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Improving the Spare Parts Management and Inventory Control in Case of Line Stop Reduction in Assembling Shop in PT.XYZ

Teuku Mirwan Saputra[1], Feri Ali Tosa[2], Yadi Santoso[3], Erry Rimawan[4]
Fakultas Pasca Sarjana, Megister TeknikIndustri, Universitas Mercubuana
Jalan Meruya Selatan no.1, Joglo, Kembangan, Jakarta Barat,
Daerah KhususIbukota Jakarta Indonesia 11650

Abstract:- Spare part management and inventory control is the way how to manage and control spare part in optimum ways. The spare parts itself are needed for maintaining and repairing the machine in order to run the production smoothly. The variability of demand of spare parts are commonly happened that create uncertainty condition in spare part. It means, those conditions can be defined as multi-period inventory system with probability approach. In PT.XYZ, the condition of spare part is usually become the causes of Line Stop that already know as prohibitively expensive conditions. The Line Stop that caused by spare part are recorded equal to 10.63% from the average total of Machine Stop percentage. In this case, Line Stop percentage can be reduced by providing an ideal spare part warehouse. An ideal spare part warehouse should have Right Part, Right Time, and Right Quantity. Those of criteria will be provided by using Vital-Essential-Desirable (VED) Analysis, Fast Moving-Slow Moving-Nonmoving (FSN) Analysis as a spare part management methods, and Periodic Review (P) system as a spare part inventory control methods. As a result, Spare part management and inventory control already success to reduce 10 % on average of Line Stop after proved in 14 main machines in assembling shop.

Keywords:- *Spare part management and inventory control, uncertainty condition in spare part, Line Stop, ideal spare part warehouse, VED analysis, FSN analysis, Periodic Review (P) system.*

I. INTRODUCTION

As one of manufacturing company that producing car, PT.XYZ dedicated to become the most outstanding company in Indonesia. In achieving their goal, PT.XYZ built three production shop which are welding shop, painting shop, and assembling shop in order to support their production of cars. Those shop already supported by certain machine both are unique machine and common machine. The unique machine are machines that can be used for one shop. On the other hand, the common machine are machines that can be used for several shop. All of those machines have their own spare parts that have to maintain and control.

Actually, there are several aspects should be considered in achieving their targets. One of aspect that should be concerned is Line Stop reduction which known as the most important aspect. In fact, the Line Stop is a prohibitively expensive conditions that cost the company so much lost regarding to the availability of their resources. Moreover, the Line Stop also can be defined as the condition when production activity is stop caused by machine, man power, environment, etc. In PT.XYZ, the Line Stop are usually happened caused by machine. Regarding to the machine, the Line Stop happened when the main machine having a troubles which is called Machine Stop. Therefore, in order to reduce the Line Stop, the Machine Stop should also be reduced especially the time needed to maintain and repair the machine.

According to recently data from PT.XYZ, The causes of Machine Stop can be categorized to Equipment, Quality, Process, and Supply. Those of causes had their own influence percentage to the total Line Stop that happened in PT.XYZ. The average total of Line Stop caused by Equipment are equal to 10, 63 %, Quality are equal to 8, 40 %, Process are equal to 9, 22 %, and Supply are equal to 0, 05 %. Since the highest Line Stop percentage are caused by Equipment, the research would like to conduct the Line Stop reduction caused by Equipment as the one of the Machine Stop's caused in assembling shop. Usually, the Line Stop that caused by equipment is related to the conditions of spare part. It means that the Machine Stop happened while the spare part is not available around the shop in order to maintain or repair the machine.

In PT.XYZ, the conditions of spare part had many problems especially in providing the spare parts when the Machine Stop happened unpredictably. For instance, when a main machine having trouble that caused Line Stop, the spare part as the material to repair the machine is not available around the shop. This condition will increase the waiting time to repair because maintenance personnel have to order the spare part to main warehouse. Actually, PT.XYZ have a main warehouse that served all work shop. The main warehouse is located far from assembling shop. Hence, there will additional time to repair the machine because maintenance personnel also have to deliver the spare part from the main warehouse to assembling shop. This conditions will increase the Machine Stop percentage and automatically will increase the Line Stop percentage.

Then, in order to prevent this conditions, the improvement have to apply in PT.XYZ which is build a spare part warehouse in each shop. This spare part warehouse will store the important parts in order to provide the spare part needed when the uncertainty condition happened. Actually, there are 8.169 spare parts that used in PT.XYZ for every machine in all work shop. It is impossible to store all spare parts because it will make the company spend a huge resource in building the spare part warehouse.

Therefore, there will be several aspects that should considered in building the spare part warehouse such as what kind of spare part that should be stored, when the spare part should be ordered, and how many spare part that should be stored. Those of

aspects are Right Part, Right Time, Right Quantity in order to provide an ideal spare part warehouse in case of Line Stop reduction.

II. METHODS

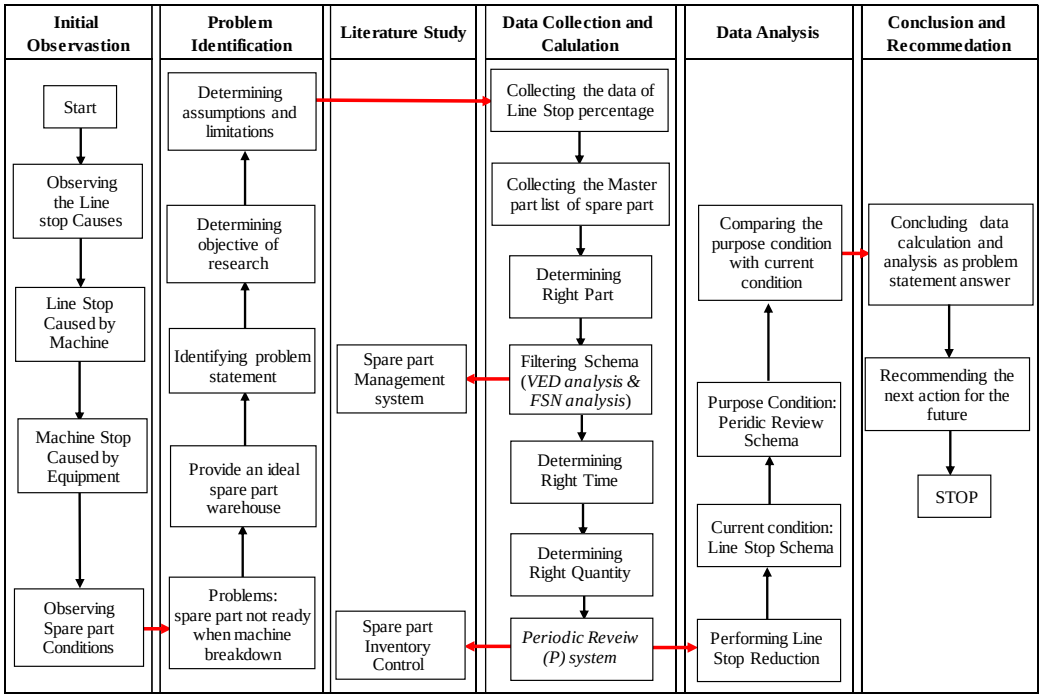


Fig 1:- Research framework

A. *Initial Observation*

The initial observation of this research started from observing the Line Stop causes in PT.XYZ. Actually, there are several causes that influence the total of Line Stop such as machine, man power, environment, etc. The observation performed by collecting the data of Line Stop causes in assembling shop from Summary Report Plant #2 of Machine Stop of PT.XYZ.After collecting the Line Stop data, the highest causes will be determining as the main focus to reduce the Line Stop which is equipment. As state before, the Line Stop that caused by equipment is related to the conditions of spare parts that caused the Machine Stop are longer to repair.

B. *Problem Identification*

There are several problems that needed to identify, related to Line Stop reduction caused by equipment. First of all, in order to reduce the time needed to repair the Machine Stop as one of the problem, the improvement that can be applied is providing a spare part warehouse in each work shop in PT.XYZ. The spare part warehouse expected to provide the spare part for maintenance activity for changing spare parts that already scheduled and repairing spare parts that not scheduled yet. However, PT.XYZ cannot build a big spare part warehouse for holding all spare part that already been used. Therefore, an ideal spare part warehouse that have a right part, a right time, and a right quantity have to provide in order to prevent the Line Stop happened that caused by equipment.

C. *Literature Study*

- *Spare parts Management System*

As an important role in achieving the target for decreasing the production cost, Spare parts management are needed to apply in case of reduce the Line Stop that caused by equipment. As known before, the Line Stop is one of prohibitively expensive conditions that cost so much lost. There are several problems faced by the company in controlling and maintaining spare parts. First of all, the spare parts itself have the uncertainty of spare part's usage when a part is required with different quantity. It is become complex due to the large number of different parts and low demand are usually occurs in actual condition. That's why, the failure of a part, either due to maintaining or repairing, cannot be predicted accurately.

The life cycle of spare parts is associated with the life cycle of the final products which use them. The demand of spare parts are affected by several factor such as size and age of the population of final product which are sales, running fleet, installed base, etc (Fortuin & Martin, 1999). It divides the life cycle of parts in three phases which is initial, normal or repetitive, and final. Throughout these phases, different decisions have to be taken (de Rego & de Mesquita, 2011):

1. To hold inventory or not: demands which are very low in the beginning of the life cycle (as well as in the end) lead the manager to question whether parts should be stored or not. For many items, the demand is so low that the decision of not storing, meeting the demand

circumstantially after its occurrence may be the best decision.
2. Initial orders: uncertainty about the demand growth hampers the planning of the initial orders.
3. Inventory control: upon deciding that the part needs to be stored, an inventory replenishment routine is necessary, considering different goals (costs and/or service level) and demand behavior (trends and seasonality).
4. Final orders: high production and maintenance costs of the productive processes associated with low demands and expected lifespan of products lead companies to interrupt the production of parts at a given time. In some cases, the last production batch is increased to provide additional spare parts final inventory.

The objective of spare parts management is to ensure the availability of spares for maintaining and repairing machine when required at an optimum cost which means to reduce Line Stop. There are many actions required to ensure that the spare part management are effective and efficient.
In order to ensure that the spare part management are successfully performed, it is essential to analyze the spare parts inventory based on various characteristics such as the frequency of issues, the annual consumption value, the criticality, the lead time and the unit price. There are several selection of policies for selective control in inventory analysis. The commonly selection technics used for selecting the spare part are ABC Analysis, FSN analysis, HML analysis, SDE analysis, and VED analysis(kumar & suresh, 2009).Regarding to research objective, the exact selection technic for this conditions are Vital-Essential-Desirable (VED) Analysis and Fast Moving-Slow Moving-Nonmoving (FSN) Analysis. Those selection technics also support the actual condition in PT.XYZ that classified their spare part based on machine rank and part rank.

- *Fast Moving-Slow Moving-Nonmoving (FSN) Analysis*

This selection technic is performing by filtering the spare part based on Frequency of usage. Actually, F, S, and N are stand for Fast moving, slow moving and Non-moving items. This form of selection identifies the frequently issued of spare part, for instance, the items can be classified as follows:

1. Fast Moving (F) = Parts that are issued below 1 years frequently.
2. Slow Moving (S) = Parts that are issued between 2 years until 5 years frequently.
3. Non-Moving (N) = Parts that are not issued\used for more than 5 years.

- Vital-Essential-Desirable (VED) Analysis

This selection technic performs by filtering the spare part based on the Criticality. There are several factors contribute to the criticality of a spare part. If a spare part is for a machine on which many other processes depend that can have caused Line Stop, it could be of very vital importance to be concerned. Also, if a spare is an imported component for which procurement lead time could be very high it's non- availability may mean a heavy loss. In general, criticality of a spare part can be determined from the production downtime loss as known as Line Stop, due to spare being not available when required.

Based on criticality, spare parts are conventionally classified into three classes which are vital, essential and desirable (kumar & suresh, 2009).

1. VITAL (V): A spare part will be termed vital, if on account of its non-availability there will be very high loss due to production downtime and/or a very high cost will be involved if the part is procured on emergency basis. In a process industry, most spare parts for the bottleneck machine or process will be of vital nature. For instance, bearings for a kiln in a cement plant will be considered vital.
2. ESSENTIAL (E): A spare part will be considered essential if, due to its non-availability, moderate loss is incurred. For instance, bearings for motors of auxiliary pumps will be classified as essential.
3. DESIRABLE (D): A spare part will be desirable if the production loss is not very significant due to its non-availability. Most of the parts will fall under this category. For instance, gaskets for piping connection.

This analysis helps in focusing the attention of the management on vital items and ensuring their availability by frequent review and reporting. Therefore, the Line Stop could be reduced to a considerable extent.

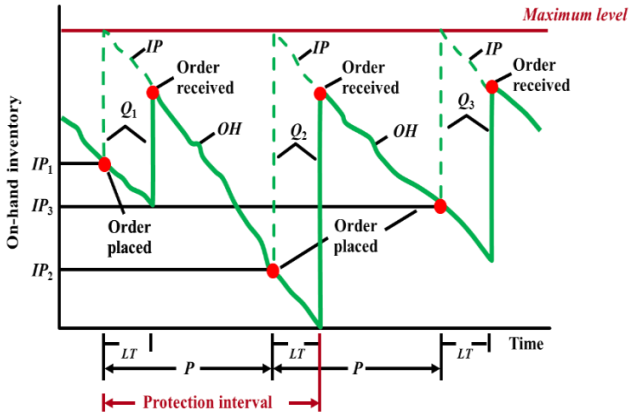
- Spare parts Inventory control

In case of spare part, managing inventories that have variability of demand and lead time are commonly happened. The variability of demand and lead time will create uncertainty during performing inventory control system. Those conditions make spare part inventory control can be defined as a multi-period inventory system with probability approach which have uncertainty of spare part's usage. Multi-period inventory systems are designed to ensure that a part will be available on an ongoing basis throughout the year. Usually, the item will be ordered multiple times throughout the year where the logic in the system dictates the actual quantity ordered and the timing of the order (Jacobs & Chase, 2013).

There are two general types of multi-period inventory systems which are fixed–order quantity models (also known as the economic order quantity (EOQ), and continuous review (*Q*) systems) and fixed–time period models (also known as periodic review (P) system). The basic distinction is that continuous review (*Q*) systems are "event triggered" and periodic review (P) system are "time triggered." That is, a continuous review (*Q*) systems initiates an order when the event of reaching a specified reorder level occurs. This event may take place at any time, depending on the demand for the items considered. In contrast, the periodic review (P) system is limited to placing orders at the end of a predetermined time period; only the passage of time triggers the model.

The Periodic review (P) system is an inventory control system that specifies inventory is ordered at the end of a predetermined time period. The interval of time between

orders is fixed and the order quantity varies. In periodic systems, the amount of inventory on hand is assed at periodic intervals such as weekly or monthly. A variable quantity is enough to bring the inventory on hand and on order up to a specified level. Usually, Periodic systems are more useful for process that call for a consistent use of part and for conditions where a single review period can be used to identify several parts that can be combined into one door. The illustration of periodic system will show in figure below, where *q* is the order quantity, P is the periodic, IP is the inventory position, SS is the safety stock, OH is on-hand inventory, and LT is the lead time.



Source: Monks, 1996, p.252
Fig 2:- Periodic review (P) system when demand is uncertainty

As described before, inventory is counted only at particular times, such as every week or every month in a Periodic review (P) system. Counting inventory and placing orders periodically are desirable in situations such as when company makes a spare part ordering policies that have to order and record every month or every 2 month depending to the policies and also balancing the budget of maintenance department. Periodic review (P) system generate order quantities that vary from period to period, depending on the usage rates. These generally require a higher level of safety stock than a fixed–order quantity system.

Periodic review (P) system assume that inventory is counted only at the time specified for review. It is possible that some large demand will draw the stock down to zero right after an order is placed. This condition could go unnoticed until the next review period. Then, the new order, when placed, still takes time to arrive. Thus, it is possible to be out of stock throughout the entire review period, placing order (T), and lead time (LT). Therefore, safety stock must protect against stock outs during the review period itself as well as during the lead time from order placement to order receipt.

There are several calculation that should be performed while conducting Periodic review (P) system as spare part inventory control which are computing average demand ($\bar{d}$), standard deviation (σ_{L+T}), Z-*value*, safety stock *(SS)*, and order quantity *(q)*.

The calculation of average demand will show in equation below, where n is the number of time range usage that can be in day, week, and month (Jacobs & Chase, 2013).

$$\bar{d} = \frac{\sum_{i-1}^{n} d_i}{n}$$

Then, the standard deviation of the demand can be calculate by (Jacobs & Chase, 2013):

$$\sigma_d = \sqrt{\frac{\sum_{i-1}^{n}(d_i - \bar{d})^2}{n}}$$

Next, the standard deviation of a sequence of independent random variables equals the square root of the sum of the variances. Therefore, the standard deviation during the period T + LT is the square root of the sum of the variances for each period (Jacobs & Chase, 2013):

$$\sigma_{L+T} = \sqrt{\sum_{i=1}^{T+L} {\sigma_d}^2}$$

Or

$$\sigma_{L+T} = \sqrt{(T+LT){\sigma_d}^2}$$

Finally, *Z value* are depending on the service level that company decided. The service level is a treatment policy for customers when there are stock outs; commonly established either as a ratio of customers served to customers demanding or as a ratio of units supplied to units demanded. If the service level already decides, the *Z value* simply can be determining by seeing the Z table or using the Excel NORMSINV function in Microsoft Excel because the value of z is dependent on the probability of stocking out or service level.

As know before, In a Periodic review (P) system, reorders are placed at the time of review (T), and the safety stock that must be reordered can be calculated by (Jacobs & Chase, 2013):

$$SS = Z\sigma_{L+T}$$

In Periodic review (P) system, the condition of spare part's usage is a review cycle of T and a constant lead time of LT. In this case, demand is randomly distributed about a mean$\bar{d}$. Therefore, the quantity to order *(q)* is (Monks, 1996):

$$q = \bar{d}(T + LT) + Z\sigma_{L+T} - I$$

Where,

q = Quantity to be ordered
T = The number of days between reviews
LT = Lead time in days (time between placing an order and receiving it)
$\bar{d}$= Forecast average daily demand
z = Number of standard deviations for a specifi ed service probability
σ_{L+T}= Standard deviation of demand over the review and lead time

I = Current inventory level (includes items on order)

D. Data Collection and Calculation

The data collection started from collecting the data of Machine Stop in assembling shop. Actually, the amount of Line Stop is confidential which means cannot be publish to the public. However, the percentage of Machine Stop causes are already enough to conduct this research. In this case, the Machine Stop percentage will be calculated as the Line Stop percentage in assembling shop. The percentage of Machine Stop causes data are Quality, Process, Equipment, and Supply. The data of Machine Stop causes will show how much the causes contribute to the total Line Stop in PT.XYZ.

Then, data collection continued with collecting the master part list that used in PT.XYZ. Since this research try to reduce Line Stop caused by equipment that related to the spare part, the master part list was necessary to be collected. The master part list will help the researcher to know what kind of spare parts that used in assembling shop. Hence, the master part list will help the researcher in filtering the spare part for decided the right part for storing in new spare part warehouse.

- *Determine Right Part*

In determining right part, the master part list that used in PT.XYZ have to be filtered. These filtering steps are useful for selecting the spare part in order to store in new spare pare warehouse. As known before, there are 8.169 part that used in every work shop in PT.XYZ. Those parts have to filter based on the unique part and common part for each work shop. Because of the research objective that would like to reduce the Line Stop, the critical spare part that caused Line Stop have to give more attention. Also, the fast moving part which means the frequency of spare part's usage are high also have to be concerned. The filtering step are performed by using Microsoft Excel. The filtering schema also using Vital-Essential-Desirable (VED) Analysis and Fast Moving-Slow Moving-Nonmoving (FSN) Analysis in order to make the filtered more accurate. Therefore, the filtering schema are shown in following Figure 3.

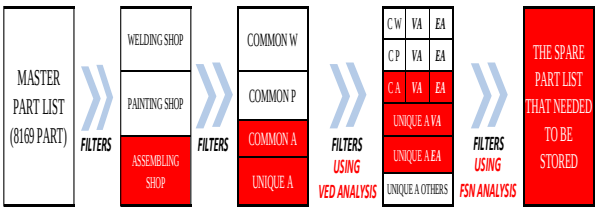


Fig 3:- Filtering Schema

As shown in Figure 3, the filtering schema started from filtering all spare parts that used in assembling shop. Then, researcher filtered the spare part into common part and unique part. Only unique part and common part that used in assembling shop will filtering using Vital-Essential-Desirable (VED) Analysis.

Actually, this analysis classified spare parts based on criticality. In this case, the critically refers to the spare part that can constantly cause Line Stop. The criticality is based on the machine rank matrix and part rank matrix. The following machine rank matrixes will show in table below.

		LINE STOP	
		O	X
BACKUP	O	E	D
	X	V	D

Table 1. Machine rank matrix

In Machine rank matrix, the machine that have no back up and caused Line Stop, will be categorize as Vital (V) which means become the first priority. Then, the machine that have back up and caused Line Stop, will be categorize as Essential (E) which means become the second priority. Finally, the machine that have back up or not and not caused Line Stop, will be categorize as Desirable (D) which means become the third priority. Because of limitation of time and resources, this research just focusses on the first (V) and second (E) priority. Next, the following part rank matrixes will show in table below.

		MACHINE		
		V	E	D
PART	A	VA	EA	DA
	B	VB	EB	DB

Table 2. Part Rank matrix

In Part rank matrix, Part category A are classified as a functional part which means if the part was broken, the machine will stop. Then, Part category B are classified as non-functional part which means if the part broken, the machine will not stop. Because of the research objective would to reduce Line Stop, the Vital-Essential-Desirable (VED) Analysis only focus on VA category and EA category. Finally, the result of this analysis will filter again using Fast Moving-Slow Moving-Nonmoving (FSN) Analysis.

As explaining before in literature study, the Fast Moving-Slow Moving-Nonmoving (FSN) Analysis help in filtering the spare parts based on frequency of usage. In this case, only Fast Moving part will be selected as the right part. Finally, the result of this analysis became the right part list to be stored in spare part warehouse. Those of the right part list will be determine the right time as the next data calculation.

- *Determine Right Time*

Regarding to the data of spare parts usage in PT.XYZ, the spare part inventory control will refer to Periodic review (P) system. It means that the placing order have to be define as the right time to order the spare parts. In determining the right time, researcher will analyze the actual condition of PT.XYZ related to order place policies and budget balancing of PT.XYZ. However, the data was confidential which mean cannot be shared to public. Therefore, the researcher

decided to make assumption for determining the placing order as the right time with several considerations.

- *Determine Right Quantity*

The spare parts that already select as the right part will be used in order to determine the safety stock and quantity as the right quantity. In determining the right quantity, the following of flowchart will be show in Figure 4.

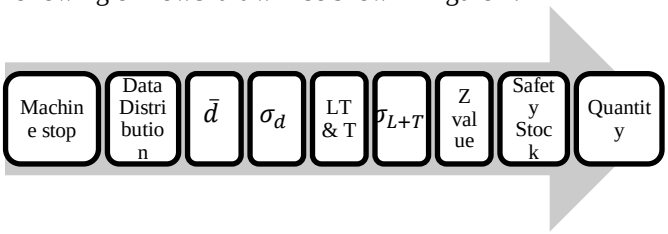


Fig 4:- Flowchart of determining the right quantity

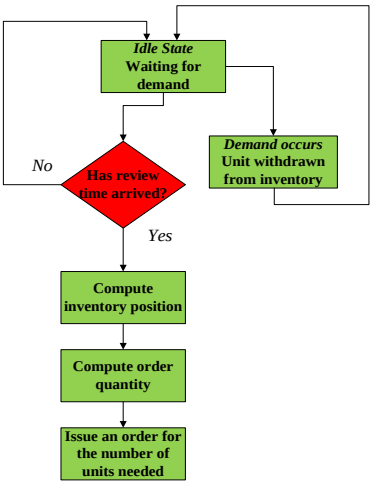
As shown in Figure 4, determining the right quantity are conducting by several step. First of all, The Machine Stop in each spare parts will be observed. This step is performed by comparing the spare parts changing schedule with the actual spare parts changing activity. If there is a spare parts changing activity without any scheduled before, that conditions will be records as Line Stop. It means that the maintenance personnel have to order and deliver the spare part from the main warehouse immediately without notice before which will increase the waiting time to repair that automatically effect to percentage of Line Stop.
Second of all, the actual spare parts changing activity will be record as the initial data. The distribution of those data will be analyzed. In this case, the researcher used STATFIT program to determine the distribution each spare parts by using *AUTOFIT* option for discrete distribution and *GOODNESS OF FIT* option for determining the p-value. The distribution of data is help us in seeing the data separation in order to determine what kind of formula that will be used in order to calculate the safety stock and order quantity.

Next, the researcher will calculate average demand *($\bar{d}$)*, the standard deviation, and Z value of each spare part. The way how to calculate average demand *($\bar{d}$)*, the standard deviation, and Z value have already been explained in Chapter II as literature study. The Z value in this case will follow the company service level value which is 90%. Moreover, there are two kind of standard deviation that need to calculate which are standard deviation during demand *(σ_d)*, and standard deviation during lead time and order place *(σ_{L+T})*. For additional, the lead time will be assuming as 1 month for each spares part regarding to company policies that already applied.

Finally, the safety stock *(SS)* and the quantity *(q)* will be calculated in order to determine the right quantity for spare part that already been selected. The way how to calculate the safety stock *(SS)* and the quantity *(q)* have already been explained in Chapter II as literature study. Actually,the quantity *(q)* will be calculated for first period or usually call the first quantity *(q_0)*. In first period, there are no on-hand spare part during that time. The $q_{1,\ 2,\ 3\ldots}$ will be determine during periodic review schema in case of line reduction.

- *Data Analysis*

The data analysis is started from analyzed the result of right part, right time, and right quantity calculations. In this case, the researcher used periodic review schema in order to prove whether the result of the right part, the right time, and the right quantity as criteria of an ideal spare part warehouse can reduce the Line Stop or not. The following periodic review schema will show in figure below.



Source: Jacobs & Chase, 2013, p.365

Fig 5:- Periodic review schema (Fixed–Time Period Reordering System)

As seen in Figure 5, the periodic review schema shows the decision to place an order is made after the stock has been counted or reviewed. Whether an order is actually placed depends on the inventory position at that time. The periodic review schema will help in determining the right quantity *($q_{1,\ 2,\ 3\ldots}$)*. When the review time arrived *(T)*, the researcher will compute inventory position which is On-hand part plus On-order. Then, the order quantity can be computed which is the first quantity *(q_0)* reduce to On-hand part and plus On-order. Therefore, the order for the number of parts needed can be issued.

Finally, the Line Stop for each condition of spare part can be determine by comparing the spare part need with spare part on-hand (stock) after periodic review schema applied. For additional information, the periodic review schema just proved for each machine that have already been selected as right spare parts that needed to store in spare part warehouse in assembling shop.

III. RESULT AND DISCUSSION

As the highest percentage of Line Stop caused, the equipment that related to the conditions of spare part still have several problems such as the availability of spare part, the quantity of spare part, and the best time to order the spare parts. Those problem can be eliminated by providing a spare part warehouse for handling an uncertainty condition happened especially when changing the spare part for repairing or maintaining activities.

Usually, for changing spare part activity, the maintenance personnel ordered the spare part to main warehouse for preparing the spare parts needed at least one month before schedule. However, the problem occurred when an uncertainty condition happened when the spare part needed are not available around the shop because the spare part needed are not scheduled yet. This condition can have increased the percentage of Line Stop caused by equipment because the maintenance personnel need to order and deliver the spare part immediately. Sometimes, the spare part needed also not available in main warehouse that will make the Line Stop are longer to repair than usual. It will cost the company so much lost if these uncertainty conditions happened. These uncertainty conditions can be described through the flowchart of handling the Machine Stop that will show in figure below.

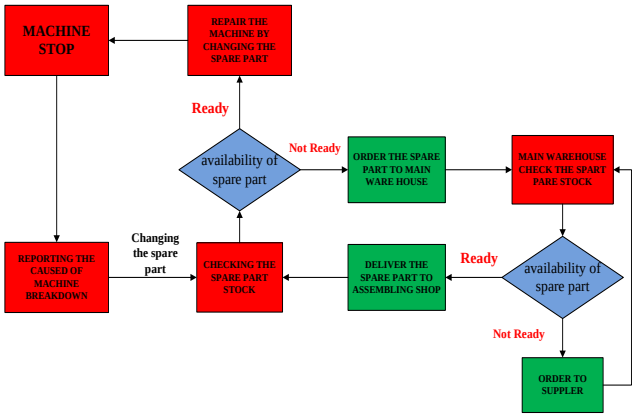


Fig 6:- The flowchart of handling the Machine Stop caused by spare part

When the Machine Stop, the worker will report the Machine Stop caused to maintenance personnel. In this case, the Machine Stop are caused by equipment that need to change the spare part to repair the machine. Then, the maintenance personnel check the availability of spare part around assembling shop. If the spare part is ready stock, the maintenance personnel will repair the Machine Stop immediately. However, if the spare part is not ready stock, it become the problem because there will be additional time to repair the Machine Stop. This condition is happened because the Machine Stop happened without any notice which means not schedule yet that classified as the uncertainty condition of spare parts.

A. Determine Right Part

In determining the right part, the following filtering schema will be conducted. The filtering schema started from divide the spare part into unique part and common part based on work shop. Then, the unique part of assembling shop and common part of assembling shop will be selected an initial data to be filtered using Vital-Essential-Desirable (VED) Analysis and Fast Moving-Slow Moving-Nonmoving (FSN) Analysis. The filtering schema will have performed using Microsoft Excel. In Microsoft Excel, the *SORT & FILTER* comment will be very useful because those common will make easier while filtered the spare parts that PT.XYZ used more accurately.

As known before, there are 8.169 part that used for all workshop. In data collection, the highest number of spare part usage are happened in assembling shop which equal to 2.809 unique parts. However, there are another common part that also used in all work shop which equal to 677 common part. Those common parts have to be filtered into assembling common part which means the part that used in assembling shop. The following of assembling filtered result are shown in figure below.

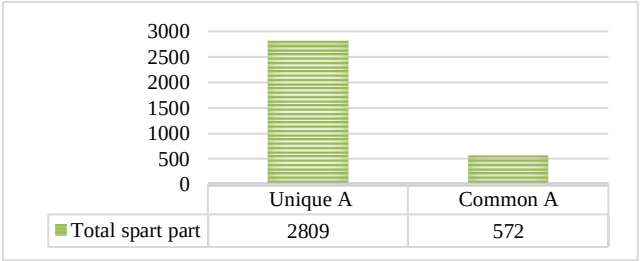


Fig 7:- Spare parts that used in assembling shop

The Vital-Essential-Desirable (VED) Analysis are a selection technic perform by filtering the spare part based on the Criticality. Regarding to the research objective, the critically in this case are related to the Line Stop. It means that the spare part has to filter as highest caused of Line Stop. Therefore, the Vital-Essential-Desirable (VED) Analysis can be performed by filtered the spare parts based on machine rank matrix and part rank matrix in order to select what kind of spare parts are the highest caused of Line Stop.

The Machine rank matrix are the way how to filter the machine that have to become the first priority. The machine rank matrix will filter the unique machine and common machine that used in assembling shop. The machines have already ranked by authorized persons of PT.XYZ. Those judgments from them will be determine the machine to several priorities. Finally, the machine that have back up or not and not caused Line Stop, will be categorize as Desirable (D) which means become the third priority. It means this categorize do not need to consider because there are no Line Stop if the machine is stop.Then, the Machine rank matrix will be used to filter spare parts by using the *SORT & FILTER* comment in Microsoft Excel. The following of machine rank result will be show in figure below.

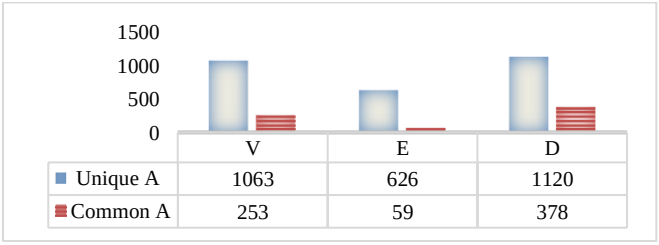
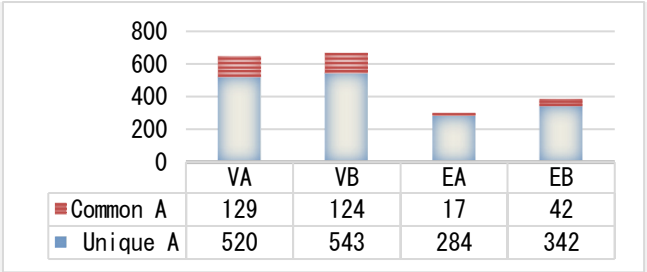


Fig 8:- The spare part filter's result based on machine rank matrix

Next, the spare part filter's result based on machine rank matrix will be filtered based on part rank matrix. The part rank will filter the part category in order to select the

right part that caused Machine Stop from unique and common machines. The part category has already ranked by authorized persons of PT.XYZ. Part categories A are classified as a functional part which means if the part was broken, the machine will stop. Then, Part categories B are classified as non-functional part which means if the part broken, the machine will not stop. Then, the Part rank matrix will be used to filter spare parts by using the *SORT & FILTER* comment in Microsoft Excel. The following of part rank result will be show in figure below.

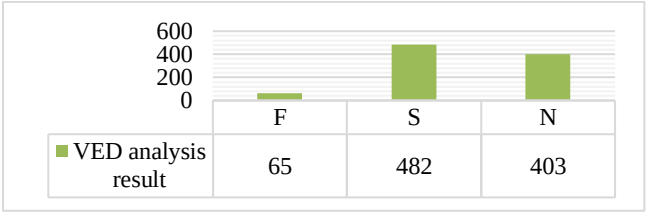


	VA	VB	EA	EB
Common A	129	124	17	42
Unique A	520	543	284	342

Fig 9:- The spare part filter's result based on part rank matrix

Regarding to research objective that would like to reduce the Line Stop, only the spare part that have rank VA and EA will be chosen to the next filtering step. It is simply because only Part Category A have contribution in Line Stop percentage. Then, Vital (V) and Essential (E) was the first and second priority as the criticality aspect. Hence, the total spare part that filter using Vital-Essential-Desirable (VED) are equal to 950 parts. Those parts will be filtered again using Fast Moving-Slow Moving-Nonmoving (FSN) Analysis in order to determine the part to be store more objectively.

The Fast Moving-Slow Moving-Nonmoving (FSN) Analysis will be conducted by authorized persons of PT.XYZ. In this case, the authorized persons will analyze of the total number of usage each spare part for several frequently time. For instance, in A/C Gas Charging machine which Coolant Valve part category, and Recovery Gun (IXX(S) 2S BSBM) as the spare part will be analyzed as yearly usage. The total number of spare part usage is four pieces. It means that there are four Recovery Gun in A/C Gas Charging machine are scheduled to change in 1 years. Hence, the Recovery Gun in A/C Gas Charging machine will be filtered as Fast moving parts. The other part also will be analyzed with the same way. The following of Fast Moving-Slow Moving-Nonmoving (FSN) Analysis result will be show in figure below after being analysis using Microsoft Excel.



	F	S	N
VED analysis result	65	482	403

Fig 10:- Fast Moving-Slow Moving-Nonmoving (FSN) Analysis result

Regarding to the actual condition in PT.XYZ, the fast moving part have the highest possibility in uncertainty condition that influence the Line Stop percentage caused by equipment. It means that the spare part that classified as Fast moving part more often broken than the slow moving part and non-moving part. Hence, only the fast moving parts (F) category will be selected as the right parts that needed to store in new spare part warehouse.

B. Determine Right Time

Because of the frequency of spare part's usage in PT.XYZ already scheduled, the Periodic review (P) system will be used as spare part inventory control method. In Periodic review (P) system, the placing order have to be define as the right time to order. The placing order (T) are needed in determining the right quantity for the right part that already selected. In this case, the placing order (T) can be assumed as *n* month.Regarding to the percentage of Line Stop caused data, the right time to order is can be assumed as 4 months as placing order (T).

C. Determine Right Quantity

In determining the right quantity, the spare part usage data of the right part that already selected to be store in spare part warehouse have to be compared. The total number of right part are 65 parts that will be analyzed and calculated in order to provide an ideal spare part warehouse in case of Line Stop.

Actually, there are two kind of spare part usage data that have to compare which is the changing spare parts schedule and actual spare parts changing activity. Both of data will give the percentage of Machine Stop that happened in each machine. The percentage of Machine Stop will be compared with the data percentage of Line Stop caused by equipment. Actually, the changing spare parts schedule already decided by PT.XYZ. Otherwise, the actual spare parts changing activity are the data that recorded from actual condition of spare part changing that have been recorded for each machine.

Next, the actual spare parts changing activity will be used in order to determine the distribution of spare part usage data. In determine the distribution, STATFIT program are used by using *AUTOFIT* option for discrete distribution. This program will help in determining the distribution of spare part usage data. Then, the p-value of spare part data usage will determine by using *GOODNESS OF FIT* option. In this case, the Periodic review (P) system with probabilistic approach can only be applied in the spare part usage data that have a Poisson characteristic.

Moreover, this program can automatically calculated the description of spare part usage data such as average demand($\bar{d}$), standard deviation(σ_d), variance, and so on. Actually, average demand($\bar{d}$) and standard deviation(σ_d) can be calculated using formula that already explain in Chapter II. For instance, In ASSY-012, the calculation of average demand($\bar{d}$) and standard deviation (σ_d) will be shown in equation below.

$$\bar{d} = \frac{1+1+1+0+0+1+0+0+1+0+0+1}{12}$$

$$= 0{,}5\sigma_d = \sqrt{\frac{\sum_{i-1}^{12}(d_i - 0{,}5)^2}{12}} = 0{,}52223$$

For the rest calculation, the STATFIT program will be used in order to determine the data distribution and calculated the average demand($\bar{d}$) and standard deviation (σ_d) of 65 parts that already selected as the right part. The Poisson characteristic will be choosing as data distribution in order to apply Periodic review (P) system for calculating the right quantity.

After determining the distribution data, average demand($\bar{d}$) and standard deviation during demand (σ_d), the standard deviation during lead time and order place (σ_{L+T})have to be calculated. Actually, in calculating standard deviation during lead time and order place (σ_{L+T}), the lead time (LT) and placing order (T) have to determined. As explained before, the lead time (LT) will be assumed as 1 month for each parts. It simply because the lead time just record from main warehouse to the spare part warehouse in case of ordering and delivering time. Moreover, the placing order (T) also have been assumed as 4 months as the right time to order that already discussed before. Therefore, the standard deviation during lead time and order place (σ_{L+T})can be calculated by using the formula 3.The calculation using formula 3 will be apply for calculating 65 parts as the right part. For instance, in ASS-012, the calculation of standard deviation during lead time and order place (σ_{L+T}) will be shown in equation below.

$$\sigma_{L+T} = \sqrt{(4+1) \times 0{,}52223^2} = 1{,}1677$$

Next, the safety stock (SS) will be calculated in order to determine the right quantity using Periodic review (P) system. In calculating the safety stock, the service level has to be determined. As explained before, the service level will influence the Z value that used in calculating the safety stock (SS). The service level of PT.XYZ is 90%. It means that only 10% of total problem can be accept happened in PT.XYZ. This service level already been deciding by PT.XYZ. Therefore, the Z value of 90% service level are equal to 1, 28 which can be calculated by seeing the Z table or using the Excel *NORMSINV* function in Microsoft Excel. Hence, the safety stock (SS) can be calculated using formula 4. Forexample, in ASS-012, the calculation of safety stock (SS) will be shown in equation below.

$$SS = 1{,}28 \times 1{,}1677 = 1{,}495 \approx 2$$

Finally, the quantity can be calculated for 65 parts as the right part. The following formula 5 will described below.

For instance, in ASS-012, the calculation of quantity (q_0) by using formula 5 will be shown in below.

$$q_0 = 0{,}5(4+1) + (1{,}28 \times 1{,}1677) = 3{,}9946 \approx 4$$

The quantity *(q)*, can be determine by sum the average demand over the vulnerable period and safety stock. Then, the sum total will be reduced by one-hand inventory *(I)*. In determining the right quantity, the first period quantity *(q_0)* will be determined by assuming there are no on-hand inventory which means I = 0. Then, the $q_{1,\ 2,\ 3\ldots}$ will be determine during periodic review schema as data analysis. The result of safety stock (SS) and quantity (q) will always round up. It simply because in spare part, there is no a half of spare part needed in actual condition. The rest of calculation of safety stock (SS) and quantity (q) will be conducted using Microsoft Excel for 65 parts.

D. Periodic review schema

The result of data calculation which are the right part, the right time, the right quantity will be analyzed whether those result can reduce the Line Stop percentage that caused by equipment in assembling shop or not. As calculated before, there are 65 part that need to store in spare part warehouse. The placing order time, safety stock, and quantity already determined for all those parts by using Periodic Review (P) system.

However, there will be only 14 spare part selected in order to prove Line Stop reduction from this result. This decision decided because the right part list is happened for 14 machine which means the 65 parts are belong to 14 machine in assembling shop. Because of the Line Stop influenced by Machine Stop, only one part from each machine need to be prove whether successfully reduce the Line Stop percentage or not. Moreover, the Machine Stop that caused by the spare part are usually have same characteristic in spare part problem even though still cannot be predict exactly.

As explain before, the Periodic system schema will show the decision to place an order after the stock has been counted or reviewed. The periodic review schema will determine the quantity *($q_{1,\ 2,\ 3\ldots}$)* when the review time arrived *(T)*. The inventory position will have calculated which is On-hand part + On-order. Then, the order quantity also will have calculated which is the first quantity *(q_0)* reduce by On-hand part + On-order. Therefore, the order for the number of parts needed can be issued.

For instance, the Periodic review schema will apply in ASSY-012. First of all, the current condition of ASSY-012's Line Stop schema will be conducted. The following ASSY-012's Line Stop schema will show in table below.

	MONTHLY DATA											
	1	2	3	4	5	6	7	8	9	10	11	12
Planed spare part needed	0	0	1	0	0	1	0	0	1	0	0	1
actual spare part needed	1	1	1	0	0	1	0	0	1	0	0	1
Receive spare part	0	0	1	0	0	1	0	0	1	0	0	1
Stock	-1	-1	0	0	0	0	0	0	0	0	0	0
Order Spare part	0	1	0	0	1	0	0	1	0	0	1	0
Judgment	Line Stop	Line Stop	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal

Table 3. Line Stop schema of ASSY-012

As seen in Table 3, the Line Stop schema of ASSY-012 are conducted with current inventory control in PT.XYZ. As mentioned before, the ordering spare part are order one month before without any safety stock. Then, the Line Stop happened in first and second month. It happened because there is no planed spare part needed in those months. However, in actual condition, there are spare part needed for those months. It will record as Line Stop condition because the stock in those month are minus (-1) conditions which means need additional spare part. Therefore, the average of Line Stop percentage for this schema is equal to 17%.Then, the Periodic review schema will be applied to reduce the Line Stop percentage in this spare part problem. In this case, the additional four months will make the Periodic review schema more accurate in solving the spare part problem in reducing the Line Stop percentage. It means the Periodic review schema can be used in future because the data distribution of the spare part usage data is following Poisson distribution that will make the spare part usage data will always fit to the Periodic review schema.

Moreover, this consideration already applied by PT.XYZ in actual condition that making the decision more focus in reducing the Line Stop rather than reducing the holding cost and ordering cost. The following Periodic review schema of ASSY-012 will be show in Table 4.

	MONTHLY DATA																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Planed spare part needed		0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0
actual spare part needed		1	1	1	0	0	1	0	0	1	0	0	1	0	0	2	1
Receive spare part		4	3	2	1	4	4	3	3	4	3	3	3	4	4	4	2
Stock		3	2	1	1	4	3	3	3	3	3	3	2	4	4	2	1
Order Spare part	4				3				1				2				3
Judgments		normal	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal

Table 4. Periodic review schema of ASSY-012

As shown in table above, the order spare part will be based on Periodic review system. For ASSY-012, the quantity of spare part that needed to order in first period *(q_0)* is equal to 4 parts. Then, the spare part condition will be review every 4 months as placing order (T). Every four months, the maintenance personnel will check the inventory level for ASSY-012. Next, the ASSY-012 will order based on the calculation that already explain before. In this case, in fourth month, the ASSY need to issues are 3 part in order to prevent any uncertainty condition in future.

As result, there are no Line Stop condition happened in ASSY-012. Although there is unpredictable spare pare needed in fifteenth and sixteenth month, the stock of spare part in spare part warehouse still can handle an unpredictable spare pare needed as uncertainty condition. Therefore, the average of Line Stop percentage in ASSY-012 can be reduce until 0% if the periodic review (P) system applied.

Finally, the rest of 14 parts selected before will be analyzed using Periodic review schema like illustrated before. The Periodic review schemas will show how much the Line Stop percentage can be reducing by comparing the current condition with purpose condition. The following result of Periodic review schema will show in table below as Line Stop Comparison.

No. item	Spare Part	Specification	Line Stop Percentage		Total reduction
			Current	Purpose	
ASSY-012	RECOVERY GUN	IXX(S) 2S BSBM	17%	0%	17%
ASSY-016	BEARING	6205ZZ	8%	0%	8%
ASSY-021	OILES BUSH	LFB-1815	8%	0%	8%
ASSY-033	OILES BUSH	SPF-1620	8%	0%	8%
ASSY-040	OILES BUSH	70B-3025	8%	0%	8%
ASSY-042	OILES BUSH	LFB-9090	17%	0%	17%
ASSY-047	ROLLER CHAIN	RF50-228L	8%	0%	8%
ASSY-048	OILES BUSH	LFB-0807	8%	0%	8%
ASSY-049	NUTRUNNER	ETV ST61-30-10	8%	0%	8%
ASSY-051	NUTRUNNER	ETV ST101-370-20-F	8%	0%	8%
ASSY-057	OILES BUSH	SPB-101420	8%	0%	8%
ASSY-062	OIL CLEANER	AS2250A(AC200V)	8%	0%	8%
ASSY-063	TYPE 600 FORGED BRASS BALL VALVE	TK-1/2B	8%	0%	8%
ASSY-065	VACUUM PAD	PUYKB-80-N	8%	0%	8%
		Average Total	10%	0%	10%

Table 5. Line Stop Comparison

As seen in Table 5, the average total of current condition is equal to 10 % which caused the Line Stop. Then, after applying the Periodic review schema, the average total of purpose condition is equal to 0 % which means there no Line Stop happened that caused by equipment. It means that the Periodic review schema successfully reduce the Line Stop percentage caused by equipment in assembling shop.

Since the Periodic review schema just applied to 14 parts of main machine in assembling shop, the percentage of Line Stop caused by equipment cannot be proved accurately. The Periodic review schema have to apply for the whole 65 part that selected as the spare that need to store in spare part warehouse. As explained before, the 65 parts have similarity in spare part usage data that have a Poisson distribution. It means that the Periodic review schema also can be applied to 65 parts. It means that the efficiency in assembling shop still can be improved if the purposed improvement will apply to all spare part especially to 65 parts as the right part to store in ideal spare part warehouse in order to achieve the target more accurately.

Hence, the ideal spare part warehouse as purposed improvement that provided in order to reduce Line Stop percentage caused by equipment are successfully have been provided. The Line Stop percentage caused by equipment can be reduced equal to 10 % on average after proved in 14 main machine in assembling shop by using spare part management and inventory control. This purposed improvement which is providing an ideal spare part warehouse in case of Line Stop reduction are believed can help PT.XYZ in achieving their target to reduce the Line Stop percentage caused by spare parts.

IV. CONCLUSION

First of all, the way to reduce Line Stop percentage in assembling shop can be conducted by providing an ideal spare part warehouse as purposed improvement which has right part, right time, and right quantity. Those of criteria already determined by using Vital-Essential-Desirable (VED) Analysis, fastMoving-Slow Moving-Nonmoving (FSN) Analysis as a spare part management methods, and Periodic Review *(P)* system as a spare part inventory control methods that already success reduce 10 % on average of Line Stop percentage after proved in 14 main machine in assembling shop. Second of all, the right part that needed to store have been determined by using the filtering schema that used the Vital-Essential-Desirable (VED) Analysis and Fast Moving-Slow Moving-Nonmoving (FSN) Analysis as spare part management system methods. As a result, the right part already filtered from 8.169 parts become 65 parts. Those parts are selected as the right part that need to store in the new spare part warehouse in order to provide an ideal spare part warehouse in case of Line Stop reduction in assembling shop. Third of all, the right time to order has been decided as the best time to order the spare parts. In this case, the right time will become the placing order (T) that equal to 4 months. It means that every 4 months, the spare part warehouse will be review in order to make sure the spare part warehouse can always provide the spare part needed in case of Line Stop reduction in assembling shop. This right time can be used to prevent uncertainty condition that usually happen in spare part case. Finally, the right quantity has been determined. The right quantity is calculated with Periodic review (P) system as one of spare part inventory control methods. This Periodic review (P) system already calculated the right quantity for 65 parts that already selected as the right part.

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