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Procurement Methodologies to Optimize the Inventory Levels of Spare Parts

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Abstract: ***Inventory is essential for the smooth running of any organization. It acts as a link between procurement and sales. Inventory constitutes of current assets/ working capital of the organization. Thus, it is very essential to have suitable control over inventories. The purpose of inventory management is to ensure availability of parts in sufficient numbers as and when required and also to minimize the accumulation. The main objective of this paper is to devise an inventory management method for spare parts management system in order to utilize the space effectively and to stabilize FIFO system which would help the company personnel to keep record of spares precisely. A three dimensional approach is performed using sales order line frequency, seasonal frequency and sales value through ABC analysis. In addition to this, four different procurement techniques are adopted viz., one bin, two bins, multi bins and zero bin. Demand variation is measured for a period of last one year and this parameter is included during the calculation of the inventory maintenance. It is evident that a large amount of money is saved without compromising the customer order fulfilment.***

Keywords ***: Inventory management, ABC analysis, Bin system, Simulation, First In First Out (FIFO).***

I. INTRODUCTION

Manufacturing and allied industrial sectors play a vital role in economy of a country. Industrial sector contributes about 29% of India's total GDP amounting to a huge sum of 3989791 Crore rupees [1]. Manufacturing, which is the conversion of raw materials available on earth to any usable form to serve human needs, transforms human lives and improves the standard of living. Labour, capital and materials used are the major resources of any industry and needs to be controlled properly. The above-mentioned three parameters govern the flow of processes and operational efficiency of industries [2]. Customer expectations need to be served by industries so as to sustain in the competitive market. To achieve this, companies/ industries adopt techniques that would best fit their manufacturing system, which are broadly classified as Mass, Continuous, batch and job shop production [4]. Also, manufacturing strategy adopted by the companies govern the way in which they operate. Make-to-order, Assemble-to-order, Make-to-stock, etc., are some commonly adopted strategies. Any manufacturing needs proper planning and control. It is highly impossible to perfectly plan and execute processes in an industry, as the customer needs are prone to fluctuations and uncertainties [2]. In order to shield against these uncertainties, inventories are used. Inventory needs to be managed properly as it has its own negative implications. Sufficient amount of inventory would help to cater the demand that is excess in addition to the production quantity whereas having too much of inventory reduces the company's responsiveness, increases inventory maintenance cost, makes certain inventory stocks obsolete, dampens innovativeness and reduces the lean aspects of the system [5, 2, 3]. Hence, it is important to observe the sales of data and forecast based on the behaviour in past. Time series forecasting is the commonly used terminology for predictive studies based on observations made over a period. Accuracy of the gathered data and the forecasting method used determine the effectiveness of inventory management [6]. Forecast methodology and inventory management strategy are selected based on the parameters that govern the performance: predictability of sales, fluctuations in demand, unreliability of supply, price protection, quantity discounts, lower ordering costs based on quantity, etc. [3]. Often, companies tend to maintain Safety Stock (SS) in the form of finished goods, preferably closer to the customer in order to reduce the transportation time [2, 4]. In addition to the attention given to finished goods, Work-In-Progress (WIP) inventory and raw material inventory are also to be taken into consideration for improving the overall delivery performance [4].

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II. LITERATURE BACKGROUND

One of the major problems faced by companies in the area of inventory management is the categorization of parts [2, 4]. Sales performance, profit, demand, and importance of the part to the company and market are some of the major factors to be understood and managed properly [2, 3]. Present study faces a similar problem, as the company has not classified the parts on any basis for management of respective inventories. A commonly used technique to address such ambiguities is the ABC inventory classification wherein the parts are grouped into three, based on their importance, as listed [2]:

1. Class 'A': Covers 20% of goods. These goods have regular sales and are highly important

2. Class 'B': Their sales is lesser than that of Class 'A' goods and account up to 30% of goods

3. Class 'C': They comprise of 50% of goods but contribute less than 10% of sales and are hence given lesser importance

After the classification of parts into any of the above-mentioned categories, techniques on how to maintain SS for each different part should be devised. Bin system is one of the simplest techniques that can be adopted for inventory management. Re-Order Point (ROP) should be defined for each part, which represents the lowest stock on hand at which order placement is done [3]. Single bin system could not be applicable as it does not involve a concept of ROP, without which there would not be any data on when the order should be placed. In a two-bin system, the first bin contains working stock and the second bin contains working reserve which is equal to the demand during lead time [3]. This technique could be applicable for Class 'C' entities. There is a three bin system which has an additional third bin with SS to account for uncertainties, with a quantity equal to half of that in bin 1 [2, 3]. Forecast of spare part demand is a complex area as there is no clear pattern followed for most of the parts over a longer period. Remanufacturing Centers (RCs) gather the returned parts, refurbish and sell them as spares to retailers. The problem lies in selection of location and setting up of RCs and Distribution Centers (DCs) to supply to retailers. This system forms a closed loop where the reverse supply chain takes place from retailers and RCs and the forward happens after refurbishing the parts and selling them back to retailers. Results indicated that the increase in number of centers opened decreased the inventory cost but increased the inbound transportation cost [7]. Industries always tend to place the centers closer to customers to assure faster delivery [4]. Event-driven predictive maintenance and spare part maintenance models were proposed. This approach was executed in an automobile lighting equipment production factory and was found that there were unexpected failures which led to shortage of parts in case of low inventory spares and unnecessary early ordering before the application of the proposed method. The approach also helps to move from a time based approach to a Condition Based Maintenance (CBM) [8]. Quantification of spare part in terms of shortage and excess to assess the overall impact of a part was done and table was prepared. Knowing the impacts would help the planners to accordingly plan and maintain inventory for different parts [9]. Airline industries wherein maintenance costs are as high as 13% of the total operational cost, planning of spare parts become vital for maintenance planning. Total cost value could be used to derive the optimal quantity and time to order. Start of the shortage period is defined by the Mean Time To Failure (MTTF) in the first mathematical without considering the accurate shortage time which has been included in the second mathematical model. The latter method takes in account the aging of parts and demands to maintain spares such that the total downtime due to shortage and inventory holding costs are minimum. In the improved model, the failure of parts were assumed to follow a normal distribution about the mean. Suggestions were put forward to improve the accuracy by considering different distributions for different parts [10]. Performance-Based Logistics (PBL) for spare part Supply Chain Management (SCM) was followed as the aircraft reached the End Of Life (EOF) phase. Analytical solutions were derived using continuous-time Markov chain for inventory management for the orders of parts to be placed, provided budget constraints [11]. A study conducted in a paper mill using five different forecasting methods and three statistical techniques showed almost similar results. Hence, an alternative approach to determine the parameters that are out of control was performed using five different approaches namely, Moving Average Forecast (MA), Exponential Smoothing forecast (ES), Croston's forecasting method (CR), Syntetos-Boylan Approximation (SBA) and Teunter-Syntetos-Babai forecasting method. (TSB). The results indicated that Root Mean Square Error (RMSE) showed closer performances for all the five approaches [12]. Another study on spare parts of aircraft revealed that it is meaningful to measure performance based on the quality of repairs rather than the level of spare parts. Algorithms were developed in alignment with the inventory policies followed based on business objectives [13]. Forecasting of dairy sales was done and customer feedback was collected with an intention to use it for production. In addition, several factors affecting use of dairy products and their interrelationships were studied and compared [14]. An extensive study was conducted on Vendor managed Inventory (VMI) to understand the routing and distribution at point of demand. One main focus was to analyse the gaps and flaws in the existing systems and suggestions to avoid and/ or overcome the identified problems were also discussed [15]. The importance of transportation in customer service and delivery was studied and a case study was conducted in a dairy manufacturing unit in order to check the effectiveness of the developed mathematical model. The case was designed as a Vehicle Routing Problem with Backhauls (VRPB) with practical constraints with a dynamic Decision Support System (DSS) for mangers. DSS would help the users of the system to match supply and demand [16].

III. PROBLEM DESCRIPTION

The study was conducted in one of the largest compressor manufacturing facilities in India. The facility was spread across 2721 square meter and had a storage capacity of about 10000 parts. There was a need to improvise the storage and management system owing to the problems faced in delivering to the customers. Problems in processing data of aftermarket requirements, planning, packing slips and triggering to supplier were some majorly faced delivery management challenges. Concept of Global Support Center (GSC) was established to cater needs globally. The subsidiaries and installations are spread across 70 countries and comprise over 100 dealers. GSC did not have categorization of parts, predefined bin stocks and Service Level Agreements (SLA) with customers and dealers, which led to incorrect supplies of parts to customers due to manual computations.

Financial Year 18-19 shows a 130MN inventory, which certainly needs an improvement. This research aims to find solutions for:

1. Inappropriate selection of inventory management methods
2. Improper assignment of Stock Keeping Units (SKUs)

A. Excess Inventory

During the Financial Year (FY) 2018-2019, the inventory level continued to increase beyond the threshold (target) from 7% to 26%, which is 10 Million (MN) more than the target, represented in fig. 1. This leads to huge inventory holding costs, occupies more space and increases the chances of parts getting obsolete.

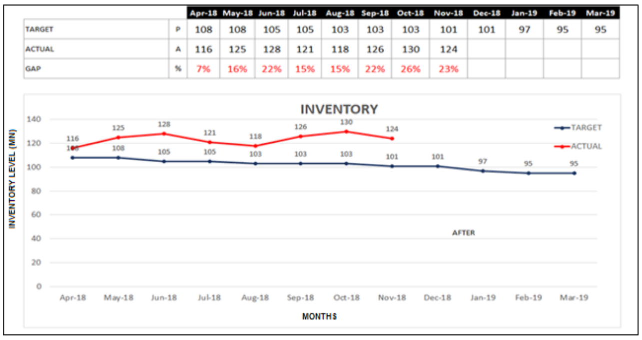


Fig. 1. Inventory trend during FY 2018-2019

B. On Time Availability (OTA) of parts

OTA of parts defined as per SLA is not met, as shown in figure 4. Also, figure 2 represents the flow of material indicating the SLA for each of the segmented item groups. Considering that data from August 2018 to November 2018, the failure rate was 23%, out of which lack of OTA of material, on time disclosure of packing slip and on time invoicing contribute to 21%, 1.5% and 0.5% respectively.

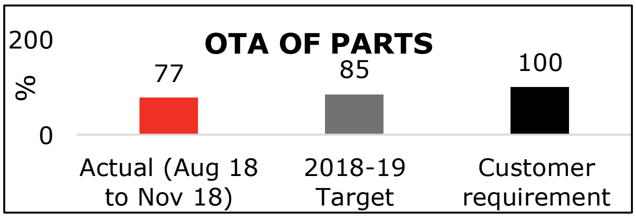


Fig. 2.On time availability of parts

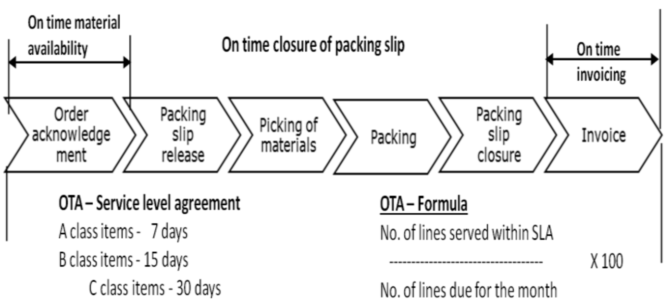


Fig. 3.OTA- Formula

IV. RESEARCH METHODOLOGY

The main objective of this research is to minimize the inventory to achieve the target and meet the lead time. This can be further described as:

1. To maintain sufficient inventory and to have an uninterrupted sales of spare parts
2. To minimize the investment on inventory to the maximum possible extent considering the above stated constraint
3. To ensure on time delivery of parts to customer

A. ABC Analysis

As discussed in literature, ABC analysis is used to classify items based on sales rate and demand. The same has been applied in the study and the parts have been grouped as displayed in table 1. It is evident from the table that the C category items are too high in numbers compared to the other two but their contribution towards revenue of the company is too less. Having analysed this, a single bin system was employed for the items under classes A and B. The system has to maintain stock levels such that replenishment of goods happen before stock outs.

Reorder point = (average usage of Inventory x Lead time) + Single Bin Safety Stock (1)

Class C items were governed using zero bin method as there are a lot of items in this category and their relative impact on sales is much lesser than the other two categories of items. The orders are placed against customer orders, more like a make-to-order system.

Reorder point = average usage of Inventory x lead time (2)

Table I: Classification of parts

Category	Duration in months	No. of items	Lead time
A	8-12 M	1169	7
B	4-7 M	854	15
C	0-3M	7382	30
	Total	9405	

Analysis was done for the customer order inflow based on the historical data available at the spare parts division. Compressor spare parts undergo quick changes and modifications based on the requirement in the market. This leads to the decline in prices of the existing products due to obsolescence and arrival of newer, more efficient models.

B. Methodology used to identify initiatives and target for On Time Delivery (OTD) of parts

In order to improve the OTA of parts, it is important to track the material movement along each of the defined set of processes that are mentioned in figure 4. OTA has a set of activities as described in the figure 4. Upon clearance of all the mentioned processes, the item would be delivered to the customer. Hence, it comes along with so many constraints that are uncertain in all these stages. Upon clearly defining the individual and company goals that are aligned with the processes at each of these stages,

it is easier to make the individuals understand the importance of their roles and responsibilities for satisfying customers.

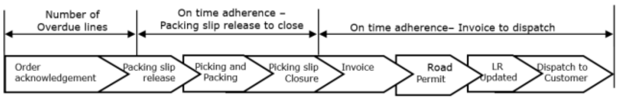


Fig. 4.OTD of parts – Process diagram

C. Pre-defined template for Bin system

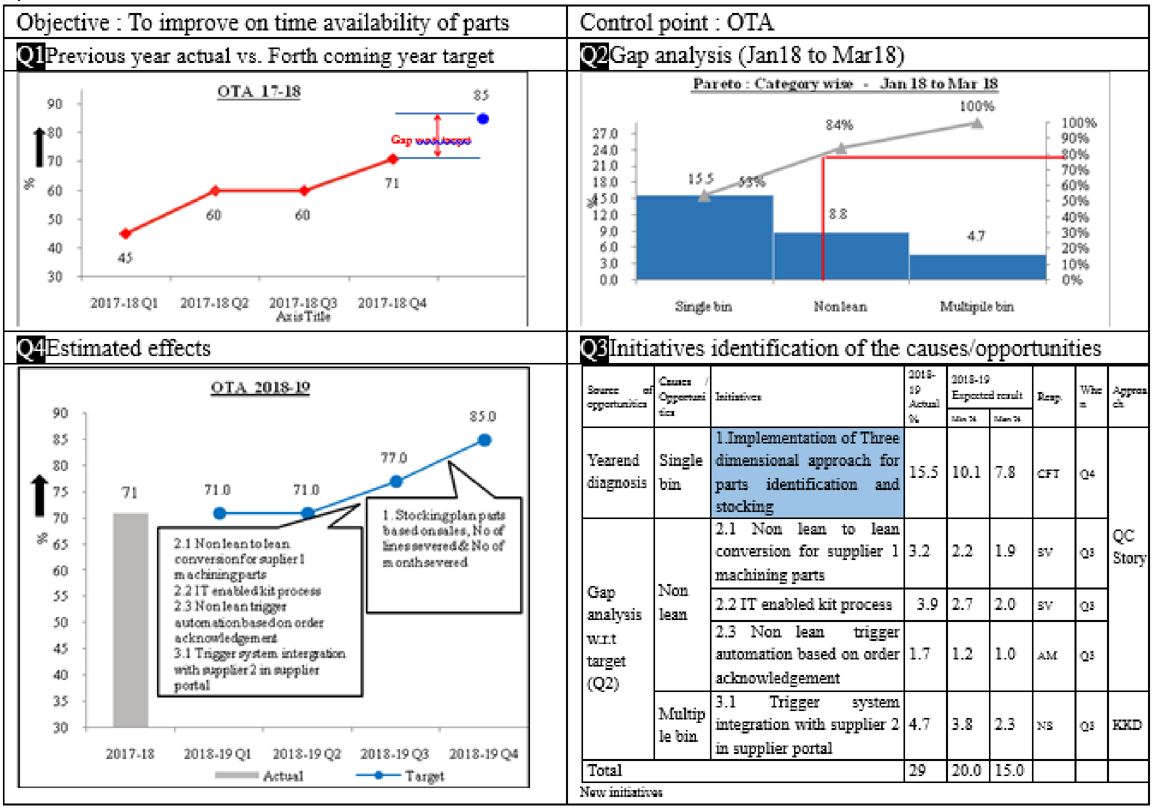
Lean approach is also followed based on the segregations made for various items.

These are helpful to adopt strategies based on the classification done for the items:

1. Non Lean: Procured based on Customer Order Quantity (COQ) or Minimum Order Quantity (MOQ)
2. Lean Allocation: When customer order is received, an automatic order gets generated based on Bin quantity (SS level zero)
3. Lean Stock: Automatic order generation when Quantity <1-Bin, MOQ=1-Bin
4. Lean multiple bin: Long lead-time items, Multiple Bins' stock is kept and also ordering is done frequently

V. RESULTS AND DISCUSSION

A. Root Cause analysis using 4 Quadrant (4Q) Approach



Source of opportunities	Causes / Opportunities	Initiatives	2018-19 Actual %	2018-19 Expected result		Resp.	When	Approach
				Min %	Max %			
Yearend diagnosis	Single bin	1.Implementation of Three dimensional approach for parts identification and stocking	15.5	10.1	7.8	CFT	Q4	QC Story
Gap analysis w.r.t target (Q2)	Non lean	2.1 Non lean to lean conversion for supplier 1 machining parts	3.2	2.2	1.9	SV	Q3	
		2.2 IT enabled kit process	3.9	2.7	2.0	SV	Q3	
		2.3 Non lean trigger automation based on order acknowledgement	1.7	1.2	1.0	AM	Q3	
	Multiple bin	3.1 Trigger system integration with supplier 2 in supplier portal	4.7	3.8	2.3	NS	Q3	KKD
Total			29	20.0	15.0			

New initiatives

Fig. 5.4Q approach

The year 2017-2018 is considered for the 4Q approach. OTA was found to be 71% and the root cause was analysed. It was clear that there was insufficient part stratification in all the classes: A, B and C stocking policy and a 4Q approach was employed to identify the target and initiatives for the forthcoming year. This analysis forms the planning phase

1. Q1 Previous year actual vs. Forth coming year target updated
2. Q2 Category wise gap analysis for the quarter Q4 (Jan18 to Mar18) 80:20 principle
3. Q3 Identified the approach to eliminate the causes and opportunities
4. Q4 Estimated the result for the forthcoming quarter

From Q1, it is seen that the company's target for OTA has increased which is clearly a positive indication of the company's approach towards maintenance of parts to ensure the readiness to serve the customers. Q2 shows the category wise Pareto (%). The value of multiple bin is found to be the minimum. Q3 represents the cause and opportunity of various categories. Various approaches have been compared for the gap analysis made with Q2 as reference. The effect diagram in Q4 clearly depicts that there are scopes of improvement for OTA in the forthcoming years. Company has estimated the target as 85% in then last quarter of 2018, which is a significant increase. Table 2 shows the categorizations done based on different parameters.

B. Bin System:

Part stratification and stocking policy was arrived based on the past six months' sales data and it was clear that the OTA was not met due to variations in inflow. So, a three dimensional approach was followed for inventory management considering Sales percentage, Sales frequency and percentage accumulation of order lines. Figure 6 shows the parts identified based on the above-mentioned parameters.

Table II: Part classification for bin system

1 Parts contributing on Sales value
XYZ definition – Based on Sales
X - Parts contributing to top 60% of sale value
Y - Parts contributing to top 30% of sale value
Z - Parts contributing to top 10% of sale value
2 Parts contributing on month of sales
ABC definition–Based on frequency (Months) of sales
A – Parts with sales more than 8 months
B – Parts with sales between 4-8 months
C – Parts with sales less than 8 months
3 Parts contributing on order/ served lines
FMS definition – Based on order lines
Fast (F) - Parts contributing to top 60% of order lines
Medium (M) - Parts contributing to top 30% of order lines
Stranger (S) - Parts contributing to top 10% of order lines

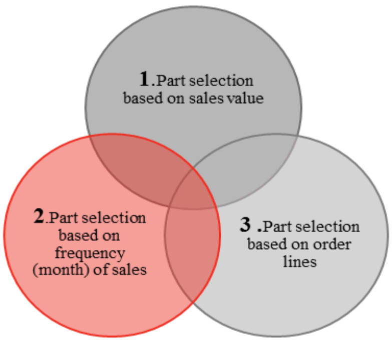


Fig. 6.Parts identification

C. Three Dimensional Approach:

From the table 3, it is seen that the number of parts classified as 'Stranger' are high in numbers. These are of lesser importance to the company in terms of contribution compared to the other parts.

Table III: 3D approach for part identification

THREE DIMENSIONAL APPROACH FOR PART IDENTIFICATION				
Parts identification in numbers	Fast	Medium	Stranger	Total
	68	21	6	95
	163	183	74	420
	71	894	3239	4204
Total	302	1098	3319	4719
PARTS SELECTION BASED ON SALES VALUE				
Sales %	X	Y	Z	Total
Fast	48	8	4	60
Medium	14	11	5	30
Stranger	1	5	4	10
Total	62	24	13	100
PARTS SELECTION BASED ON ORDER LINES				
Order lines %	Fast	Medium	Stranger	Total
X	24	1	0	25
Y	28	6	0	34
Z	8	23	10	41
Total	60	30	10	100

THREE DIMENSIONAL APPROACH FOR PART IDENTIFICATION				
Class	**A**	**B**	**C**	**Total**
FAST	**301**	**0**	**1**	**302**
X	**68**	**0**	**0**	**68**
Y	**162**	**0**	**1**	**163**
Z	**71**	**0**	**0**	**71**
MEDIUM	**689**	**359**	**50**	**1098**
X	**17**	**4**	**0**	**21**
Y	**150**	**30**	**3**	**183**
Z	**522**	**325**	**47**	**894**
STANGER	**453**	**901**	**1965**	**3319**
X	**3**	**2**	**1**	**6**
Y	**31**	**36**	**7**	**74**
Z	**419**	**863**	**1957**	**3239**
Total	**1443**	**1260**	**2016**	**4719**

Observations on classification made with respect to the sales value, it is clear that the parts with a faster sales rate are high in proportion. Hence, they need to be prioritized as the chances of getting customer orders are high and the lead-time for these parts is also much lesser. They sum up to 48% of the total sales value. All fast moving parts are seen to have a much higher accumulation in order lines, which is obvious from the fact that they need to be processed for a longer time to satisfy the demand. During the year 2017-18, the Stocking policy was redefined from 2395 to 1480 parts. Upon analysis, it was found that the root cause was due to insufficient part stratification. In 2018-2019, procurement method and stocking matrix was redefined for 1480 parts, which constituted 96% of the overall sales value, and 90% of order line accumulation. To measure the effectiveness of implementation for the different types of procurement methodologies, parts were grouped and assigned for different bin techniques. The number of parts in each bin system are as follows:

1. Zero bin: 253 parts
2. Single bin: 768 parts
3. Two bin allocation: 405 parts
4. Multiple bin: 4 parts

Zero bin allocation:

Here the orders will be generated based on the customer requirements. It is adopted for parts of Classes A and B categories. This is suitable for the inventories with delivery lead-time less than three days.

The steps involved in zero bin allocation system are Trigger from GSC, Dispatch from supplier stock, Trigger to sub-supplier(s), Stock replenishment from supplier end and Stock at supplier end. This cycle continues to operate for all orders.

Single bin allocation:

This is employed for parts classified under classes A and B based on the replenishment policy that there should not be any stock out at any cause. These systems maintain a stock level with a corresponding threshold which upon reaching a minimum value, the bin quantity would be ordered.

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Similar to the zero bin allocation process, even in single, two and multiple bin allocation processes, there are a defined set of steps such as the order acknowledgement, procurement, checking the bin SS (inventory level), placement of order to the suppliers, delivery of orders in the defined lead-time.

Two bin allocation:

This is used for parts classified in class A with high frequency of sales order, high accumulation of order lines, and higher sales value. This is adopted for parts that are strictly defined to have stock outs. Replenishment of stock is initiated (placement of order) once the stock out happens in the working bin. This means that the second bin would be able to suffice the lead-time demand.

Computation of SS and ROP:

Safety stock formula: $Z\alpha \times \sqrt{E(L)\sigma 2D + (E(D))2\sigma 2L}$

Re order point formula: Safety stock + E (D)

where $Z\alpha$ is obtained from normal distribution table based on the service level

E(L) and σL are the mean and standard deviations of lead-time

E(D) and σD are the mean and standard deviations of demand for unit time

Multiple bin systems:

This is employed for parts with a longer variation between the forecast and actual consumption, to maintain the OTA. The IT enabled multiple bin triggering process is defined in the figure 7. Parts classified under this category have a longer lead-time and a higher degree of uncertainty in demand.

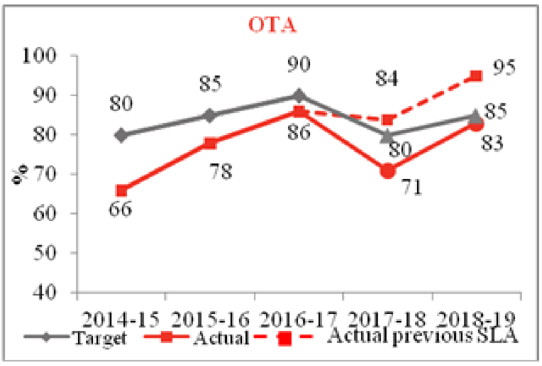

Fig. 8.OTA Comparison chart

The graph displayed in figure 9 depicts that the number of parts being stocked is reduced from 1742 to 1480 and also the percentage of sales order inflow has been increased. Thus, the inventory has been controlled without any impact of the process, accompanied with improvement in sales.

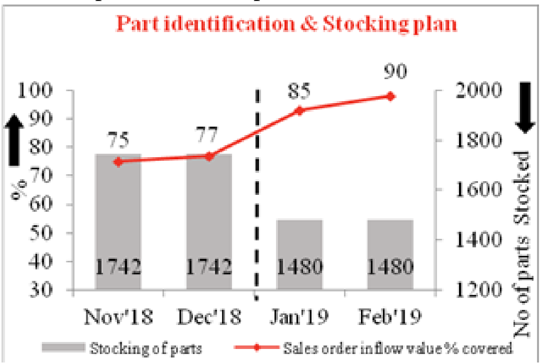

Fig. 9.Part identification and Stocking plan

Fig. 7.Multiple bin system working process

VI. CONCLUSION

Single dimension approach was initially followed over a course of 6 months for 2395 parts. 1480 parts were identified to be considered for stocking as shown in figures 8, 9 and 10. The considered stocking policy included 1480 parts that contributed to 96% of overall sales value, consisted of 98% of sales frequency and occupied 90% of order lines. Also, the SLA was met in a period of 7 days. It is clear from the OTA that the target is set significantly higher than the actual OTA values. Also, the improvement in SLA is in sync with the increase in OTA.

It is seen from the figure 10 that though the number of parts are higher for the single bin system, its contribution in MN is less significant. Hence, there is not much impact in the inventory. Parts classified under two bin system needs to be taken care of as they have a significant contribution towards inventory, say 34MN.

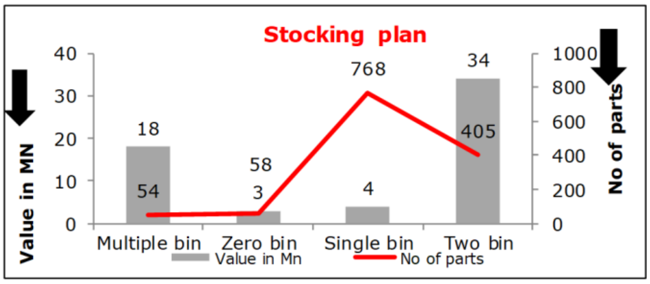

Fig. 10. Fig. 10. Stock plan

As the policy was redefined from 2395 to 1480 parts, the safety stock was reduced form 52 MN to 48 MN and the inventory cost was reduced by 4MN. Nevertheless, the business sales is increased. Monthly inventory trend is show in the figure 11.

It is also clear from the stock values that the number of parts stacked have decreased but the sales has increased considerably.

		Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19
No of parts stocked	Nos	2395	2395	2395	2395	1480	1480	1480	1480
Stock Value	MN	52	54	54	49	42	42	44	48
Sales actual 2018-19	MN	228	242	233	215	257	258	236	320

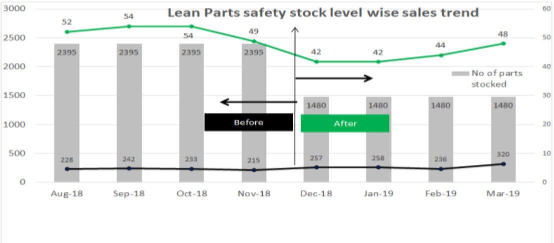

Fig. 11. Lean parts safety stock level wise sales trend

This improved the on time available of parts with defined lead-time (order acknowledgement to invoice). OTA performance was increased from 81% to 88% and an improvement of 7% was seen in OTA though there was an increase in fluctuation of customer demand.

		Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19
SLA	%	82	81	82	85	86	88	84	88

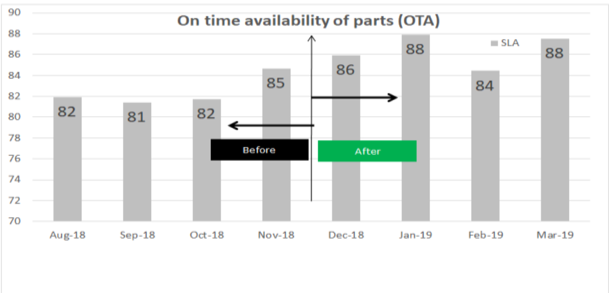

Fig. 12. On time availability of parts (OTA)

As the policy was redefined from 2395 to 1480 parts, the safety stock was reduced form 52 MN to 48 MN and the inventory cost was reduced by 4MN. Nevertheless, the business sales is increased. Monthly inventory trend is show in the figure 13. It is also clear from the stock values that the number of parts stacked have decreased but the sales has increased considerably.

		Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19
No of parts stocked	Nos	2395	2395	2395	2395	1480	1480	1480	1480
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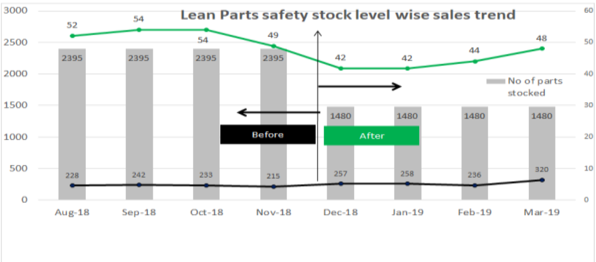

Fig. 13. Lean parts safety stock level wise sales trend

		Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19
SLA	%	82	81	82	85	86	88	84	88

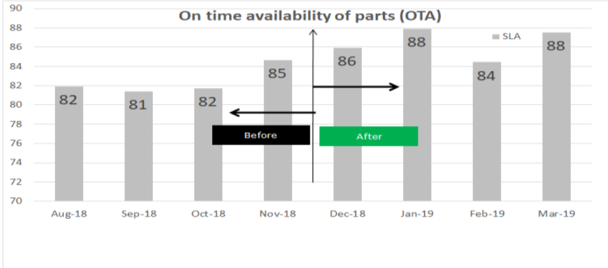

Fig. 14. On time availability of parts (OTA)

In this paper, an inventory model with the ABC category has been developed. The procurement techniques and part groups along with the SLAs and assignment of SKUs have been suggested. The well-known single dimension approach has been enhanced by integrating programming and optimization. ABC grouping differs from the current optimization models in the literature with two typical feature namely order line frequency and sales order value

Four different procurement systems were introduced such as zero bins, one bin, two bins and multi bins. These were introduced with a view to eliminate stock outs based on the nature of sales of the items.

One bin system was employed for the products that have very less lead time, less frequent products. Two bins were employed for the products with high frequency and multi bins are employed for the products that have longer lead times.

A zero bin system is also introduced for the products that have less than 3 days of lead-time. There are nearly 253 products in this category and this largely avoids the space utilization of the respective products. In this system, the products are directly routed to the customer owing to the lesser lead-time. In addition to this, bin quantities were re-evaluated based on the products and their respective sales. Earlier the bin quantities were fixed with the lead times of the suppliers as specified in the contract but during the revision it was observed that, the suppliers were able to supply the products bin before the lead time. This will benefit the organization by reducing the safety stocks level thereby reducing the money spent stocking. Demand variations were measured for a period of one year and was included during the calculation of the inventory maintenance. The proposed approach would serve as an SKU rationalization tool and help

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