

3. RESULTS AND DISCUSSION

3.1 Two Phase Inventory

Perishable raw material inventories are generally discarded after a specified storage period and are acceptable for regular use. The single-phase model is a commonly used inventory system without an updating process. The main concern of the single-phase model is to control the level of Inventory that will be used up within a specified storage period. An example is a fresh wine that is stored without additional processing. Phase 1 models must consider the tradeoff between processing costs and extended Inventory holding costs. As a result, it is necessary to determine whether an update will be performed before deciding when to do so.

On the other hand, the two-phase model is an inventory system with separate shelf lives for specific products. An example of a wine product is processing fresh grape raw materials into fermented grape extract. This two-phase model inventory is included in the regular production process flow, so additional phase 2 process costs are not incurred. Thus, this type of inventory system is a case that incorporates cost-free renewal. In this case, planning additional processing is the main decision problem, which concerns when and how much Inventory to renew under perishability constraints on phase 1 and 2 inventories.

According to Shin et al. (2019), excess phase 2 inventory was related to a shortage of raw materials, so it was stored, and if it passed the expiration date, it had to be thrown away to avoid an impact on market prices. Thus, phase 2 inventory levels must be below the amount of undersupply within their holding period to prevent ordered Inventory from being damaged or discarded (i.e., perishability constraints).

Similarly, phase 1 inventory levels are limited to the number of renewal processes in their holding period. Therefore, the expected supply and demand quantities, at least during the entire storage period (including phase 1 and phase 2), must be considered to make efficient decisions on ordered and released quantities.

Phase 1 and 2 inventory levels are limited to a predetermined storage capacity, and the updated capacity from Phase 1 to Phase 2 is also limited (i.e., capacity constraints). Furthermore, the inventory management problem can be considered a production planning problem of the renewal process (i.e., the salting process). Because the renewal process converts phase 1 inventory (e.g., fresh grapes) into phase 2 inventory (e.g., semi-finished product, i.e., fermented grape extract), production planning of phase 2 inventory is a primary concern to ensure proper inventory levels in phase 1 and 2 which is in Figure 2.

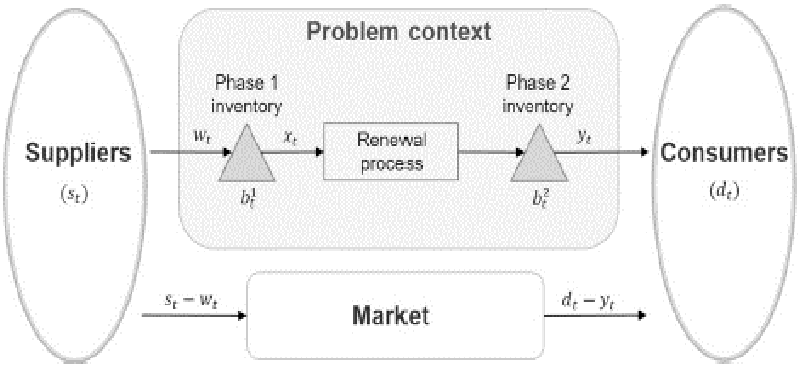

Fig 2. 2-phase Inventory Model

1. Material Requirement Planning

Planning raw material requirements using MRP is divided into several stages: n*etting*, *draw*ing, and *offsetting*. On the stop *netting*, raw materials calculated net requirements (*net requirement*). *The net requirement* will be input to the next stage, namely stage *draw*. Level*draw*is determines the number or quantity of orders (*lot size*) from the supplier. Techniques and calculations of order quantities are often called EOQ and LFL techniques. EOQ and LFL are technique*s of lot sizing* that can create optimal solutions. The results obtained are in order quantities, then used as input for the stage *offsetting*. Besides the order quantity, *lead time* is also a significant input at the level *of offsetting* because it will determine when the packaging raw materials are ordered from the supplier in Table 1.

Table 1. Data of raw material for making process the product wine

Independent Demand	Period (Month)	2	4	6	8	10	12
Grape (Kg)	1	536	555	619	589	456	531
SiO_2 (Kg)	1	268	27,75	30,95	29,45	22,8	26,55
Saccharomyces C. (Kg)	1	37	38,75	39,95	38	31,9	37,4
Classifier Enzyme (Kg)	1	53,6	55,5	61,9	58,9	45,6	531
Extract of Fermentation (Kg)	1	740	775	799	760	638	748
Sugar (Kg)	1	148	155	159,8	152	127,6	149,6
Water (Kg)	1	2344	2220	2476	2356	1824	2124

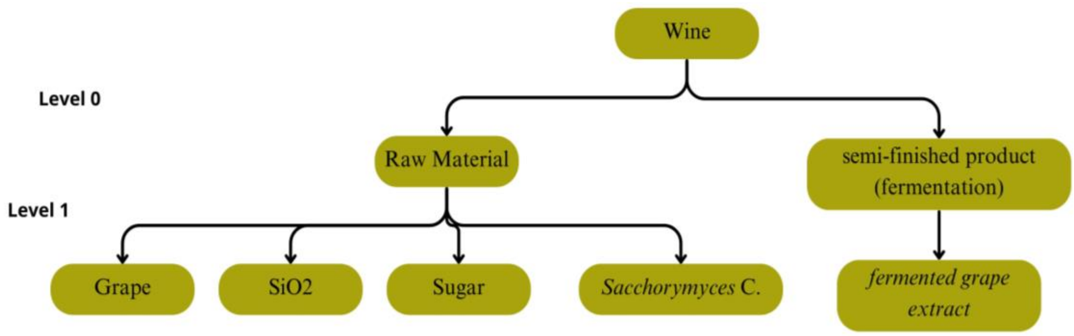

Fig 3. Wine Product Bill of Materials

Level 1. Netting

The first step is determining the net requirements (*netting*) for materials. Input required in stop *netting*, namely gross needs (*gross requirement*), scheduled arrival (*schedule receipt*), and Inventory on hand (*on hand*) which can be seen in Table 2.

Table 2. Gross Grape Requirements

Period	Gross Needs (Roll)	Scheduled Arrival (Roll)	Supplies on hand (Roll)	Clean Needs (Roll)
1	450	0	0	450
2	536	0	0	536
3	534	0	0	534
4	555	0	0	555
5	632	0	0	632
6	619	0	0	619
7	600	0	0	600
8	589	0	0	589
9	689	0	0	689
10	456	0	0	456

11	542	0	0	542
12	531	0	0	531

The net requirements entered into the MRP table result from calculating gross requirements – scheduled arrivals – Inventory on hand. Results of the stage *netting* can be seen in Table 6 in the form of an MRP table 3.

Table 3. Netting Stage

Code	**Period (Month)**	**2**	**4**	**6**	**8**	**10**	**12**
0	Gross Requirements	536	555	619	589	456	531
1	Scheduled Receipts	0	0	0	0	0	0
1	Projected On Hand	0	0	0	0	0	0
1	Net Requirements	536	555	619	589	456	531

Level Lottery (Determination*Lot Size* Optimal with EOQ and LFL Methods)

1. **EOQ**

At the level of raw calculation, the optimal number of orders for raw materials per order month was carried out by comparing three methods of lot *sizing*, which is sufficient to meet the net needs of the product. Three methods of lot *sizing* were used, namely *for Lot and Economic Order quantity*, to determine the optimal order quantity size for raw materials: grapes*, SiO2, yeast, clarifying enzymes, sugar, water, and fermentation extracts*—calculation and preparation of order quantities using Microsoft Excel software.

Determining the optimal order quantity size method is based on the minor total procurement costs, which provide minimum inventory costs and is by the company's inventory policy. This causes the amount of raw materials ordered each month to be unequal. At the end of each month, raw material supplies may be zero or in such low quantities that they need to be more sufficient to meet the needs of the following month. Determining the optimal order quantity for raw materials for each product in Jan-Dec 2018 is carried out according to calculations and preparation methods drawn. For example, in the EOQ calculation for wine, where the average demand is 561.3, ordering costs are 54700, and storage costs are 150, the results of the EOQ calculation for wine are as follows:

$$Q = \sqrt{2}dCo/h \qquad 2$$

$$Q = \sqrt{2}\,(561.3)\,(54700)/150 = 640 \qquad 3$$

2. **Lot for Lot (LFL)**

This technique is referred to as the most straightforward discrete ordering. It provides a period with a net requirements coverage period, and the planned order quantity always equals the covered net requirements quantity. These order amounts must be calculated each time the respective net requirements change. The goal of using this technique is to minimize Inventory holding costs, which is often used for expensive purchasing items or items that have intermittent demand (Singh 2017). In this research, ten tables were produced for calculating the number of orders for each raw material using the

LFL technique MRP method. The results of calculating the number of orders for raw materials using the LFL technique MRP.

Level *Offsetting*

Level *Offsetting* will determine when raw materials are ordered to meet net needs by considering lead *time* order, the shelf life of raw materials, and production in Table 4. *Lead time* The production process for completing each product is one month.

Table 4. Calculation of order lead time, shelf life, and production

No	Raw material	Inventory in storage (kg)	Lead time (month)	Shelf life set by the company (Month)	Actual of Shelf life
1	Grapes	180	1	1	1
2	Saccharomyces C.	85	1	6	8
3	clarifying enzyme	40	1	6	8
4	SiO_2	45	1	5	7
5	Sugar	100	1	0	0
6	Extract of fermentation	800	2	1	1
7	Water	100	1	1	1

Product procurement can be done if the raw materials are procured on time. After carrying out several stages, you can find out the frequency of ordering raw materials, the number of orders for raw materials from each stage drawing method, and the total costs of procuring raw materials, which are presented in Table 13, namely the results of the stages offsetting. The results of this evaluation can be used as a comparison between the procurement of raw materials carried out by the company and those using the method of lot *sizing* so that the best alternative can be determined which can produce minimum costs.

Comparison of Planning and Control of Raw Material Inventory between the MRP Method and the Company Method

Inventory costs are incurred by a company for its raw materials (Handoko 2008). Minimum inventory costs and optimal levels indicate good raw material inventory planning and control (Anders., 2017). The raw material inventory planning and control method used as a recommendation for the company can be identified by comparing the company's method with the MRP method of EOQ, LFL, and PPB techniques. Based on the results of the comparative analysis of inventory costs that have been carried out, the raw material supplies of water, sugar, salt, *yeast*, and an emulsifier produce the lowest costs using the MRP method PPB technique, while for raw materials wheat flour, eggs, milk, *shortening*, and butter *oil substitute* inventory costs with the lowest costs are using the LFL technique MRP method. The EOQ technique MRP method only sometimes produces the lowest costs compared to the LFL technique because the number of 12 economic orders produced is higher, so inventory costs are also high. A comparison of inventory costs for raw materials for bread A can be seen in Table 8. Comparing company method inventory costs with the MRP method for wine raw materials produces savings of 15% per year. SiO2 raw material produces savings of 58% per year. Cleaning enzyme raw materials produces savings of 41% per year. Water raw materials produce savings of 4% per year. Sugar raw materials produce savings of 28% per year. Fermented extract raw materials produce savings of 14% per year.

Table 8. Price Comparison Results from Companies, EOQ and LFL

Raw Material	Methods	Frequency of ordering (time)	Ordering cost per order (Rp)	Ordering cost (Rp)	Storage of average (kg)	Holding cost (Rp)	Storage cost (Rp)	Inventory Cost (Rp)	Savings (Rp)	Percentage Savings (%)
Grape	Company	12	54700	656400	730	150	109500	765900		
	EOQ	11	54700	601700	320	150	48000	649700	116200	15%
	LFL	12	54700	656400	0	150	0	656400	109500	14%
Sacchromyces C.	Company	7	12000	84000	85	50	4250	88250		
	EOQ	3	12000	36000	67	50	3350	39350	48900	55%
	LFL	7	12000	84000	0	50	0	84000	4250	5%
SiO_2	Company	5	23000	115000	50	45	2250	117250		
	EOQ	2	23000	46000	84,5	45	3802,5	49802,5	67447,5	58%
	LFL	5	23000	115000	0	45	0	115000	2250	2%
Classifier Enzyme	Company	7	11500	80500	85	35	2975	83475		
	EOQ	4	11500	46000	96	35	3360	49360	34115	41%
	LFL	7	11500	80500	0	35	0	80500	2975	4%
Sugar	Company	8	15000	120000	100	40	4000	124000		
	EOQ	5,5	15000	82500	168	40	6720	89220	34780	28%
	LFL	8	15000	120000	0	40	0	120000	4000	3%
Extract Fermentation	Company	12	120000	1440000	800	250	200000	1640000		
	EOQ	12	120000	1440000	424,5	250	106125	1546125	93875	6%
	LFL	12	120000	1440000	0	250	0	1440000	200000	12%
Water	Company	12	1000	12000	601,333	0,8	481,06667	12481,06667		
	EOQ	12	1000	12000	316,5	0,8	253,2	12253,2	227,86667	2%
	LFL	12	1000	12000	0	0,8	0	12000	481,06667	4%

The LFL method has the lowest costs for three raw materials because there are no storage costs. Raw material costs in the LFL method are zero because this method orders raw materials according to the required quantity, resulting in no inventory being stored (Shin et al., 2019).

4. CONCLUSION

The two-phase model is an inventory system with separate shelf lives for specific products. Wine products are processing fresh grape raw materials into fermented grape extract. This two-phase model inventory is included in the regular production process flow so that additional phase 2 process costs are not incurred and can save inventory costs—a comparison of total costs with changing storage costs due to lot sizing techniques. Cost comparison contains a comparison between the original costs of purchasing actual materials on demand each month and the costs calculated using MRP. Cost comparison is done by combining the total prices of each month in a table and comparing the values in price and percentage. Also, an efficiency column contains information regarding the difference between the original costs before MRP and the costs obtained after implementing MRP. The efficiency column is provided in rupiah or price value and value in percentage. Comparing the company's inventory costs with the MRP method for wine raw materials resulted in savings of 15% per year, and EOQ was more economical. SiO2 raw material produces savings of 55% per year, and EOQ is more economical. Purifying enzyme raw materials produces savings of 41% per year, and EOQ is more economical. Water raw materials produce savings of 4% per year, and LFL is more economical. Sugar raw materials produce savings of 28% per year, and EOQ is more economical. Fermented extract raw materials produce savings of 14% per year, and LFL is more economical.

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