Order Frequency as a Variable to Determine Slow Moving D Items in ABC Inventory Categorization

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***Abstract*— Many researchers have studied inventory models for deteriorating items that become waste or obsolete and Supply Chain Managers need to look specifically at how inventory is categorized as order volume used in ABC inventory categorization can lead to items that are decreasing in popularity to be overly stocked. Researchers have considered multiple variables in inventory categorization but this study aims to recommend the use of the order frequency variable to separate popular from non-popular finished goods inventory. An algorithm called the Vaz algorithm is explained in this study that uses the order frequency variable in inventory categorization, so that supply chain managers will be able to keep low inventory of such items and apply small batch and/or a fast response manufacturing strategy to reduce slow moving inventory within fast moving consumer goods (FMCG) businesses.**

***Keywords*—** *days cover policies, fast moving consumer goods, inventory categorization, inventory replenishment, multi criteria inventory classification, safety stocks, stock in days, Vaz algorithm*

1. Introduction

Various factors such as a slowing down of demand or a change of product specifications may influence creation of slow-moving inventory as there are problems associated with managing large amounts of stock keeping units (SKUs) within the FMCG business. Inventory items within electronic components, food items and fashion goods tend to become slow moving due to changing technology and slowing demand patterns but a lot depends on how supply chain managers categorize finished goods and apply manufacturing strategies to overcome slow moving inventory build-up [1]. Process industries excluding pharmaceuticals, account for €2750 billion in revenues globally and inventories make up 56.7% of working capital for these industries [2]. According to Ref. [3], Cisco had to write-off $1.2 billion worth of inventory due to holding too much of slow-moving items in finished goods. Tesco UK has admitted it had generated 30,000 tonnes of food waste in the first 6 months of 2013 [4]. The Food and Agriculture Organization of the United Nations (FAO) has indicated that about 32 percent of different types of food produced globally is lost or wasted.

In attempting to categorize many SKUs to a few categories for inventory replenishment rules, items that are not popular are being held in finished goods inventory in varying volumes which then become slow-moving over time due to declining popularity. This will lead to obsolete inventory, leading to costs to an organization.

2. Literature Review

The literature section traces the evolution of the ABC approach used by supply chain managers to categorize inventory before looking at how categorization is being used to manage large amounts of inventory items to set inventory targets.

2.1 Definition and evolution of categorization

Categorization implies that objects are grouped into categories usually for a specific purpose. Categorization is the process in which ideas and objects are recognized, differentiated and separated so that specific treatment can be applied to these categories. Early studies on categorization began from a late nineteenth-century economist/sociologist, who found that 80% of the country's wealth was distributed among 20% of the country's population [5]. His reported observation then

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forms the basis for what we now call the Pareto Principle or the 80:20 rule.

We can say that the Pareto Principle identifies 2 categories, namely A and B categories as per Table 1.

Table 1: How categorization is developed in the Pareto Principle.

% of the population	% of wealth possession	categories
20 %	80 %	A
80 %	20 %	B

According to Ref. [5] , he observed that only 20% of his garden pea plants generated 80% of the healthy pods. He also found that 80% of land in Italy at that time was owned by 20% of the population and that 80% of production came from 20% of companies. We can also observe that the 80:20 phenomena is evident even among many aspects of people's lives. In our daily lives, we use 20% of our clothes 80% of the time and even in major industrial businesses, 20% of an organization's customers may purchase 80% of the organization's output. Even after world war II, the Japanese used the Pareto Principle to determine 20% of identified items that contributed to 80% of the total number of defects as one of the Total Quality Management (TQM) tools.

2.2 Inventory Categorization

The Pareto principle has been used most often in inventory and the most common unit of measure used in inventory categorization is order volume measured in either sales units, cases, pallets, container loads, weight, length or litres. In 1951, General Electric was the first company to apply a 3rd category called the C category, hence ABC categories were developed (Table 2), [6].

Table 2: How categorization was developed to include the C category.

% of the inventory items	% of order volume	categories
20 %	80 %	A
30 %	15 %	B
50%	5%	C

Order value is also a popular variable used but order volume relates well to size of incoming orders and therefore directly relates to size of batch capacity installed. A popular way of categorizing inventory is to classify volume or value of sales units by SKUs received into ABC categories. Ref. [7] demonstrated how inventory is classified in Figure 1.

Percentage of items	Order Volume
20%	80%
30%	15%
50%	5%

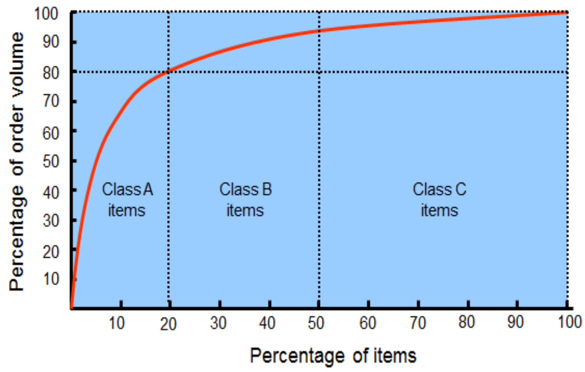

Figure 1.ABC classification of inventory, based on order volume.

Once several SKUs have been categorized into ABC categories, supply chain managers may then be able to easily set days cover policies for each category for inventory replenishment. However, order volume is a measure of importance and an item low in volume but high in popularity can be more important than a high volume item with low popularity [8]. This being the case, ABC categories based on order volume (or value) may not detect any slowing down in popularity of demand.

2.3 How inventory is measured

We can say that inventory can be categorized into many categories because there are many ways to measure inventory (Table 3). We can see that besides volume and value, inventory can also be measured in turns, days cover, lead times, service levels and even stock-outs.

Table 3: How inventory is measured.

	Description of inventory measure
Volume	Either in sales units, cases, pallets, container loads, weight, length or litres.
Value	Sales units multiplied by cost of goods sold or sales price for revenue earned.
Turns	Cost of goods sold / average inventory investment in raw materials, work-in-process & finished goods.
Cover	Inventory cover in seconds, minutes, days, weeks, months (usually days), usually determined as the current quantity in stock divided by the anticipated future daily rate of usage or sales.
Lead Times	Length of time taken to obtain or supply a requirement from the time a need is ascertained to the time the need is satisfied.
Service Levels	The actual service level attained in a period, usually the number of times an item is provided on demand over the number of times the item has been demanded.
Stock-outs	Expressed as a percentage of demand not met within the total stock population during a given period.

2.4 How inventory categories are developed

Inventory categorization allows for the setting of days cover policies for each category of inventory. This in turn allows supply chain managers to control the target days of inventory. We can demonstrate how inventory categories are developed and also how these categories are used to determine target stock-in-days (SID) of finished goods held.

Even though we may manage many SKUs, let us say for ease of explanation, we use the 7 SKUs in Table 4 to develop these categories. Example, if we use A=0 to 80%, B=81 to 95% and C=96 to 100%, we can determine A, B & C categories based on order volume as per Table 4 by sorting the SKUs in order of volume popularity, then determining their cumulative percentages in volume, before separating them into grades of A, B and C categories.

Table 4. How ABC categories are developed.

N	Inventory items	Order Volume	Cumulative volume	Cumulative percentage	Grade
1	SKU1	50	50	50/100*100=50.00%	A
2	SKU2	30	80	80/100*100=80.00%	A
3	SKU3	9	89	89/100*100=89.00%	B
4	SKU4	5	94	94/100*100=94.00%	B
5	SKU5	3	97	97/100*100=97.00%	C
6	SKU6	2	99	99/100*100=99.00%	C
7	SKU7	1	100	100/100*100=100.00%	C
	Total	100			

2.5 How days cover policies are used to determine re-order points and quantities for replenishment

Once ABC categories have been established, we can use these categories to determine the replenishment points [also called the re-order point (ROP) or (R)] as well as quantities for replenishment (Q). The main benefit of doing this is to reduce the complexity of having to set ROPs and Qs for each and every single SKU in the business. It has been shown in a recent study, that days of supply can be an effective measure of inventory performance [9]. Let us use the sample data in Table 5 to determine R and Q for each ABC category and let us assume that for each category, we were able to summarize the total average withdrawal rate per day (or orders received).

Table 5. Average withdrawal rate per day for ABC categories.

Category	Units demand a day
A	80 units a day
B	15 units a day
C	5 units a day
Total	100 units a day

Supply Chain Managers may then set self determined days cover policies for each category as per the parameters in Table 6.

Table 6. Setting of ROP and Qs day cover using inventory categories

Category	ROP (days)	Q (days)	ROP (units)	Q (units)
A	7	14	560	1120
B	14	28	210	420
C	28	84	140	420
Total			910	1960

The ROP is usually set based on days of lead time to obtain supplies plus safety stock (in days), usually to cover fluctuations in demand and a smaller Q is preferred as inventory held on average can be calculated as Q/2 (or the mid- point between zero and Q).

2.6 How days cover policies are used to determine target days of inventory.

We can also determine target stock in days (SID) from these days cover policies. We have derived average inventory (or Q/2) if no safety stocks are held but if there are safety stocks held to cover demand fluctuation, then average inventory can be determined as Q/2 + safety stocks. Using the data in Tables 5 and 6, we can compute Q/2 as 1960/2 = 980 units and in terms of days, this is 9.8 days held on average, at 100 units a day for the inventory policies in the example. If another 1000 units (or 10 days at 100 units/day) of safety stocks are held, the formula for average inventory held will then be Q/2 + Safety stocks, yielding a target of 19.8 days. Safety stocks can be determined using 2 approaches [10].

- determine safety stocks by arbitrarily setting 'x' weeks (or days) of cover.
- determine safety stocks by calculating standard deviation of the demand data and determining the probability of meeting 'x' percentage of SKUs ordered.

Many other statistical approaches can also be used to determine safety stocks but other approaches can be a bit confusing. For example, a well-known approach called the Brown formula can be used to better determine lost sales due to stock-outs but several problems arise as the user must perform awkward interpolation on the data which many may find confusing [11]. The result of inventory policies thus allow target SID for any given inventory policy to be determined and this can then be compared with actual inventory held for management to consider inventory reduction policies that may reduce working capital or improve customer service.

2.7 Multi criteria inventory categories

Multi criteria inventory classification (MCIC) have evolved since the beginning of the 20th century. During the early part of the twenty-first century, many authors began to consider multiple attributes for ABC classification in their publications. Ref. [12] classified inventory based on product applications, demand types, maintenance repair and operating material as well as usage and value ABC classifications. Ref. [13] developed thinking into multi-criteria ABC inventory classification using exponential smoothing weights for multi criteria apart from unit price and usage. Variables included lead-time, ordering costs, scarcity, durability, sustainability, reparability, criticality, commonality as well as number of hits and average per hit. Ref. [14] also developed ABC inventory classification using multiple-criteria and weighted linear optimization. The model used a maximization objective function as all the criteria were assumed to be positively related to the importance level of the SKU. It has also been well known that other factors besides order volume will contribute in deciding the importance of an inventory item, such as average unit cost, lead time, substitutability, commonality, scarcity and demand distribution [14]. On the other hand, Ref. [15] developed ABC categories of services within the building industry based on value and risk. Ref. [16] classified inventory based on product/market classification on groups of customers, markets or customers with similar characteristics to facilitate inventory management. It can be noted that even though many studies have considered single or multiple attributes, there has been little research done on the order frequency variable that may impact SID performance. Order volume-based categories of inventory may be used to determine size of orders received in relation to capacity and warehouse space required but order frequency will determine popularity of an item where low order frequency may be an indicator of slow-moving inventory, for example. We can say that high order frequency inventory items may have lower excesses and obsolescence than a slow-moving category item because it moves faster and more frequently [7].

2.8 Order frequency variable

Studies on order patterns have evolved around consideration of shorter lead times, which constitute a major source of competitive advantage [18]. In another study, order frequency was defined as a measure of the number of times a customer placed an order in a given period [19] but the study did not relate to inventory days held. In subsequent studies, Ref. [20] considered order frequency as a variable in addition to order size and customer order anxiety to determine online shopping behaviour for retail website online business. The business carried about 3000 SKUs belonging to 20 different publishers and the study showed that there were adverse reactions seen in several dimensions of customer shopping behavior and where order frequency and order size decreased, customer anxiety level also increased. We can also say that in a business setting, high order frequency could also be a result of many small customer orders as well as popularity of orders ordered throughout the supply chain. Ref. [21] indicated that small orders are a perennial problem in most organizations and that an analysis of a typical company's purchase order transactions may reveal that a sizeable percentage (sometimes 80 per cent) of an organization's purchases involve small expenditures and that these orders constitute a small percentage (seldom 10 per cent) of the firm's annual value expenditure.

Batch producers such as those manufacturing many SKUs may make their products in large batches, example 1000 agricultural machines at a time or small batches, perhaps 6 machine tools at a time. Processes can be categorized as a project, jobbing, batch, mass and continuous according to product volume and variety dimensions. It has been found that process and product associations provide competitive performance for firms [22]. Batch processes supporting the FMCG businesses hold vast amounts of inventory and have demand variability and inventory obsolescence issues [23]. Studies have also shown that small batches and lean practices in manufacturing will reduce unnecessary waste [24]. Alternately, when smaller batches are made, it supports the higher frequency of smaller orders received from the trade and fewer inventories are held. With the popular practice of just-in-time (JIT) and lean production, manufacturing activities use minimal inventory of raw materials, work-in-process and finished goods and parts arrive at the next workstation 'just-in-time' and are completed and moved through the process quickly [25]. Ref. [23] also indicated that most supermarkets carry only a few day's supply of product and out-of-stock does occur with some frequency. Ref. [26], indicated that suppliers use cross-docking methods where inventory is moved directly from upstream processes to meet market or manufacturer needs and are not placed in storage in the warehouse. Additionally, distributors may attempt to reduce additional transaction costs by placing larger batch orders on manufacturers and this will cause additional inventory to be held. When order volume received by distributors are small (as denoted by higher order frequency and lower time between orders), distributors may place bigger orders from their manufacturer and excess inventory is kept.

Additionally, over a period of time, leftover inventory due to technological or market changes could also result in slow moving and obsolete inventory. On the other hand, with the rise of consumerism today, perfect orders are required by customers where orders are delivered to the customer for the right quantity and assortment of products to the right location on time, damage-free and correctly invoiced [19]. Ref. [27] noted that in order to meet demand, manufacturers have been designing new products and offering wide choices for consumers. Not only do customers have wide choices, they can order any quantity at any interval.

We can therefore determine order frequency as the number of times an inventory item is ordered from the market. Order frequency will have an impact on SID held, i.e., the higher the frequency, the lower the SID held as new incoming orders tend to deplete inventory held regularly.

We can observe that the literature for MCIC has not really identified the use of the order frequency variable to categorize items that could become slow moving as a result of decreasing popularity.

3.0 Recommendation

This study aims to recommend the use of an algorithm called the Vaz algorithm. It has been named after the main author of this article because of its use in the sewing thread industry where the author worked for a good part of his career. The Vaz algorithm is based on order frequency and order volume to derive A, B, C & D categories of finished goods inventory. A, B & C categories are used to derive make for stock finished goods items whereas the D category is used to identify made to order items. The Vaz algorithm is explained in detail and discussed in this section and the new inventory category called D items is developed in addition to ABC categories. These are stock keeping units (SKUs) = < user defined x times for the frequency an SKU is ordered in a user defined period, usually a 1 year period [28] & [29]. The author's thesis in his post-graduate studies helped developed the academic aspect of the algorithm.

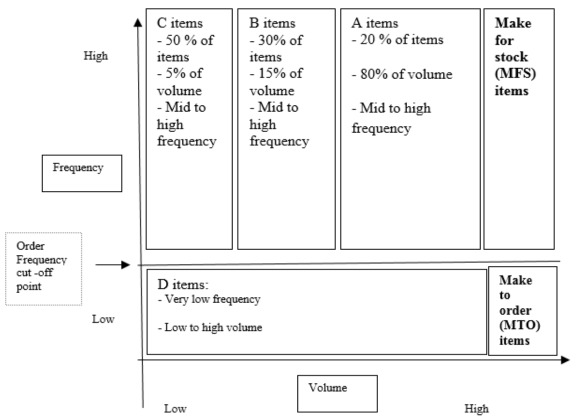

Figure 2. The Vaz Algorithm - inventory categorization using order frequency and order volume.

Source: [28] & [29]

3.1 Vaz Algorithm assumptions and explanation

Let f = order frequency of a stock keeping unit (SKU) within the user-defined period

$$= \sum_{i=1}^{n} fi \qquad (1)$$

where n= number of SKUs ordered within the user-defined period,

And x = a user defined number of times an item is ordered, or the cut-off point between make for stock versus make to order finished good items,

v = volume of orders in sales units (or a user-defined value) for each stock keeping unit within the user-defined period and,

V_t = Total volume of orders in sales units (or user-defined value) for a user-defined period

$$= \sum_{i=1}^{n} vi \qquad (2)$$

where n = number of different stock- keeping units (SKUs) ordered within the user-defined period

3.1.1 Vaz Algorithm computation

- When f = or < x = **D** category of finished goods inventory. V_D is thus defined as the total volume of orders in sales units (or user-defined value) that have frequencies that are less than the cut-off frequency and v_D represent individual make to order items by SKU
- When f > x = **A**, **B** or **C** categories of finished goods inventory within the remaining volume of orders in sales units (or user-defined value) = V_t - V_D = V_R
- Using V_R, determine the percentage of volume for each of the remaining SKUs (or v/V_R x 100), sort in order of descending order volume by SKU by cumulative percentage
- Finally, derive A, B, C categories (or V_A, V_B, V_C by SKU) from cumulative percentages of V_R.
  V_A SKUs = 0 to 80% of V_R for each SKU
  V_B SKUs = >80 to 95% of V_R for each SKU
  V_C SKUs = >95% to 100% of V_R for each SKU

3.2 Discussion

The recommended Vaz algorithm in this study can be used by supply chain managers to adopt inventory strategies that will reduce incidence of excess slow-moving inventory. Supply organizations may be able to respond to orders instead of keeping high inventory. Organizations may apply a make-to-order strategy if the customer is able to wait long enough. This is applicable in the case of McDonalds, where customers are able to wait just long enough in the queue from ordering of product to receiving the product during drive-ins, in particular. In a study on what fast food operators need to focus on for customer satisfaction, it was found that perceived waiting time significantly influence customer satisfaction for fast food restaurants [30]. However, inventory related importance among companies tend to focus on product availability as a main objective [29] because consumers will not wait for the product when they attempt to make a purchase especially from supermarkets but consumers in make- to- order environments may wait for products after an order has been made, for example in laptop assembly or car manufacture.

Alternately, when finished goods inventory has reached zero, a supply chain manager may decide to produce a small batch. Small batch capacity for fast moving consumer products, example, beverages, tobacco, soft drinks have nowadays taken the form of vending machines and a real-world deployment in incorporating the Internet of Things (IoT) system for vending machines are in place which allows for mobile proximity payment for unattended point of sales. The idea is to be able to order products from a smartphone without interacting with the vending machine. When the transaction occurs and the products are dispensed, the consumer is physically close to the vending machine [31].

4.0 Conclusion

This study aims to highlight to Supply Chain Managers in batch process industries that the order frequency variable can also be used as a supporting variable, in addition to order volume as order volume on its own could lead to inventory obsolescence issues when such volume is less frequently ordered.

4.1 Limitations and Future Research

The increase in small batch capacity and product dispensing represents an investment and while advances have been made in Industry 4.0 for full supply chain integration, many small medium enterprises (SMEs) may not have the financial resources to implement innovative technology as there are considerable costs in implementing technology which impede small and medium-sized enterprises from accessing innovation [32]. However, the recommendations in this study will contribute in allowing supply chain managers to effectively categorize slow moving inventory into 'D' categories and keep a close eye on a manufacturing strategy to reduce or eliminate slow moving inventory. Greater understanding on how to reduce inventory waste will help mankind become thrifty and less wasteful. In the area of food waste, for example, it was found that as much as around one third of all food produced for human consumption (equivalent to a staggering 1.3 billion tons), is lost or wasted annually [33] and the findings in this study will perhaps help reduce this statistic.

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