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Inventory Management with EOQ Model for Telecommunication Tower Accessories (Study Case at BMTec)

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ABSTRACT: BMTec is a telecommunication infrastructure manufacturer based in West Java, Indonesia. They produce tower accessories made of steel materials with various fabrication processes. The ineffectiveness of their current inventory management system has driven them to stockpile raw materials, resulting in reduced material quality in the form of corrosion and obsolescence. This brings up the question regarding how to improve the inventory management in the company, then drives the research to compare the effectiveness of BMTec's current inventory management with the new-preferred inventory model. Before analyzing the mentioned issue, the primary data is gathered, accompanied by semi-structured interviews for the additional empirical data. An ABC classification is used to distinguish the essential items, which results in the telecommunication tower harmonica fence as the most crucial product in BMTec. Demand forecasting is applied based on the pattern of historical demand data. The Holt-Winters method was chosen due to the ability to adjust the seasonality and trend factor, although the forecasting inaccuracy reached 4.7 (MAD) and 78.4% (MAPE). By comparing the inventory costs over the current company's method and EOQ model, analysis shows that with the EOQ model, BMTec could save their inventory cost 2022 up to 68%. The discussion in this paper begins with the background of the research's underlying issues, followed by a literature review to update the scientific development for related studies. The third section conveys how the flow of this research is conducted, then discusses the findings or results from the analysis of collected data and chosen methods.

KEYWORDS: Demand forecasting, EOQ, Holt-Winters, Harmonica fence, Inventory management, Steel, Telecommunication infrastructure.

I. INTRODUCTION

Steel is a crucial material in infrastructure due to its properties which can withstand tensile and compressive loads greater than other materials. With its lightweight, it also can build a strong structure with smaller dimensions. The world's steel consumption in 2021 is up to 1,833.7 million tons and keeps increasing year-on-year, with Asia accounting for 70% of the total consumption [1]. Consumers of steel materials in Asia have a wide range of industries. Southeast Asia's top three steel-consuming sectors are construction, infrastructure, automotive, and shipbuilding. Among them, the proportion of the flat-steel product is the most favorable and has increased significantly, becoming 51% in 2018 [2].

Meanwhile, the business player among those consumers also varied from Small to Medium Enterprises (SMEs) to large companies. Muchaendepi et al. (2019) conveyed that SMEs face ineffective usage of the company's working capital, which eventually affects the overall profitability. The phenomenon had a tight relationship with the mismanagement of inventory inside the company.

This paper uses a case study for one of the SMEs in Southeast Asia, BMTec, which utilizes steel as the primary material for their manufacturing business. BMTec is a telecommunication infrastructure accessories manufacturer based in Indonesia. They mainly supported Indonesian government-owned companies as sub-contractor. This company faced a declining profitability growth in 2022 of 20% where one of which might have been caused by inventory mismanagement. This paper will use one of BMTec's most crucial products, harmonica fences (for telecommunication towers), as a test case for conducting inventory management improvement.

Flat steels such as plates, strips, hollow sections, and pipes are BMTec's primary material to be fabricated into telecommunication accessories. The fabrication processes mostly carried out on these steels are welding, bending, and bolting. Arifin et al. (2020) said there is a strong correlation between the bending angle processed on steel, water exposure, and corrosion rate. A smaller bending angle leads to a faster corrosion rate due to the larger stress area, while rainwater exposure with higher pH tends to be more corrosive than tap water. With its current inventory management method, BMTec is still experiencing difficulties controlling raw material supply and Work in Progress (WIP) goods. This resulted in stockpiled steel materials, which caused decreased quality in the form of corrosion due to rainwater exposure and obsolesce because of being stored too long.

According to the researchers' bibliographic analysis, the previous inventory management studies for telecommunication infrastructure accessories are still small. The data acquisition through the Scopus website using the keywords "inventory management" and "telecommunication" only generated 445 articles. In addition, most of these researches focused on wireless communication systems for network inventory. Only 1.35% discuss inventory management in terms of "physical-manufactured goods," while these all relate to spare parts management, which relies highly on technology. Thus, the paper aims to fill the research gap by providing a case study about inventory management for physical goods versions of telecommunication infrastructure accessories made from steel materials. The large number of product parts in BMTec makes it hard to model when the order takes place and how many units to order for each item. An ABC classification will be utilized to distinguish between significant and insignificant information. By grouping items into three categories using the Pareto principle, it will be possible to assess each item's level of control [5]. Regarding the harmonica fence product, each government's project has its size requirement of the same raw materials. The Holt-Winters forecasting method is chosen to predict future demand based on BMTec's historical demand characteristic. With differences in product sizes, demand forecasting is made by inputting one dimension of the harmonica fence that is most ordered or representing other sizes. The forecasted demand is used for conducting the EOQ inventory model to prove that it will be used as an inventory decision for the company in the future, with greater cost efficiency.

II. LITERATURE REVIEW

A. Inventory Management

Inventory is generally defined as the stock of any item or resource used in a firm. While management terms refer to those control and set of policies to monitor the stock level when to replenish and maintain, and what number to order [5]. Thus, it is possible to keep the production rates high while minimizing the cost [6]. Inventory management is the significant element that determines a firm's success or failure, with the main objectives to provide the appropriate quality of customer service, ensure that an organization's resources are available, streamline operations and minimize the inventory investment [7], [8]. The company's profitability is strongly influenced by how effectively it manages its inventory; studies show that the correlation coefficients are up to 85.3% (r) and 72.7% (r^2) [9]. For the SME business level, Ngubane et al. (2015) conveyed that a lack of inventory management skills makes the firm unable to compete effectively in the manufacturing industries. One of the factors is inadequate storage records and documentation.

1) Economic Order Quantity (EOQ)

Fixed-order quantity models try to predict both the specific point (R) and the size of an order (Q). with R, as the order point is a constant number of units. Chopra & Meindl (2016) conveyed that the EOQ model was built with basic assumptions such as steady demand at D units per unit time, no shortages allowed (all demand must be supplied from stock), fixed lead time, constant price per unit of product, and constant ordering or setup cost. The holding cost is based on average inventory. The EOQ inventory method will work best with normal and predictable demand items. If there is seasonal demand, then it should be added another adjustment. The quantity of order (Q) will be determined for the optimal one (Q*), which indicates that this quantity generates the lowest total annual cost (the cumulative of material cost, ordering cost, and holding cost). Optimal order quantity is found when the annual setup cost equals to annual holding cost, then described as the formula below:

$$Q^* = \sqrt{\frac{2DS}{hC}},$$

Which generates the minimum total annual cost (TC) with the formula as follows:

$$TC = CD + \left(\frac{D}{S}\right)S + \left(\frac{Q}{2}\right)hC,$$

Where D is demand per unit of time, S is the fixed cost incurred per order, and hC is the annual holding cost. While the reorder point (R) formula is:

$$R = \bar{d}L,$$

With $\bar{d}$ is average daily demand (constant) and L is a constant lead time in days [5].

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Table I shows the background of EOQ method selection which indicates the compatibility between method assumptions and BMTec's characteristics.

Table I. Selecting the EOQ Inventory Management Model

EOQ Assumptions [5]	**Compatibility with BMTec**
Constant price per unit product, no quantity discounts	Purchasing, invoices, and tax notes at BMTec use price-per-unit quantification. The raw material price fluctuation is low (<5% yearly) and does not affect purchasing behavior.
Ability to do single order for an item at any time	Can be applied because BMTec appoints different suppliers for almost every type of goods
Demand or inventory withdrawal is known, constant, and uniform throughout the period	BMTec has fluctuating demand which can be considered in the safety stocks. The demand for the product is known and uniform
Favors more expensive items because average inventory is lower	Suitable to the type of raw material used by BMTec, where steel and iron are expensive goods
Requires more time to maintain and closer monitoring since every addition or withdrawal is logged. Suitable for important items	As a partner of the government's project, BMTec need closer monitoring to ensure their products are of good quality for the wide use
Ordering or setup costs and lead time are constant	BMTec has constant ordering costs and lead time since they have a subscription supplier

EOQ has a weakness that cannot handle uncertain demand. Nevertheless, this can be handled by determining the safety stock. Darmawan (2015) said companies could benefit from safety stock to guard against risks such as running out of raw materials (stock out), delays in receiving ordered raw materials, and expected spikes in demand that are not predictable in advance by the company. It can be described as the amount of inventory held over and beyond the expected demand [5]. Safety stocks can be determined using the following formula.

$SS = z\sigma_L$,

With the z as the number of standard deviations for a specified service probability, and σ_L is the standard deviation of usage during lead time. This inventory amount will be added to the reorder point (R) to cover the uncertainty demand element.

2) Inventory Cost

Inventory costs include holding (or carrying), setup, and ordering costs. These all are important factors affecting the inventory size [5]. Holding costs are an expense which is related to storing the unsold inventory. It covers the building, material handling, labor, investment, and loans for purchasing goods. Low inventory levels and frequent replenishment are typical results of high holding costs. Ordering costs are costs incurred when placing the inventory order from the suppliers, such as purchase costs, administration costs, and transport. The setup cost occurred in manufactured goods whenever the stock was replenished. It includes the costs of preparing machinery and equipment for use in the production process.

B. ABC Classification

ABC analysis is a simple method and relatively easy to use [13] that comes from the issue where the control or treatment cannot be given to each inventory item. It uses the Pareto principle, which conveys as 80% of the consequences come from 20% of the cause, then categorize the inventory items into three groups according to the level of importance. Thus, the critical items can be separated from the insignificant items [5] *and* then focus the management's attention on the critical ones [14]. According to Mor et al. (2021), the three categories used in this ABC classification are as follows:

I. Group A (highly important): these are only 10-20% of the total items, which account for 70-80% of the total annual inventory value.
II. Group B (medium important): these are 25-30% of the total items contributing 15-25% of the total annual inventory value.
III. Group C (low important): the lowest contributor of total annual inventory value, only accounts for 5% while the amount is 50% of total items.

This ABC analysis is critical for SMEs in particular. The guiding principles will help the management to make important decisions on how to maintain inventories, no matter how large the business is. Nevertheless, SMEs who face unique challenges compared to larger enterprises are considered still low in adopting ABC Classification in their system [3].

C. Demand Forecasting

Forecasting can help management make rational decisions and consider policy variables. Forecasting is concerned with how the world will look, whereas planning is concerned with how the world should look. Planners can use forecasting methods to predict the outcomes of alternative plans. They can revise the plans until the desired outcomes are achieved. **Figure 1** shows the stages of forecasting [15].

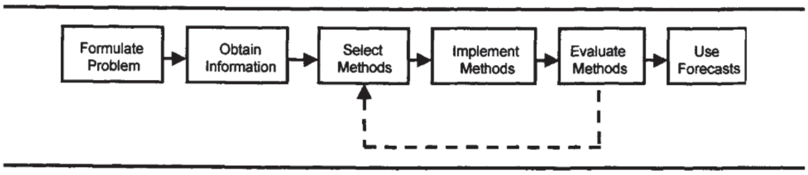

Figure 1. Stages of Conducting Demand Forecasting [15]

The selection of an acceptable forecasting model depends on several variables, including the forecasting time horizon, the availability of data, the level of accuracy needed, the forecasting budget size, and the availability of skilled employees [5].

Forecasting and the management decisions that go with it are extremely difficult when the supply of raw materials or the demand for the finished product is highly unpredictable. In general, the higher a company is in the supply chain (or the further it is from the consumer), the more distorted the information it receives. Several studies have found that combining multiple forecasting methods to create a combined forecast is more effective than using just one method. When forecasting demand, businesses must balance objective and subjective factors. Companies must also include human input when making final forecasts, such as knowledge of market conditions [11].

Due to the irregular and lumpy data features, demand forecasting for spare parts requires specific consideration. It might also be connected to some explanatory factors, such as the frequency of failures and maintenance actions. The moving average and single exponential smoothing are the most popular forecasting techniques in business practices [16].

1) Holt-Winters Multiplicative Method

Holt-Winters seasonal method is the extended version of Holt's method to deal with demand seasonality. It consists of a forecast equation and three smoothing equations. ℓ_t for the level, b_t for the trend, and s_t for seasonality. The equation also added up with corresponding smoothing parameters α, β, and γ. To indicate the seasonality's frequency, the parameter m is included.

When the seasonal variations change proportionally to the level of the series, the multiplicative variation is preferred use. The seasonal component is expressed in relative terms or percentages, and the series is seasonally adjusted by dividing by the seasonal component. Meanwhile, the seasonal component will total approximately m per year. The followings are the equations for Holt-Winters Multiplicative Method, including the level equation that is identical to Holt's linear method.

Level equation:

$$\ell_t = \alpha \frac{y_t}{s_{t-m}} + (1-\alpha)(\ell_{t-1} + b_{t-1});$$

Trend equation:

$$b_t = \beta(\ell_t - \ell_{t-1}) + (1-\beta)\, b_{t-1};$$

Seasonal equation:

$$s_t = \gamma \frac{y_t}{(\ell_{t-1} + b_{t-1})} + (1-\gamma) s_{t-m}.$$

Where the above three equations become input to determine the forecast equation as follows:

$$\hat{y}_{t+h|t} = (\ell_t + h b_t) s_{t+h-m(k+1)};$$

2) Forecasting Accuracy Measurement

The forecasting accuracy parameters are needed to tell how the model fits the data. There are three main parameters that are usually used to measure accuracies, such as the Absolute Mean Deviation (MAD), Mean Absolute Percentage Error (MAPE), and

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Mean Squared Deviation (MSD). Chopra & Meindl (2016) defined the MAD function as predicting the standard deviation, MAPE as showing average absolute error in percentage, and MSD as the variance of forecast error to predict the random component in the demand data.

Among these three parameters, some literature reviews conveyed different views regarding which parameters to use in the practical study cases. Bula et al. (2018) used one MAD parameter as the deciding factor to determine the best forecasting system for the case of a steel manufacturing company. Meanwhile, Nadiyah (2019), for their spare parts inventory management and used all three parameters to validate the demand forecasting methods. Besides these three parameters, Hyndman et al. (2016) introduced a new metric called the Mean Absolute Scaled Error (MASE). It is the scale-free error metric which considered more appropriate for the one that has intermittent demand data.

III. METHODOLOGY

This paper uses a case study approach to provide an overview of inventory management implementation in the telecommunication accessories manufacturing sector. The literature review was carried out to comprehend the current research on this topic. Secondary data, organized as historical company operational data, is used in this paper, accompanied by a semi-structured interview with BMTec's management team. To collect empirical data, an observation technique was also used during the site visit.

It is suggested for spare parts inventory management cases to use a framework that contains grouping items, estimating demand, applying inventory management methods [8], and evaluating the implementation through performance assessment [16]. Nevertheless, the scope of this paper based on **Figure 2** is limited to the proposed inventory management phase. Resulting in the total inventory cost comparison between the one that uses forecasted demand and total inventory cost from BMTec real data in 2022. There will be no performance assessment.

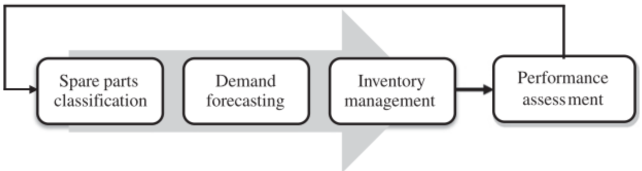

Figure 2. An Integrated Approach to Spare Parts Management [16]

The data regarding raw material items in BMTec will be classified into three categories using ABC analysis, generating the output information in the form of items that are considered crucial. Then the demand forecasting from those crucial items is determined using the company's 3-year of historical demand data. The forecasting model is chosen based on historical demand data patterns. Forecasted demand, along with other inventory costs, will be processed into optimal order quantity information through EOQ methods. The total cost is also determined to show how effective the inventory management will affect the reduction of the company's inventory investment.

IV. FINDINGS AND DISCUSSIONS

The inventory analysis starts with the ABC classification over all of BMTec's products. According to the ABC classification analysis shown in **Table II** and **Table III**, the most crucial item is the Harmonica Fence which accounts for 28.456% of the total value. This item will be the main object for this paper to be tested.

Table II. BMTec's ABC Classification summary

Classification	Percentage of total inventory value	Percentage of total list of different stock items	Amount of Product Types
A	**75.501%**	**13.56%**	**8**
B	19.964%	30.51%	18
C	4.536%	55.93%	33

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Table III. BMTec's Products in Group A

Product	Total Value (in mil. Rupiah)	Percentage of Total Value	Cumm. of Percentage	Category
Harmonic Fences	**7,591**	**28.456%**	**28.456%**	**A**
Mounting	3,725	13.962%	42.418%	A
On-site Assembler	2,785	10.441%	52.859%	A
Tray	2,493	9.345%	62.204%	A
Mounting Bracket	1,055	3.954%	66.157%	A
Double-swing Harmonic Door	1,047	3.923%	70.080%	A
KWH Pole	911	3.414%	73.494%	A
BRC Fences	535	2.006%	75.501%	A

Using the monthly historical demand data of the harmonica fence in 2020-2022 can be known from **Figure 3** that the data has seasonality, although the surge in data that occurs every year is not all repeated in the same month. The magnitude of the seasonal pattern is changed as the level of data changes. Besides, it also has an insignificant trend factor. To tackle this demand data characteristic, the forecasting method chosen for this paper is Holt-Winters Multiplicative which has smooth weights adjustable for the trend and seasonality.

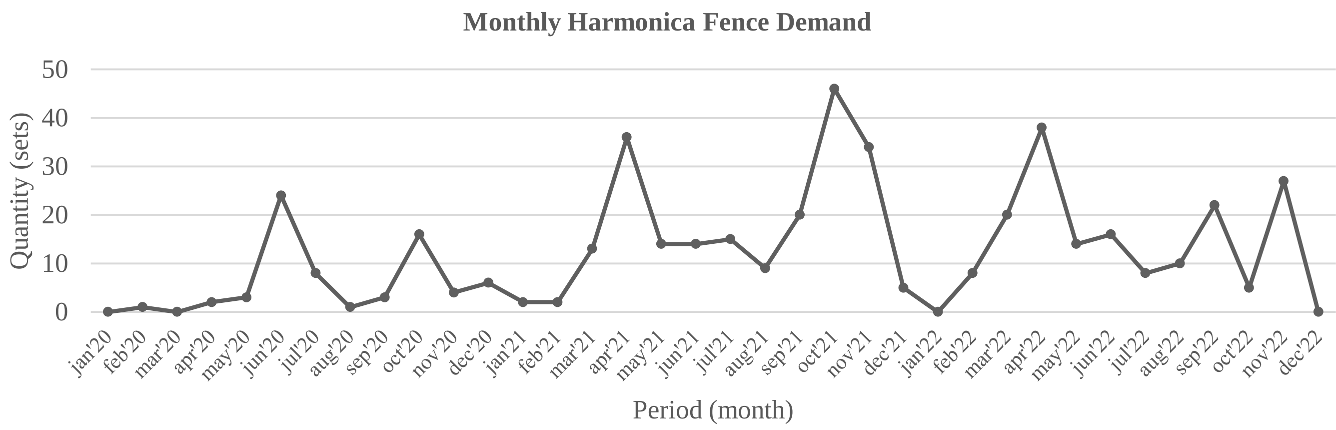

Figure 3. Monthly Harmonic Fence Demand in 2020-2022

The demand forecasting calculation is conducted using Minitab software with a seasonal frequency (m) of 12 due to the monthly data, and the pattern is repeated yearly. By changing the smoothing parameters (weights) for level, trend, and seasonal, it can be known what parameters to use in order to reach the best accuracy. The iteration shows that the best weights for the Holt-Winters method are 0.2 for the level factor, 0.2 for the trend, and 0.002 for seasonal. The seasonal weight input is low, which means that it will give less weight to recent data. This is in accordance with the condition of the seasonal pattern of demand in BMTec, which is not too formed. Meanwhile, the weight for trend and level is at fair value, which means that the weight over recent data is deserved to be high.

With these weight values, it generated the error as 78% (MAPE), 4.7 (MAD), and 50.5 (MSD), which are still relatively high or inaccurate. The demand forecast results for the three associated years are shown in red line as plotted in **Figure 4**. According to what was conveyed by Hyndman et al. (2016), the high value of MAPE might occur due to the availability of infinite or undefined as a result of zero value in a series. This frequently happens if there is intermittent-demand data.

BMTec is currently using assemble-to-order strategies for their harmonica fence production due to each government project has its own fence size requirement. Nevertheless, the government project has subscribed BMTec as their sub-contractor partner, and

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all the pre-order fences are still made of the same raw materials. Thus, the demand for harmonica fences will always exist, although they come in different sizes. The next analysis for the EOQ inventory management model in this paper is narrowed to their main raw material, which is steel pipe. The 10m x 10m type of harmonica fence is chosen due to the most ordered and is considered can represent the dimension of all the fence products in the company. There are 11 steel pipes required for making 1 set of 10m x 10m harmonica fence, and the recapitulation based on forecasted demand, and actual sales of 2022 are shown in

Table IV.

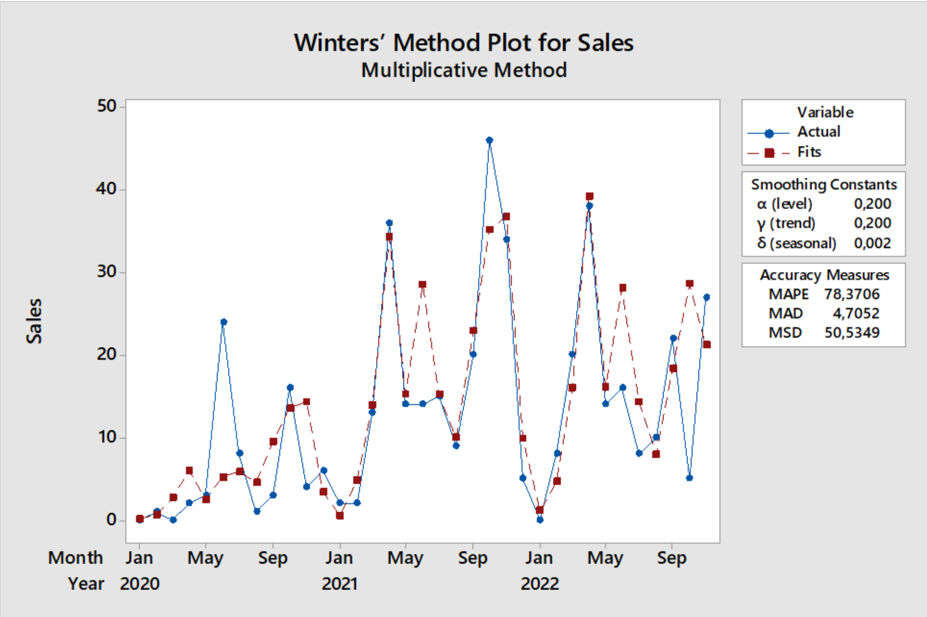

Figure 4. Holt-Winters Method for Demand Forecasting

Table IV. Demand Forecast 2022 using Holt-Winters Method

Steel Pipe Materials for Harmonic Fence Product		
Period	**From 2022 Demand Forecast (Holt-Winters)**	**From Actual Sales 2022**
jan'22	13	0
Feb '22	52	88
mar'22	176	220
Apr'22	432	418
may'22	178	154
jun'22	309	176
Jul'22	158	88
Aug'22	88	110
Sep'22	202	242
Oct'22	315	55
Nov'22	234	297
Dec'22	62	0

By using the real data of storage cost, ordering cost, and unit cost can be calculated the optimal order size for the steel pipe material through the EOQ inventory model. The calculation shows that the optimal order size is equal to 117 pcs, which led to 19 orders per year. Then can be determined the total inventory cost consisting of holding and ordering costs for this model is equal to IDR 6,105,780 for 2022. Currently, BMTec is adopting fixed quantity orders, such as 200 pcs of steel pipe that is ordered regularly every month. With this current inventory model, they invested IDR 19,245,000 in 2022. The whole detail and comparison between both models are shown in **Table V**. The analysis indicated that with the EOQ inventory model, the company could save costs as high as 68%.

Table V. Comparison of inventory costs between EOQ and current BMTec method

EOQ Inventory Model			**BMTec's Current Inventory Method**		
Forecasted demand for 2022 (D)	2219		Sales in 2022	154	
Annual storage cost per unit (h)	Rp	52,500	Monthly storage cost per unit	Rp	4,375
Ordering cost (S)	Rp	160,000	Ordering cost	Rp	160,000
Unit cost	Rp	424,000	Unit cost	Rp	424,000
Optimal order size	117		Monthly order quantity	200	
Number of orders per year	19		Number of orders per year	12	
Holding + ordering cost	**Rp**	**6,105,780**	**Holding + ordering cost**	**Rp**	**19,245,000**

V. CONCLUSIONS

In this paper, a practical case regarding the inventory management model is tried to be solved. It started with the ABC classification, which resulted in the harmonica fence product as the most crucial one. From the plotting of the harmonica fence's historical demand, it can be concluded that there is seasonality and an insignificant trend pattern. Thus, this paper utilized the Holt-Winters Multiplicative method for executing demand forecasting due to the ability to adjust the seasonality and trend dependence over the recent data. Nevertheless, some inequal demand spikes from year to year have occurred, which affected the moderate level forecasting inaccuracy at 4.7 if using the MAD parameter and 78.37% for the MAPE parameter. Compared to the company's current inventory system, by using the EOQ model for its inventory management system, the company could save inventory costs by up to 68%. There are some matters that can be improved in the analysis of this paper. For instance, the factor of intermittent demand data which not yet been considered and might be the main cause of the inaccuracy of forecasting results. Still, the paper did its best to give suggestions for future inventory decisions that will result in greater cost efficiency for the company.

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