Brief approach to stock management methods and techniques

Maxim Balitki[1]

1. INTRODUCTION

One of the primary responsibilities of industrial organizations with large fleets of production equipment is maintaining these assets in optimal working condition. This task requires balancing various maintenance, repair, and operations (MRO) needs while effectively managing material, financial, and human resources.

In today's highly competitive and rapidly changing business landscape, the efficient management of materials is often a critical factor in an organization's success. Poor management can lead to excessive costs, missed opportunities, and threaten the company's financial sustainability.

In inventory management, companies face the challenge of striking the right balance between product availability and waste reduction. Holding large amounts of stock ensures that customers and departments can access needed items immediately. However, it also carries the risk of overstocking, which reduces return on investment (ROI) and may result in losses. Conversely, limiting inventory to only high-demand items can compromise customer or requester satisfaction, especially when less frequently needed items are unavailable or not delivered promptly.

To address this challenge, many organizations are working to develop comprehensive, coordinated, and efficient inventory management systems. The key to success lies in balancing the availability of essential goods while minimizing excess stock, ensuring both customer satisfaction and operational efficiency.

This article explores inventory management methods and strategies that can be applied to maintenance and production management, fostering a more efficient and integrated approach.

2. JUST-IN-TIME

One of the most well-known expressions in production, "Necessity sharpens ingenuity," aptly captures the emergence of the Just-in-Time (JIT) manufacturing process. The origins of JIT can likely be traced back to the Japanese manufacturing industry [1,2]. After World War II, Japan's industrial sector faced severe challenges, including shortages of resources, capital, and labor. These difficulties made it hard to maintain a balanced supply chain, leading to issues such as overproduction and, at times, an inability to meet demand.

To address these production challenges and improve profitability and quality, Japanese companies, particularly Toyota, adopted a strategy of converting small quantities of raw materials into small quantities of parts and finished products. This innovative approach revolutionized automotive production by cutting costs through the elimination of excess inventory and unnecessary labor [3]. Toyota's implementation of JIT had a profound influence on management practices across industries globally, becoming a benchmark for operational efficiency and a model for quality and innovation.

A key issue with raw materials, components, and finished products is that, with few exceptions, they are not immediately used upon arrival in the warehouse. Instead, they often remain in storage until an employee or warehouse manager prepares them for shipment. This extended storage period incurs additional costs, which rise the longer materials stay in stock. However, with the application of JIT methods, the stock of unfinished goods (Work in Progress – WIP) is minimized [4]. Reducing inventory helps cut storage costs and prevents resource wastage [3,5].

In production management, a distinction is often made between push and pull systems. Push systems plan production based on demand forecasts, while pull systems only produce in response to actual demand. JIT is categorized as a pull system, characterized by its zero-stock strategy [6,7].

JIT promotes flexibility and rapid response to market changes, focusing on eliminating waste, increasing productivity, and efficiently distributing resources [4,5,8].

3. ABC ANALYSIS

ABC analysis, also known as the "Pareto Principle" or, in some cases, the "80/20 Rule," is a method used to classify materials and items into three main categories (A, B, and C) based on their significance to the organization.

Category A consists of the fewest materials but accounts for the highest proportion of the total value. Conversely, Category C represents the largest share of items in storage, with each individual item having a minimal impact on overall

[1] **Maxim Balitki**, Navaltik Management, Lda.
(email: mbalitsky@manwinwin.com)

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management. Category B serves as the intermediary between A and C, representing materials of moderate importance.

The primary goal of ABC analysis is to identify the most valuable assets to the organization, helping to prioritize their management. For example, consider the following application of the method.

Table 1 – ABC analysis of articles based on unit cost

Description	Unit Cost [€]	%	% accumulate	Category
COOLANT PUMP FEBI BILSTEIN 103966	946,23 €	19,08%	19,08%	A
1FK7042-5AF71-1EA5 SIEMENS SERVO MOTOR	900,00 €	18,15%	37,23%	A
SENSOR ALLEN BRADLEY 872C-A10N18-A2	500,00 €	10,08%	47,31%	A
SENSOR ALLEN BRADLEY 872C-D4NP12-D4	400,00 €	8,07%	55,38%	A
DRIVE BELT CAMERA X STD (PART 188682)	273,15 €	5,51%	60,89%	A
STARTER DEUTZ 04125683 HELI	251,45 €	5,07%	65,96%	A
ENCODER INCREMENTAL BAUMER OG83 UN 1024	240,00 €	4,84%	70,80%	A
WATER PUMP 51065007131 W/ ELECTROMAGNETIC CLUTCH MAN	210,00 €	4,23%	75,03%	A
AVIATION OBSTRUCTION LIGHT	159,00 €	3,21%	78,24%	A
ANGULAR ULTRASONIC SENSOR SWB 60-2E.2 MHZ 14X14	139,09 €	2,80%	81,04%	B
LOCTITE 2701 250ML THREADLOCKER	132,40 €	2,67%	83,71%	B
INDUCTIVE SENSOR	130,23 €	2,63%	86,34%	B
CARBON STEEL FLANGE DN50	99,00 €	2,00%	88,34%	B
SPHERICAL ROLLER BEARING 15498	98,98 €	2,00%	90,33%	B
NON-RETURN VALVE 320B 80L/M 2VS3-06-CS (GL)ARGOHYTOS	91,83 €	1,85%	92,18%	B
BOSCH 0 130 111 204 ELECTRIC MOTOR	69,05 €	1,39%	93,58%	B
CLUTCH KIT RIDEX 479C0101	51,97 €	1,05%	94,63%	B
MOBIL SUPER™ 3000 X1 5W-40	50,00 €	1,01%	95,63%	C
WAGNER 9992505 OIL	35,00 €	0,71%	96,34%	C
ADHESIVE,300 ML/10.3 OZ CARTRIDGE,WHITE	30,79 €	0,62%	96,96%	C
BRACKET,TRAY SUPPORT,240X208X61MM	29,91 €	0,60%	97,56%	C
PLUG TYPE H FA. STOEFFL RUDOLF @ ORDER-NO.54	29,15 €	0,59%	98,15%	C
CABLE, WTOWERLIGHTST2.4, 10300MM	28,67 €	0,58%	98,73%	C
DOUBLE PITCH CHAIN 15.875 5/8 10B-2 DIN 8187	18,00 €	0,36%	99,09%	C
SAFETY VALVE 1/2"X 3/4" 3 BAR	17,00 €	0,34%	99,43%	C
AIR FILTER ADC42515 BLUE PRINT	14,99 €	0,30%	99,74%	C
TRIPLE PINION 12-Z9-T	6,67 €	0,13%	99,87%	C
ROTO SYNTHETIC ULTRA OIL	4,00 €	0,08%	99,95%	C
PNEUMATIC FLEXIBLE PIPE DIAM. 10 BLUE	1,39 €	0,03%	99,98%	C
PNEUMATIC FLEXIBLE PIPE DIAM. 8 BLUE	0,97 €	0,02%	100,00%	C
Total	4 958,92 €	100,00%		

In this table, materials are classified according to their range. Materials with an accumulated percentage of total value less than or equal to 80% fall into Category A. Items with an accumulated percentage greater than 95% are placed in Category C, while the remaining materials are classified as Category B. While the standard distribution is often 80%-15%-5%, this can be adjusted to suit the specific needs and objectives of the organization.

The parameters for the ABC analysis should align with the organization's strategic goals. Some common criteria include:

- Annual consumption
- Unit cost
- Annual demand
- Stock values
- Profit margin
- Lead time

ABC analysis is a powerful tool for inventory management, enabling organizations to optimize resource allocation and focus on the most critical assets for operational success.

4. ECONOMIC ORDER QUANTITY

Whenever stock is necessary in a warehouse, it is important to minimize the associated costs, which can be divided into two main categories:

- Holding Costs:
  - Capital cost
  - Labor costs for storage and inventorying
  - Energy and insurance costs
  - Provision for obsolescence and damage
  - Warehouse cost and its maintenance
- Ordering costs:
  - Supplier proposal request
  - Cost of reception and transfer to the warehouse
  - Cost of goods inspection
  - Transport costs

While it may seem intuitive that reducing one type of cost directly leads to an overall cost reduction, practice demonstrates that the relationship between holding and ordering costs is not linear. Therefore, it is crucial to determine the optimal stock quantity that minimizes the total cost by balancing both types of costs. This optimal stock level is known as the Economic Order Quantity (EOQ) (Figure 1).

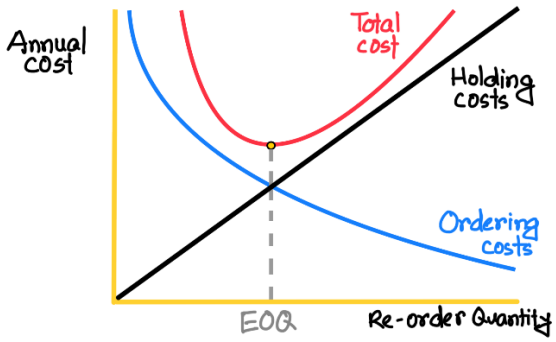

Figure 1 – Economic Order Quantity represented graphically [10]

Based on the holding and ordering costs, the minimum point on the total curve is determined through mathematical manipulations. This point is determined by using the well-known Wilson formula:

$$QEE = \sqrt{\frac{2 \cdot \overline{D} \cdot O}{M \cdot C}} \qquad (4.1)$$

Where:

$\overline{D}$ = Average annual demand [unit]

O = Order cost [€]

M = Annual rate of holding cost [%]

C = Unit purchase cost [€/unit]

The product of the annual rate of holding cost, M, and the unit purchase cost, C, is called the holding cost, C_p. This calculation allows the previous equation to be rewritten as follows:

$$QEE = \sqrt{\frac{2 \cdot \overline{D} \cdot O}{C_p}} \qquad (4.2)$$

In the context of stock management, it is of paramount importance to determine the optimum time interval between two consecutive orders, known as the Economic Order Interval (EOI):

$$EOI = \frac{EOQ}{\overline{D}} \qquad (4.3)$$

5. SAFETY STOCK, REORDER POINT AND MAXIMUM LEVEL

Effective inventory management, particularly for consumables, requires the establishment of strategic levels to enable well-defined procedures. These levels ensure operational efficiency and continuous supply, while minimizing the risk of stock-outs or overstocking.

This chapter explores how to mathematically define three critical parameters: Safety Stock (SS), Reorder Point (ROP), and Maximum Level.

Safety Stock (SS) refers to the "buffer" inventory that helps prevent stock shortages. It is essential to maintain safety stock to account for unforeseen events such as logistical delays.

Before delving into the mathematical formulation of Safety Stock, it is important to understand two fundamental inventory models:

- Continuous review model – In this model, replenishment occurs when inventory reaches a predefined reorder point, with a fixed order quantity.
- Periodic review model – Here, inventory is replenished on a predetermined schedule, with the objective of restoring stock to the maximum level.

For the periodic review model, safety stock is calculated as follows:

$$SS = z \cdot D_p \cdot \sqrt{L + P} \qquad (5.1)$$

Where:

z = No. of standard deviations of the assumed probability of shortage (Gauss table)

D_p = Standard deviation of demand

L = Lead time

P = Provisioning frequency

Similarly, for the continuous review model, the SS is calculated using the following formula:

$$SS = z \cdot D_p \cdot \sqrt{L} \qquad (5.2)$$

Next, the definition of the ROP or Minimum Level plays a crucial role in inventory management. Late replenishment can result in stock-outs, while early replenishment leads to unnecessary holding costs. Therefore, determining the point at which the purchasing process should be triggered is essential for efficient warehouse operations. For the continuous review model, the analytical expression for the reorder point is given by:

$$ROP = \overline{D} \cdot L + SS \qquad (5.3)$$

In contrast, in an environment where periodic review model predominates, due to its nature, the corresponding maximum level is calculated:

$$Maximum\ level = \overline{D} \cdot (L + P) + SS \qquad (5.4)$$

In the Continuous Review Model, certain criteria can also influence the definition of the maximum level based on sensitivity analysis. These factors include:

- The physical space in the warehouse.
- Unit price of the material.

6. AVERAGE NEED AND SERVICE LEVEL

The previous chapter focused on managing consumables, which, by nature, are replaced more frequently than spare parts (rotables). This raises an important question: how should spare parts be managed?

One of the key objectives of efficient materials management is ensuring that necessary resources are readily available whenever needed. In maintenance contexts, managers often face the dilemma: "To buy or not to buy?" When a specific spare part is unavailable in the warehouse at the time of a breakdown, the organization may experience prolonged downtime, as the lead time for that spare part could be significantly longer than for standardized materials. On the other hand, there are instances where managers purchase spare parts, but these parts remain unused throughout the equipment's life cycle, becoming capital assets with low turnover rates.

In this scenario, it is critical to determine the appropriate amount of spare parts to maintain in stock to ensure they are available when required. The optimal inventory level is determined based on the Average Need (E) for each spare part:

$$E = N \cdot n \cdot h \cdot \left(\frac{1}{TBO} + \frac{1}{MTBUR}\right) \cdot \frac{TAT}{365} \qquad (6.1)$$

Where:

E = Average need [unit of stock]

N = No. of equipment where the spare is applied

n = No. of spare parts in each piece of equipment

h = Operating time per equipment per year [h]

TBO = Time Between Overhaul [h]

MTBUR = Mean Time Between Unscheduled Removals [h]

TAT = Turn Around Time [days]

The average need, calculated using the equation above, represents the number of stock units required to achieve a service level (SL) of 50%. The service level refers to the percentage of times a stock item is available in the warehouse when requested. It is argued that SL below 95% can lead to operational delays and disruptions, while a SL above 97% reveals "heavy" and uneconomic warehouse, with an excess of items [11]. Therefore, a SL between 95% and 97% is generally considered optimal [11].

If the goal is to achieve a higher service level and reduce the risk of material shortages, the average need must be recalculated based on the following probability distribution models:

- Poisson distribution ($E \leq 10$)
- Normal (Gauss) distribution ($E > 10$)

If the scenario under analysis estimates $E \leq 10$, for example $E = 5$ units and whose SL corresponds to 95%, the accumulated table of the Poisson distribution is used to determine the new value, E', which in this case will be $E' = 9$ units ($E' \in \mathbb{N}$).

On the other hand, if $E > 10$, for example $E = 15$ units and $SL = 95\%$, then:

$$E' = z\sqrt{E} + E \qquad (6.2)$$

Where:

E' = New average need [unit]

z = No. of standard deviations corresponding to the service level (Gauss table)

So, for the previous example:

$E' = 1{,}65 \times \sqrt{15} + 15 = 21$ units, $E' \in \mathbb{N}$

FINAL REMARKS

The Just-in-Time philosophy stands out as an efficient approach to production management, focusing on eliminating waste, reducing stock, and aligning production with actual demand. Its implementation enhances companies' flexibility, enabling them to respond swiftly to market changes. Additionally, JIT optimizes resource use and reduces costs, making it an indispensable tool for achieving excellence in stock management.

However, adopting this strategy makes stock management more dynamic and necessitates precise synchronization with material suppliers.

ABC analysis, the second methodology discussed, is a critical resource for prioritizing and classifying materials based on adjustable criteria such as annual consumption, unit cost, or stock values. Its practical application enables organizations to identify and focus on the most crucial items, contributing to effective and resourceful inventory management.

While JIT promotes the goal of zero stock, this is not always feasible in practice. Thus, it becomes essential to minimize the total costs associated with managing inventory. In this context, Wilson's formula can be applied to calculate the EOQ, optimizing both holding and ordering costs.

Managing consumables requires defining strategic parameters, such as safety stock, reorder points, and maximum levels. These parameters align the supply chain with actual needs, minimizing the risk of stockouts and excessive holding costs.

Finally, efficient spare parts management is crucial to ensure the availability of critical items while maintaining a balance between cost and operational efficiency. Determining the average need provides a solid mathematical foundation for stock planning, ensuring that spare parts are available when required without tying up excessive fixed capital. This is achievable as long as stock levels are aligned with a carefully balanced service level.

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