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AIRCRAFT SPARE PARTS INVENTORY MANAGEMENT ANALYSIS ON AIRFRAME PRODUCT USING CONTINUOUS REVIEW METHODS

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Abstract: *The research aims to find the factors that cause high inventory value, increase the value of forecasting precision, service level and cost efficiency with fishbone diagrams and proposed methods. The research sample is 9 spare parts included in classification A in the ABC analysis and maintenance list 2018. Forecasting methods use Moving Average, Single Exponential Smoothing and Syntetos-Boylan Approximation as well as Mean Square Error calculation, deterministic inventory calculation and Continuous Review Method. The results of this study are an increase in logistics costs by $ 808.71 in the inventory management proposal. An increase in service level from 95% to 99% and the error value in the calculation of the proposal becomes smaller using the proposed method. This study also found that the factor causing the high inventory value was due to inaccurate planning methods so that other comparative methods were needed that could increase the precision of demand forecasting.*

Keywords: *Inventory Management, ABC Analysis, Forecasting, Continuous Review*.

INTRODUCTION

Background of Problems

In the current situation, the world aviation industry was experiencing rapid development, based on a study released by the International Civil Aviation Organization (ICAO), which has an increase in the number of aircraft passengers per year from 2000 to 2017. The peak in 2017, there are 3.9 billion passengers worldwide are using planes and currently increasing in number (World Bank, 2018). It does not stop there, there has predicted by International Air Traffic Association (IATA) research tells that in 2036, passengers who choose air transportation will double compared to 2016, which around 7.8 billion passengers (IATA, 2018).

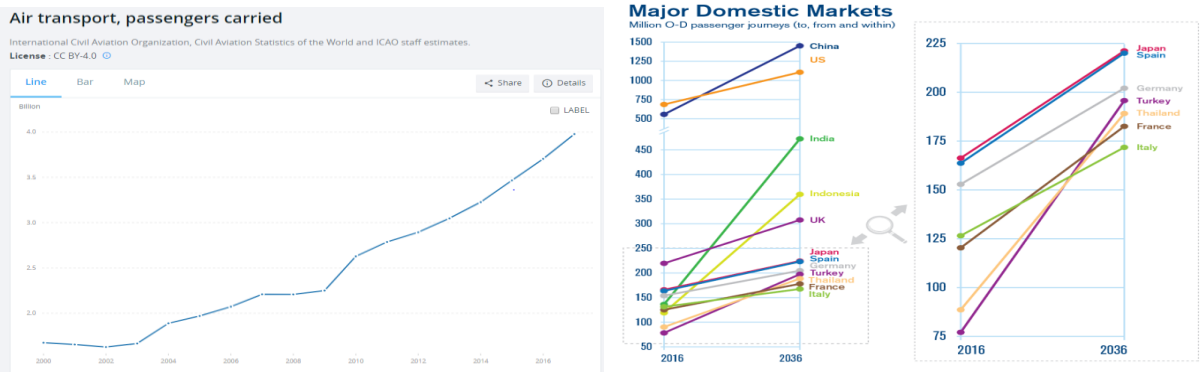

Figure 1. Number of World Aircraft Passengers 2000-2017, those estimated Number of World Aircraft Passengers in 2036
Sources: World Bank, IATA (2018)

Based on these data, all aviation business supporters from operators, airports, MRO, and other aviation business stakeholders must be prepared to capture this considerable business potential. Specifically for stakeholders engaged in aircraft MRO (Maintenance, Repair & Overhaul). Among the many factors that affect the improvement of MRO competitiveness against other competitors, managing spare parts inventory is one of the keys in increasing competitiveness because it can affect the quality of MRO services to the operator who demands that aircraft maintenance be completed on time and have good quality work results following civil aviation standards.

This research will discuss the inventory turnover in PT. A B C. There were 31,280 spare parts received on the warehouse within 36 months (January 2016 to December 2018). From the obtained data, as much as 19,164,138 USD or 9% of all PO values that have been received at the spare parts warehouse (213,801,642 USD) did not move for more than 3 months, the potential for a surplus of 10,588,315 USD or 5% of all PO values that have been received at the spare parts warehouse (213,801,642 USD) also do not move for less than 3 months, where this 5% figure has the potential to contribute to the company's burden if it does not move for more than 3 months.

Table 1. Data on Purchase Value & Parts Inventory on January 2016 - December 2018

Product	Purchase value received at warehouse	Purchase value received at warehouse	Potential surplus (immovable inventory)
Airframe	$ 107,591,545	$ 8,139,969	$ 4,552,980
Cabin	$ 26,699,554	$ 2,273,069	$ 764,501
Component	$ 35,081,140	$ 2,972,038	$ 1,794,176
Engine	$ 44,429,403	$ 5,779,062	$ 3,476,657
Total	**$ 231,801,641**	**$ 19,164,138**	**$ 10,588,315**

Source: PT ABC Internal Data (2018)

Based on the type of product, airframe parts contribute the most surplus compared to cabin, component & engine products. The airframe product is used in many maintenance projects in companies where the maintenance project is broadly divided into 3 groups, namely Planning, Finding & AOG where there are 2301 spare parts have not moved for more than 3 months. The total number of spare parts is divided into 3 classifications, A, B, and C. Classification A accounts for 75% of the total value stored in the warehouse, classification B accounts for 20% of the total value stored in the warehouse, and classification C accounts for 5% of the total value stored in the warehouse.

Clasification	Part Total (Item)	Part Total (%)	Part Value ($)	Part Value (%)
A	438	19%	$ 3,036,662	75%
B	711	31%	$ 810,474	20%
C	1152	50%	$ 202,994	5%
Total	**2301**	**100%**	**$ 4,050,090**	**100%**

Table 2. Analysis of ABC Project Maintenance Planning on Airframe Products
Source: PT ABC Internal Data (2018)

Based on the ABC analysis results above, this study will use parts that are included in the 2018 maintenance list in classification A which is 9 part numbers. The choice of spare parts in classification A is because the parts in classification A affect the value of the largest surplus inventory, which is 75%, so the inventory calculation must be closely monitored and controlled. Things that are suspected to cause a surplus inventory & deadstock, among others, due to inaccurate aircraft maintenance lead time & arrival time for aircraft parts, purchased parts not following production needs, inaccurate inventory data and errors in calculating spare parts consumption used in production, so that there needs to be an improvement in the conditions of surplus inventory and deadstock so that the ideal situation is the absorption of material into production can run optimally by finding the factors that influence the accumulation of inventory and finding solutions that apply to the company.

Research Purposes

The objectives of this research are:

1) To find out the factors that cause the high inventory value of airframe parts
2) To provide proposals to companies to optimize inventory turnover.
3) To find out forecasting and planning of inventory control on parts of airframe products in planning maintenance projects that are precise and can streamline costs.

LITERATURE REVIEW

Inventory

According to Tampubolon (2014), inventory is one component that has an important role in business activity. The expeditious production process and fulfillment of demand (sales) will be greatly influenced by how to manage its component well. How inventory items could be classified and how accurate inventory records could be maintained. Then, we will look at inventory control in the service sector. Operations managers around the world have realized that good inventory management is very important.

Based on Ginting (2007) to find out these optimum inventory policy, information about parameters is needed, which estimated needs, inventory costs and lead time. One of popular model in deterministic models is Economic Order Quantity (EOQ) model. According to Handoko in Adam and Imaroh (2019) EOQ is amount of material purchased every each purchase with most minimal cost. This EOQ model is various based on development of inventory methods. The important thing to be concern is level of service which is fair to face uncertain demand, the level of service (service level) is a complement to probability which running out of inventory. One of method to reduce inventory decrease is to keep an additional units as an stock. Those inventory is usually called safety stock, safety stock has involves adding a number of units as a buffer to reorder point (Heizer, 2014: 575).

Inventory Control

Practically, probabilistic inventory policies were break down into three decisions, namely determining the size of economic order lot (Qopt), discover when reorder should be made (ROP) and find out those amount of safety stock (SS). To discover how much safety stock (SS / Safety Stock) at a leadtime (L) with service level (η) it is necessary to know how the distribution pattern of possible demand during the leadtime.

According to Ginting (2007) in probabilistic inventory control system, there are two Order Point Policy (OPP) methods, namely the Q (Continuous Review) method and the P (Periodic Review) method. In this Q method, inventory with a fixed number of orders and time interval for ordering is always change. On this method, reordering is carried out when inventory reachs re-order point by calculated those fluctuate during lead time, inventory to reduce lead time fluctuations called a safety stock. Whereas on P method those inventory system with a fixed order interval, but amount of material that ordered is always change. Therefore the order which made at a certain time where time interval between two orders is always fixed. The security inventory has greater than the Q system, because these inventory would also needed for all inventory consumption.

Inventory Cost

Most of the company's resources were often linked to inventory that could be used in company. Those inventories value have to recorded, and classified according to type and then the details of each item which made in relevant period. In allocating those budgets, those company often knows cost centers to measure the results achieved in a certain period in connection with the determination of the company's financial position as a business unit. According to Eddy Herjanto (2010), the cost elements contained in inventory can be classified into three, namely ordering costs, storage costs, and inventory shortage costs.

ABC Analysis

ABC analysis divides inventory into 3 groups based on volume in the amount of money. ABC analysis is an implemented of inventory by Pareto principle. Based on Heizer and Render (2014) ABC analysis used to find out these money volume annually. ABC analysis was measures those annual demand for each inventory and multiplied by unit cost. The advantage from using this ABC analysis is policies and controls could be assigned to each class.

Forecasting

The company also requires an accurate forecast for consumer demand to reduce those lead time, inventory levels, production time and efficiency of company's facility. Forecasting is an art and science in predicting future events, forecasting would include taking historical data and count on them to future by mathematical models (Heizer and Render, 2014). Heizer (2014) further explained that there were 2 methods forecasting method which could sort of these decision models matters, such as qualitative forecasting and quantitative forecasting. In forecasting variable, a measure of forecast accuracy is commonly used, which is Mean Absolute Deviation (MAD), and Mean Squared Error (MSE).

Fishbone Diagram

Causality diagram is a systematic approach that allows further analysis to find out causes of problems, incompatibility and gaps that occur. This diagram could be created using brainstorming to identify why this problem occurs and digging up detailed towards problem.

Theoretical Framework

These following table is theoretical framework of this research:

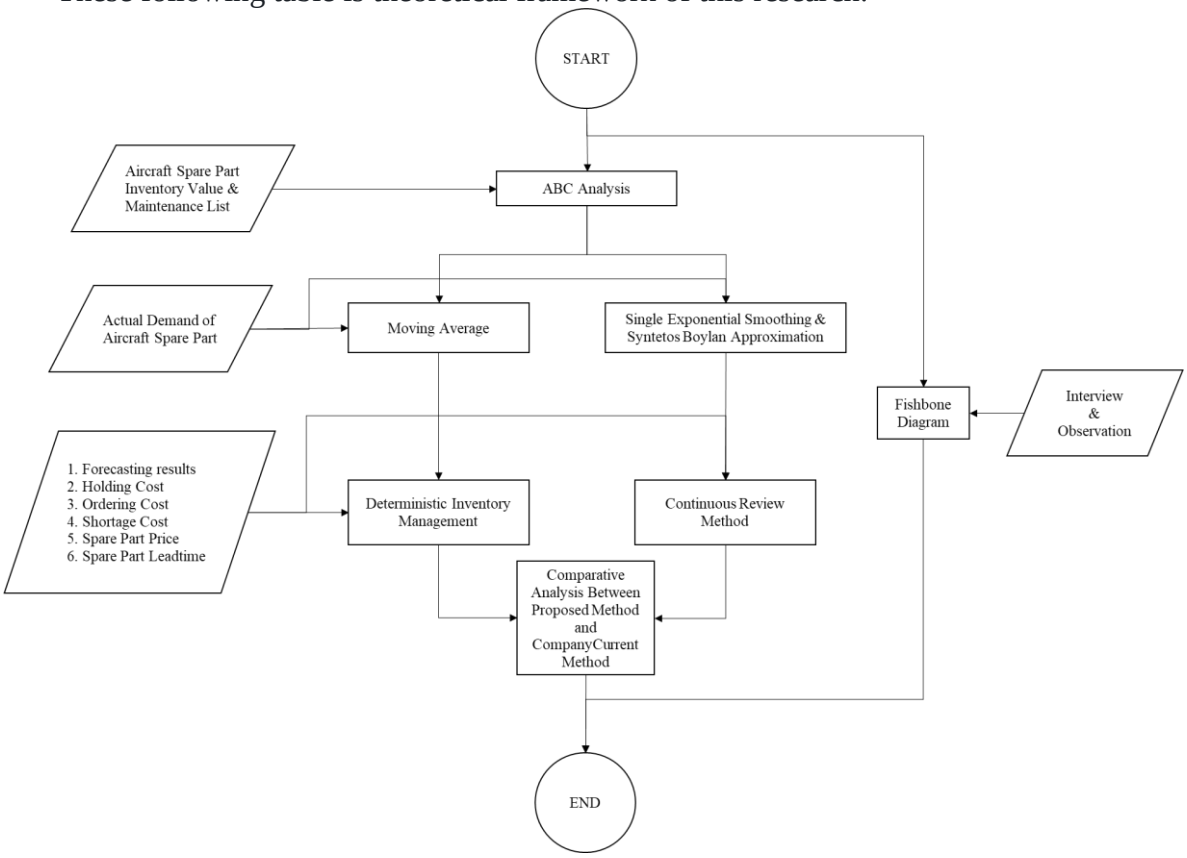

Figure 2. Theoretical Framework Diagram

RESEARCH METHODS

This research is descriptive quantitative research, whereas this research seeks to discover over those factors which influence the dependent variable in the form of fixed inventory values and find solutions to improve the number of immovable inventory values. The dependent variable in this research is the efficiency of inventory costs at the company, while independent variables in this research are airframe product parts on project maintenance planning, demand data of airframe parts on project maintenance planning.

The population in this research was the value of aircraft spare parts purchase documented in the SAP software from January 2016 to December 2018. The target population is the purchase of aircraft parts value which not moved for 3 months for airframe parts on planning maintenance projects. Research sample in this research were spare parts which contributing surplus to airframe product at maintenance project planning in classification A which entered the maintenance list in 2018.

Research data was collected by taking secondary data in the form of aircraft spare parts purchase data documented in PT. ABC SAP and other secondary data sources obtained from several previous studies, books, and other scientific journals. These research data also collected by interviewing those respondents, including Inventory Control staff and Purchaser staff of PT. ABC. The data analysis method in this research used the ABC analysis method, Fishbone Diagram, Forecasting, Inventory Calculation.

FINDINGS AND DISCUSSION

Research Result

Early research shows that those products with the highest inventory value in the company are an aircraft product on a Planning maintenance project. Then, an ABC analysis was performed to categorize which part of numbers contributes to huge surplus value to the 2018 maintenance list, 9 part numbers should be controlled by inventory. To find out several conclusions from this research first thing that should do is collect data and do an analysis afterward.

From this data collection stage, it is known that there have many factors that cause immovable inventory. However, the main causes and interrelations are unused material because this airplane model is not maintained in Hangar, and inaccurate planning results in too many/little purchases. This immovable inventory occurs because of inaccurate inventory planning methods, which causes parts to be purchased either too much or too little. Inventories that purchased too much from actual demand have the potential to be immovable inventory. Inventories purchased less than actual demand will potentially cause lost sales. Not only that, but there is also a second contributing factor, namely spare parts which no longer in use because aircraft models are no longer being treated in the hangar or newer replacement parts are available therefore spare parts that have been purchased and stored can no longer be used (obsolete).

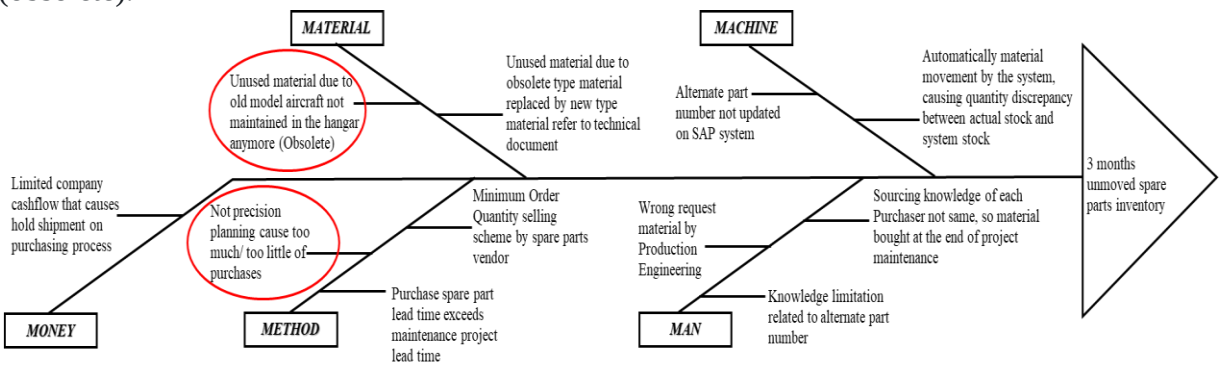

Figure 3. Fishbone Diagram

The next step is to control and plan inventory. In this research, those calculations will be divided into calculations currently used by companies and suggested calculation That would be compared at the end of the research. Forecasting methods used by companies are 3 Month Moving Average and deterministic inventory control calculations. By using forecasting and calculations currently used by the company, a total inventory cost is needed in 2018 is $ 160,807.10.

Table 3.Safety Stock, Re-order points, EOQ and Total Logistics Cost of Parts

Parts	Safety Stock	Re-Order Point	EOQ	Total Logistic Cost
137847-1	2	4	6	$ 13,616.12
AE1011836K0260	4	6	7	$ 9,170.78
AE1011836K0461	5	8	8	$ 11,873.46
AE2463936J0262	3	5	7	$ 5,115.13
APPLIED3-471	117	140	532	$ 40,665.33
DESOCLEAN45	3	5	25	$ 81.06
GA68100090007	4429555	12440134	2566589	$ 68,521.59
HT3326-5-200	3	6	14	$ 3,615.52
P603152	7	10	4	$ 8,148.12

In the proposal, there are 2 methods of forecasting to be used, namely Single Exponential Smoothing forecasting & Syntetos-Boylan Approximation forecasting. These two methods are used because of the different demand patterns for each spare part. The Single Exponential Smoothing method is suitable for parts with a continuous demand pattern, while the Syntetos-Boylan Approximation method is suitable for parts with intermittent demand patterns.

In Single Exponential Smoothing forecasting, there is α used as a smoothing constant, in this research, the writer will use a value of α 0.1; 0.3; 0.5; 0.7 and 0.9. Based on an example calculation using AE2463936J0262 parts, these value of MSE with α = 0.9 has the smallest value, so for AE2463936J0262 spare parts will use forecasting data with the value of α = 0.9 in subsequent calculations.

Table 4. MSE Calculation Results for Material AE2463936J0262

α	0.1	0.3	0.5	0.7	0.9
MSE	1.56	1.54	1.53	1.50	1.49

In these Syntetos-Boylan Approximation forecasting, there are α and β which used as calculation constanta. In this research, the authors will use a value of α 0.1; 0.3; 0.5; 0.7 and 0.9. The same value also used on β constant therefore there will be 25 combinations of calculations. Based on these estimation example by AE2463936J0262 parts, the MSE value with α = 0.5 and β = 0.9 has the smallest value, so for AE2463936J0262 spare parts will use forecasting data with values α = 0.5 and β = 0.9 on next estimation.

Table 5. MSE Calculation Results on Material AE2463936J0262

α; β	0.1; 0.1	0.1; 0.3	0.1; 0.5	0.1; 0.7	0.1; 0.9
MSE	4.09	3.81	3.63	3.54	3.54
α; β	0.3; 0.1	0.3; 0.3	0.3; 0.5	0.3; 0.7	0.3; 0.9
MSE	4.29	3.86	3.56	3.39	3.33
α; β	0.5; 0.1	0.5; 0.3	0.5; 0.5	0.5; 0.7	0.5; 0.9
MSE	4.82	4.20	3.73	3.42	3.27
α; β	0.7; 0.1	0.7; 0.3	0.7; 0.5	0.7; 0.7	0.7; 0.9
MSE	5.83	4.91	4.20	3.68	3.37
α; β	0.9; 0.1	0.9; 0.3	0.9; 0.5	0.9; 0.7	0.9; 0.9
MSE	7.47	6.13	5.06	4.24	3.68

After testing, Single Exponential Smoothing forecasting is effectively used on data with a continuous pattern, while the Syntetos-Boylan Approximation forecasting is effective in predicting requests with intermittent patterned data. The following are the forecast results chosen for each spare part.

Table 6. Selected Forecasting Methods for Each Part

Parts	Data Pattern	Selected Forecasting Methods		
		Forecasting Methods	MSE	
			α	β
137847-1	Intermittent	Syntetos Boylan Approximation	0.90	0.90
AE1011836K0260	Intermittent	Syntetos Boylan Approximation	0.90	0.90
AE1011836K0461	Intermittent	Syntetos Boylan Approximation	0.90	0.70
AE2463936J0262	Intermittent	Syntetos Boylan Approximation	0.50	0.90
APPLIED3-471	Continious	Single Exponential Smoothing	0.10	-
DESOCLEAN45	Intermittent	Syntetos Boylan Approximation	0.10	0.10
GA68100090007	Continious	Single Exponential Smoothing	0.70	-
HT3326-5-200	Intermittent	Syntetos Boylan Approximation	0.90	0.90
P603152	Intermittent	Syntetos Boylan Approximation	0.10	0.10

After getting the forecasting results with the best method based on data patterns for the demand for 9 parts studied, the calculation continues to get the value of safety stock, re-order points, the optimal number of messages or economic order quantity (EOQ) and total logistic costs for 2018 using continuous review method inventory control calculations. Based on the calculation, the total inventory cost needed in 2018 was obtained using the proposed calculation is $ 161,615.81.

Table 7. Safety Stock, Re-order points, EOQ, Max Stock, Service Level and Total Logistic Cost of Parts

Parts	Q Opt	Safety Stock	ROP	Service Level	Max Stock	Total Cost
137847-1	7	1	21	99.7%	28	$ 19,998.43
AE1011836K0260	8	1	31	99.4%	39	$ 13,289.96
AE1011836K0461	9	1	40	99.2%	49	$ 15,355.77
AE2463936J0262	8	1	22	99.4%	30	$ 7,000.60
APPLIED3-471	470	27	218	99.7%	688	$ 29,190.72
DESOCLEAN45	30	1	22	99.1%	52	$ 116.48
GA68100090007	4253468	1835875	84926151	98.6%	89179619	$ 60,028.85
HT3326-5-200	16	2	32	98.7%	48	$ 4,270.52
P603152	5	1	45	97.4%	50	$ 12,364.48

Discussion

Based on the results of the interviews shown in the Fishbone diagram, 11 factors cause spare parts inventory at PT. ABC has not moved for more than 3 months reviewed from the 5 indicators on the diagram. The main factor that contributed to the high value of the inventory of PT. ABC that has not moved for more than 3 months is a method indicator where the planning method in the company is not precise with the actual demand in the company.

The forecast method used in planning material needs has an impact on the procurement process, where the procurement of this material becomes less or more. The impact of the less and more on the procurement process is unmoved of previously purchased inventory because it is not absorbed by production activities and there is a delay in the production process because the required materials are not available in the warehouse which results in loss of sales and a decrease in the Customer Satisfaction Index.

According to Oguji (2018), strategies that can be carried out by the company in dealing with high inventory is a Proactive strategy, which is a strategy to prevent excess inventory from new purchases with several strategies, one of them is using the Syntetos-Boylan Approximation forecasting method to predict intermittent demand data wherein the MRO industry, intermittent material demand patterns this is very often found.

Refer to comparison results, total logistic cost has increased by $ 808.71 or about 0.5% from total logistic cost on company policy. This increase would occur due to an increase in the number of requests in 2018 for each spare part, except for APPLIED3-471 parts which decreased by 863 L and GA68100090007 which decreased by 4,532,17 grams on their annual demand.

Viewed from these data, it could be described that this annual demand as a result of forecasting has increased in the precision of forecasting. Viewed from MSE value that becomes smaller while compared between those values of MSE in company policy with the value of MSE in the submission method.

Not only did on the precision increase in the annual demand forecast value, but there was also an increase in service level in the proposed method where initially, the service level was set at 95%, in the proposed method, the service level value increased to an average of 99%.

From those discussions above, it could be said by using these submissions methods, there has an increase of 0.5% in logistic cost, but these service level values and precision of forecasting value would increases. The use of these submission methods was given back to Company, By using this, there will be an increase in costs by 0.5%, but with increased service levels and forecasting precision makes this submission method a separate value from the company to prevent loss sales do not occur and customer satisfaction index could be increased.

Table 8. Comparison of Total Demand 2018, MSE Value, Service Level and Total Cost of Company Policy and Submission Methods

Parts	Company Policy				Proposed Method			
	Total Demand of 2018	MSE Value	Service Level	Total Cost	Total Demand of 2018	MSE Value	Service Level	Total Cost
137847-1	17	2.22	95%	$ 13,616.12	25	1.49	99.7%	$ 19,998.43
AE1011836K0260	20	4.00	95%	$ 9,170.78	29	2.55	99.4%	$ 13,289.96
AE1011836K0461	21	5.00	95%	$ 11,873.46	27	2.02	99.2%	$ 15,355.77
AE2463936J0262	19	5.01	95%	$ 5,115.13	26	3.27	99.4%	$ 7,000.60
APPLIED3-471	3017	206612.45	95%	$ 40,665.33	2154	6002.31	99.7%	$ 29,190.72
DESOCLEAN45	6	2.22	95%	$ 81.06	9	1.86	99.1%	$ 116.48
GA68100090007	33418363	5334826589545.10	95%	$ 68,521.59	28886190	64877756149.21	98.6%	$ 60,028.85
HT3326-5-200	29	9.60	95%	$ 3,615.52	34	6.79	98.7%	$ 4,270.52
P603152	6	0.13	95%	$ 8,148.12	9	0.13	97.4%	$ 12,364.48
Total				**$ 160,807.10**				**$ 161,615.81**
Gap	**$ 808.71**							
Gap Percentage	**0.50 %**							

CONCLUSION AND SUGGESTION

Conclusion

Several conclusions could be drawn in this research such as:

1) The most dominant factor which caused the high inventory value from airframe parts at planning maintenance project is an inaccurate planning method so it has occurred those purchases with fewer / more quantities than it should. Another factor besides this inaccurate reason is a planning method that all material already in the warehouse but cannot be used because that material is no longer used in the aircraft maintenance process at the hangar (obsolete).
2) Companies can do a Proactive strategy, which is a preventive strategy so deadstock inventory not arising from new procurement activities with one of the strategies is to use a forecasting method that can calculate intermittent demand patterns such as the Syntetos-Boylan Approximation method.
3) This suggestion forecasting method on this research was to use Single Exponential Smoothing forecasting methods on continuous demand patterns and using the Syntetos-Boylan Approximation forecasting method for intermittent demand patterns. For inventory control calculations, this research use Continuous Review method. Although in terms of cost, there was an increase of 0.5%, the proposed method was effective to increase these precision of forecasting value and service level.

Suggestion

Suggestions for companies to reduce the value of its inventory based on this research include:

1) Using the contributing factors obtained from the Fishbone diagram in this study to start building strategies that seek to minimize deadstock opportunity in the company

2) A Proactive Approach is not the only way to minimize inventory value in the company. Two strategies can be used, they are strategy with Reactive Approach and Strategic Approach. Reactive Approach strategies include the process of scraping over unused excess, selling at a discount, and disassembling material into sub-materials so that they can be used or sold. Then, Strategic Approach includes business processes adjustment, the establishment of Inventory KPIs, perform buyback of suppliers goods, and improves analysis of Big Data Inventory.
3) Apply proposed forecasting and planning methods in this study, Single Exponential Smoothing forecasting methods and Syntetos-Boylan's Approximation forecasting method. Also Continuous Review method as the proposed inventory control calculation.

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