8 Baskets Inventory System

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Abstract

The 8 baskets inventory analysis is exploited to the spare part management for the maintenance approach and to be developed from the ABC analysis. This analysis has contributed from 3 factors as movement, necessity (critical) and cost. With the 3 dimensions (3D) matrix are to be obtained for analyzing the inventory and stock level of the spare parts for ensuring those spare parts are to be optimized. The 3D matrix of 8 baskets inventory system that has been decomposed the spare parts type into 8 classes (baskets) which are to be optimized them in accordance with the inventory management concept. This management system will reduce the amount of spare parts keeping in the inventory system, reduce the expense of maintenance cost and eliminate the complicated management in spare part inventory.

Keywords: inventory system, 8 baskets, spare part optimization
1. Introduction

The 8 baskets inventory system is adopted for the maintenance approach and developed from ABC analysis. The ABC analysis does not emphasize on the spare part necessity (critical part), it only cares with the usage quantity of materials and material cost. Some parts are scarcely used but they have necessity (critical) to the system. If there is some damage with this part then the new one has to be replaced immediately such as a main circuit breaker and so on. Therefore, these materials have to be stocked and replaced immediately whenever it damages. Basically, 8 baskets inventory system composes of 3 elements as Movement, Necessity and Cost. Movement is not using quantity of materials/parts same as ABC analysis. But movement is the flowing of materials/parts usage, some parts may not be the majority parts but they always defect or damage on anytime (usually, those parts are used at the high work load locations then they have chances to be defect). Necessity (or critical) is the parts that have vital to a system if there is some damage/defect then the new one has to be replaced as soon, cannot wait on anytime such as the circuit breaker. Normally, the necessity parts have to be stocked at least one unit but it not limit. Sometimes we have to spare more than one, depend on the using location. Cost is the valuable parts. Actually, these are specific parts, cannot buy them in the common market, we have to directly purchase from the supplier or producer.

2. Relevant literatures and Relate works

The complexity of spare part management is a big problem for all manufacturers. Especially, we would realize that big factory or central warehouse of multi-echelons is usually had plenty of spare parts or a lot of components. More parts have more complicated management and have driven more cost, then the good management will have been adopted and exploited in according to reduce the required spare parts or material repairs. Nevertheless we cannot avoid stocking all of them but some ease have to stock as least as possible.

However, most of previous research studies such as [1], [8], [9], and [10] have been attempted to obtain the spare parts optimization. Most of them look forward to minimize the spare parts usage by concentrating with the causes of parts using such as system availability [13] and reliability, maintainability, demand on lead-time [11]. Some of those studies try to eliminate the causes of the spare part problems [12] such as try to forecast the accuracy spare part demand, try to solve and establish the complicated mathematic of parts usage and its models [5], [6], and [7] minimized the factors which have effected to spare part wastes, inventory control under some constraints such as [13] and so on. Moreover, some case studies have learned with the concept of multi-echelons and pull part concept and inventory management such as [14], and [15].

Unfortunately, almost of them has studied without insight in management of the spare parts classification and characteristic to use. There are some papers that study with this matter but they do not interest and care with some important factors such as [16] has studied and suggested Information Technology for spare parts management, therefore our research study has oriented and fulfilled these tiny points but it is the better way and easier to initiate the conceptual of spare part management and more reliable than the previous research studies. By the conceptual of spare part type classification that is look quite similar to the ABC analysis, it will be illustrated and provided the new context solution of spare part management which is optimized the required spare parts in the inventory system.

3. The 3 dimensions analysis

The 3 dimensions (3D) matrix has to be exploited for analyzing the inventory and stock level of the spare parts in the store or storage system for ensuring that spare parts are optimized. Figure 1 has shown the 3D matrix of 8 baskets inventory system that has been decomposed the spare parts type into 8 classes (baskets) as follow:

Basket 1 – FMH : Fast-Much-High
= Perpetual Inventory Model (PIM)
Basket 2 – FML : Fast-Much-Low
= Maximum Model (MaxM)
Basket 3 – FLH : Fast-Less-High
= Shortage to Maximum Model (SMM)
Basket 4 – FLL : Fast-Less-Low
= Shelves Inventory Model (SIM)
Basket 5 – SMH : Slow-Much-High
= Minimum Stand-by Model (MSM)
Basket 6 – SML : Slow-Much-Low
= Two Bin System (TBS)
Basket 7 – SLH : Slow-Less-High
Basket 8 – SLL : Slow-Less-Low

Basket 8 – SLL : Slow-Less-Low
= Minimum Model (MinM)

3.1 Basket 1 – FHM (Fast-Much-High)
This material type is usually been an unique part, independent demand, used for main production line with no redundancy, and usually been an electro-mechanical or mechanical part with high speed, high tension, high pressure, high workload or work 24 hours. Normally, this is a specific part and cannot be repaired if there have some damages or defects then the new part will have to be immediately replaced such as shaft, pulley, bearing, solenoid, motor, reducer gear, conveyor (belt). Basket 1 is to be considered and managed by Perpetual Inventory Model (PIM) [2] with Safety stock (see figure 2).

\[
Q = \frac{2n}{\lambda S} \quad (1)
\]

Where: 
- \( Q \) is Economic Order Quantity
- \( A \) is annual demand
- \( S \) is purchasing cost per 1 time (or once time setup cost)
- \( C \) is material cost per unit
- \( I \) is holding cost (percentage of material cost)

Whilst, the annual demand of repairable system \( A \) is observed from the breakdown/failure events which are the multiply between annual failure rate \( \lambda \) and total parts in system \( n \), then:

\[
A = \lambda \cdot n
\]

So,

\[
Q = \frac{2n\lambda S}{N} \quad (2)
\]

The equation (2) does not interest with the variation. But in the real world, the failure rate variation sometime is affecting to the demand rate.

\[
\text{Demand (A)} = (\lambda + Z\sigma)^* n \quad (3)
\]

If the failure rate is exponential distribution then variance is

\[
\text{Variance} = \lambda^2
\]
equal to failure rate, so:

\[ A = (Z + 1) n \lambda \]  

(4)

Therefore, the safety stock will be applied to ensure that is no any shortage. Anyway, the materials in this basket are usually too expensive so we would not stock them too many (normally, it is depended on required service level). Supposedly, demand on lead time is same as the previous period. Then safety stock is:

\[ SS = (\overline{D} + Z \sigma)T - DT \]

\[ SS = Z \sigma T \]  

(5)

If the distribution is exponential distribution then \( \sigma \) is \( \overline{D} \), so:

\[ SS = Z \overline{D}T = Zn \lambda \overline{T} \]  

(6)

Where: SS is safety stock  
\( \overline{D} \) is average demand  
\( Z \) is density probability function of exponential distribution  
\( T \) is purchasing cycle time (time between repurchase)  
\( \sigma \) is standard deviation of exponential distribution  
\( \lambda \) is failure rate (in one year)

**Figure 4: The variation of spare parts usage**

**Source:** Adapted from [3]

Regarding to figure 4, if we do not care with lead time because lead time does not have an affecting with safety stock but the variation is principal. Therefore, to be avoid the too big safety stock then we have to repurchase at a short time is rather than long time. Practically, these materials type have a fast movement so the safety stock is depended on the failure rate and required service level. Principally, if the system has too many components then \( n^2 \lambda \) is too greater than \( Z \), so for this case, we have cared only the number of components (which are same function and same condition) and annual failure rate.

### 3.2 Basket 2 – FML (Fast-Much-Low)

This material type is independent demand, general used items to be used for support, such as material support, internal lubricant, sealant, fixing material. Normally, this basket contains the small shape with to be used for high speed or high tension parts but it has been vital for the system. Usually, these materials in this basket can be bought in the common market. They are not to be neither specific nor special parts. If there is some damage, the new parts have to be immediately replaced or repaired such as gasket, driving belt, chain, sprocket, spoke, set screw, bolt & nut, washer, ring, common fuse. Another part in this basket is the forceful equipments or refurbishment components such as general or common tool (cutting saw, milling tools). Basket 2 is to be considered and managed by Maximum Model (MaxM). Normally, the amount of demand is observed by previous period (year) historical data. The purchasing quantity of this model is looked quite similar to Perpetual Inventory Model (PIM) with safety stock but the minimum stock of MaxM is the minimum required spare parts. This is depended on the determination of basic usage which is not quite similar to safety stock that is come from the uncertainty demand on lead time. And the purchasing quantity is purchased at the maximum using (on given period).

The new parts will be replenished in the store or stock inventory as soon when some of them are used until the determined stock level (replenishment before they reach the determined level, no stock out), because we can buy them in the common market, low cost and normally these material type is durable products then the holding cost is also low, especially they have been an essential to a system.

**Figure 5: The Maximum Model (MaxM)**

Normally, the average demand for each period does not same (slope, see figure 5). We care only the minimum stock level and average inventory level. If the spare parts are used until reach the average inventory stock level (under an average
inventory and above minimum level), then the replenishment parts will have to be refilled to the store or stock inventory.

\[ Q_{\text{MAX}} = MS + Q_0 \]  

(7)

Re-Order Point (= Average Stock)

\[ \text{Average stock} = \frac{Q_{\text{MAX}}}{2} \]

Whilst, the minimum stock level is,

\[ MS = \text{Maximum demand on lead time} \]

And the purchasing order is:

\[ Q_i = \text{maximum demand–demand after pass average inventory} = \frac{Q_{\text{MAX}} - x}{2} \]  

(8)

While: \[ x = d^*t_i \]  

(9)

Where: \( x \) is require inventory after pass average stock

\( d \) is average demand

\( t_i \) is time period after pass the average stock

Practically, it is very difficult to find the average demand and time period after pass the average stock therefore we will avoid this matter. Alternatively, whenever the inventory reaches the average inventory stock level, we will have repurchased the new order and the purchasing order is normally equal to the \( Q_0 \) so the inventory stock level after replenishment should more than \( Q_{\text{MAX}} \) in accordance with the demand rate of each period and replenishment again after the stock level pass the average stock.

3.3 Basket 3 – FLH (Fast-Less-High)

This material type is independent demand, usually been an optional part (or supplementary) with high speed and high tension using, specific shear waste materials or special tools such as cutting tool for milling, lathe, saw, ink or toner (for printer), data backup components (magnetic tape, DVD, CD), machine facility, special lubricant (for food grade). Whenever there is some damage then the new parts are not necessarily changed or replaced suddenly, we can either use the options or other machines, no need to repairs or replaced its as soon. Basket 3 is to be considered and managed by Shortage – Maximum Model (SMM) or modifying Q-System. This model is look like the Fixed Order Size System (Q-System) but it allows the parts to be shortage and the purchasing quantity (Q) is maximum using quantity same as Maximum Model. Practically, this basket contains the high cost materials then this model allows stock-out although the movement is fast but we can wait its until the new parts are arrived. Normally, this basket contains the high cost materials but we can sometime buy them in the common market, or has to wait them arrive on a short time.

![Figure 6: The Shortage to Maximum Model (SMM)](image)

\[ Q = Q_{\text{MAX}} = \text{the average demand} + \text{variation (at maximum)} = \bar{D} + 3\sigma \]  

(10)

If we require maintain the inventory at \( Q_{\text{MAX}} \), then the required service level have to be 100% therefore Z is 3.0 (suppose, these materials is normally distributed). Replenishment (re-order point) whenever the materials are empty (zero inventory).

\[ Q = \bar{D} + 3\sigma \]

Re-Order Point = Zero inventory (Empty)

3.4 Basket 4 – FLL (Fast-Less-Low)

This material type is independent demand, usually been an accessory or consumable material which is non-durable and shear waste materials or constituent materials. Normally, there has a certainty life time, change or replace it whenever it expires such as external lubricant, grease, oil, battery, filter, brush, color, anti corrosion, spray and sub-material. Basket 4 is to be considered and managed by Shelves Inventory Model (SIM). Normally, this basket has too many sub-shelves for keeping the miscellaneous components or accessory parts and it is look like shelf module then we will call this model as “Shelves Inventory System”. Because each of them have too many sub-type such as color (e.g. red, green, blue, etc.), grease and oil is also has too many grades, sub-material (such as paper for dot matrix printer, laser printer), accessory and miscellaneous with no force (nut & bolt, spring, washer, ring). Besides this, it is not so expensive, movement is fast and low necessity with the small shape. Indeed, we have to stock them at the maximum stock level but the
materials in this basket are usually have too many sub-types (as
mention before) and some of them have a short period duration
such as battery, color etc. so, the optimal stock is rather
preference than the maximum stock.

Usually, the materials in this basket contains the sheer waste material and
sub-material so we can buy them in the common market
nevertheless they are too many sub-classes (need too many
space to keep some materials) and some of them have been
expired such as color, grease, battery and so on, then these
materials are possible to stock-out and bought them again
whenever they are empty and purchasing quantity is same as
fixed order Interval System (P-System, see figure 7).

\[
P = \frac{Q}{A} \sqrt{\frac{2AS}{CI}} = \sqrt{\frac{2S}{CIA}}
\]

(11)

Basically, an optimal inventory for the first purchasing is
same as EOQ (Perpetual Invent ory Model) but we do not care
with the safety stock because we have allowed the inventory to
be stock-out. Then the target inventory is:

\[
T = \frac{D}{A'}
\]

(12)

Where: \( T \) is target inventory
\( A \) is annual demand
\( D \) is average demand on \( P+L \)

Practically, the materials in this basket is usually had a short
lead time and we allow the inventory to be stock-out then the
target inventory is equal to average demand on each period.
Therefore, we will repurchase these materials every \( P \) interval
period and the purchasing quantity is equal to average demand
(we buy them until reach the average demand, see figure 8).

\[
SB = Q_{MIN} = \min \{\text{Total parts in the system, Max. Demand on }
\text{considered period}\}
\]

\[= \min \{Q_T, D_{MAX}\}
\]

(13)
Where: SB is standby unit(s)

\[ Q_I \] is total part(s) or component(s) in the system

\[ D_{\text{MAX}} \] is maximum demand on the considered period

Normally, these materials have been installed a little in the system (almost one or two pieces). The repurchasing period (Re-Order Point) whenever the standby unit(s) is used for replacing the existing (defect) and will replenish them until reach the standby quantity level or equal to the standby unit(s).

3.6 Basket 6 – SML (Slow-Much-Low)

This material type is dependent demand, usually been an electrical part which is not a specific part (general part) or been a common material such as electrical wire, controlled wire, coaxial wire, illumination component (light bulb, switch, breaker), relay, magnetic contactor, disconnect switch, general tools (screw driver, wrench, pliers, and so on), safety device (ear plug, PPE). Another part in this basket is the part which is used for safety purpose such as safety guard, emergency switch. Normally, this is durable material and endurance. Basket 6 is to be considered and managed by Two Bins System (TBS).

The concept of a two-bin system can be likened to an empty standardized container. The container is then returned to the supplier once it becomes empty. Attached to the container is a card instruction on how the bin should be refilled. This way, production requirements and priorities are communicated clearly using simple instructions and visuals that let the customers or suppliers consciously participate in the production process if the situation so permits. We can generally say that the just like Kanban, the two-bin system connects the production process with an invisible conveyor that can be translated into simple content-transmissible items such as cards, balls, boxes, carts, bins, electronic signals, etc.[17].

![Figure 10: Two Bins System](image)

**Source:** Adapted from: [4]

Kanban has a characteristic to be conformed to Q-System (fixed order size system: \( Q \) units for a purchasing, normally \( Q \) comes from the historical data). The new replenishment will be refilled in the inventory whenever stock in hand reduces until reach to re-order point (RP) then purchasing quantity must be much more than demand on lead time or two bins system (see figure 11).

![Figure 11: The Two Bins System (TBS)](image)

Two bins will be represented the each type of materials or parts. The first bin has quantity equal to purchasing quantity subtract with quantity at re-order point while the second bin has the maximum quantity at re-order point. The repurchasing quantity is exploited the Perpetual Inventory Model (EOQ).

\[
Purchasing \, order \; = \; Q \; \text{units} \]

\[
\text{Re-order point} \; = \; \text{Demand on lead time} \]

\[
RP \; = \; D + SS \quad (14)
\]

Whilst the safety stock is:

\[
SS \; = \; Z \sigma \quad (15)
\]

Then the re-order point is:

\[
RP \; = \; D + Z \sigma \quad (16)
\]

Where: \( D \) is average demand

\( Z \) is probability density value (for normal distribution)

\( \sigma \) is standard deviation

The re-order point or materials in the 2nd bin is depended on the required service level and the purchasing quantity is similar to the Perpetual Inventory Model (PIM).

3.7 Basket 7 – SLH (Slow-Less-High)

This material type is independent demand, usually been an instrument and equipment tool such as test instrument, special tools or been a specific machine cover and frame, supplementary part or optional part such as specific meter, inverter (motor controlled speed), grounding system, sensor, encoder, detection unit, alarm system. Normally, it is hard to damage but if there is some damage, we have some waiting time to repair/replace its, it is not necessary to fix its suddenly but this is still vital to the
whole system and cannot be omitted. Basket 7 is to be considered and managed by Issue Replacement Model (IRM) [2].

![Figure 12: Issue Replacement Model (IRM)](image)

Basically, this basket contains the high cost materials, slow movement, and non-essential parts then it is not necessary replaced as soon whenever breakdown occurs. This model allows material stock-out therefore this model will be purchasing the parts as required demand (equal to breakdown parts) then no need to stock any parts in store or keep in inventory system. This model has to emphasize on the purchasing lead time, we will repurchase the new component(s) when the existing is defect (repurchase = defect). This model is very easy to arrange the inventory level because we will buy them equal to the amount defect/breakdown) and after received the component(s) or part(s) then the new part(s) is to be replaced instead of the existing defect. So, this model looks like the zero inventories.

- **Purchasing quantity** = No. of the defect part(s)
- **Re-order point** = When there is breakdown
- **Inventory level** = Zero inventories (Empty)

### 3.8 Basket 8 – SLL (Slow-Less-Low)

This material type is independent demand, usually been a general used parts (big part), almost of them are materials for supporting the factory structure or machine frame with big body or big shape such as cubical, frame, metal, steel structure, conduit, wood, storage parts for keeping the products (shelves), material support with big shape. Normally, this is not fast movement parts, hard to damage and usually can buy them in the common market (it is not specific part and some of them can be modified by using the general material). By the causing of big shape and easy to buy, then no needs to stock them because we have to spare the huge space and it scarcely uses. Basket 8 is to be considered and managed by Minimum Model (MinM).

![Figure 13: The Minimum Model (MinM)](image)

Basically, this basket usually contains the low cost material but have a big shape and scarcely damage, and the demand of these materials type is almost come either from an accident or misuse. Indeed, we should stock this kind of materials a little.

- **Purchasing quantity** = Required quantity
- **Re-order point** = When inventory level is lower than minimum required level
- **Inventory level** = Zero inventories (Empty)

### Minimum Model (MinM)

The concept of Minimum Model does not interest to the safety stock (allow stock-out). The re-order point is the inventory level which is lower than minimum required stock. If the rest of inventory stock is still over than the minimum required stock then it is not necessity to buy its more. In this case, we can obtain the parts in warehouse for fixing the damage. If it is not enough to fix then we have to buy its more. Usually, the minimum required stock is corresponded with sizing of the warehouse or places for keeping the parts or materials. Additionally, the purchasing quantity is purchased as required (see figure 13) which is compared to the minimum required lot size (usually, the lot size come from the sizing of the law materials, for ex. a shelf (for keeping the products) has damage at the shelf tray approx 10 sq.cm. (has a hole), so we cannot buy the steel plate which is used for repairing the shelf's tray as required (10 sq.cm.), anyway we have to buy steel plate at least 1 sq.m. (assume: 1 sq.m. = one steel plate = one lot size) and then we have to cut it approx 10 sq.cm. for repairing the damage, the rest will be spared or stocked for the future damage. Usually, we have to purchase them as minimum lot sizes as required (as mention before) because this material type is a big shape then we cannot stock it too much (need too many space for keeping the parts).

The re-order point is the inventory when inventory is lower than minimum required stock level ($Q_{MIN}$), purchasing quantity ($Q_l$) is bought until reach the minimum required lot sizes ($L_{MIN}$).

$$Q_{MIN} = \text{Inventory that is available of space for keeping the materials}$$
\[
Q_i = L_{MIN} + S_{out} \quad (17)
\]

\[
ML_{MIN} = \text{Max} \{D_i, L_{MIN} \} \quad (18)
\]

The re-order point is:
\[
RP = Q_{MIN} \quad (19)
\]

Where: \( S_{out} \) is Stock-out level
\( L_{MIN} \) is minimum required lot sizes
\( ML_{MIN} \) is minimum required lot sizes compare with the required materials (Demand). Practically, the material in this basket is required a lot of space for keeping them although materials cost is cheap but the sizing of materials are very big shape and it is scarcely used, so in the real world, we should avoid to stock its nevertheless some of them have to stock as general used items or supplementary.

4. Conclusion and Suggestion

The Material repair, Operation items and Spare parts (MRO) are the materials, parts, devices, equipments, components, elements or items which are used for repairing, fixing, retrieving, recovering and do maintenance whenever the system or machines fault, failure and breakdown. Furthermore, these are composed of replacement parts, supplementary devices, complementary, sustaining or supporting equipments, general hardware, office supply, stationary, sub-materials, consumable materials and safety devices. The MRO are materials or products which are not been the intermediate goods or finished goods. Actually, most of them are shortly called “Spare parts”. MRO can be classified into 2 groups if we interest to the characteristic of utilization. The first group is dependent (certainty) and the second is independent (uncertainty) demand.

This research study has combined both of certain and uncertain demand, so this inventory system and theoretical will be useful for the spare part management and ensuring those are optimized. However, this inventory model would realize to the big factory or central warehouse of multi-echelons with have plenty of spare parts or a lot of components utilization.

The 8 baskets inventory system is originally modeled and adopted for maintenance approach. This inventory system is beneficially used for the big factory or huge plant which has a lot of machines with high utilized spare parts usage or the central warehouse which is exploited for keeping a plenty of material repairs, Operation items and spare parts (MRO) such as the car service center’s central warehouse, airport, mass rapid transit, power plant with sub-station, telephone exchange and it remote station and so on. Nevertheless, this inventory system model is un-benefit with a small factory or the plant which has a little machine or low spare parts usage.

Moreover this study can exploit to another purposes such as material planning for manufacturing. However, this study is only the frame work concept of spare part planning and inventory management, we do not emphasize with another factors such as the warehouse space, maintenance budget, setup time. Therefore, the future study may consider with another factors for developing the inventory model to be entirely completed this conceptual.

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