A MULTI-CRITERIA DECISION FRAMEWORK FOR INVENTORY MANAGEMENT

Pradip Kumar Krishnadevarajan
Research Scholar, Karpagam University, Coimbatore, Tamil Nadu-India
Assistant Director, Global Supply Chain Lab, Texas A&M University, USA

S. Balasubramanian
Professor, Department of Mechanical Engineering University,
Rathinam Technical Campus, Coimbatore, Tamil Nadu-India

N. Kannan
Professor. St. Mary’s School of Management Studies, Chennai, Tamil Nadu-India

Vignesh Ravichandran
Bachelor of Engineering, Mechanical Engineering
PSG College of Technology, Coimbatore, Tamil Nadu-India

ABSTRACT

Inventory management is a process / practice that every company undertakes. Most companies fail to apply a comprehensive set of criteria to rank their products / items. The criteria are too few or subjective in nature. Inventory is required to stay in business and meet customer needs. If it is not done right it causes deterioration in customer service and could lead to damages to both customer and supplier relations and eventually cause business breakdown. A simple multi-criteria driven holistic framework developed by industry input is critical to the success of inventory management. An inventory management framework using FIVE main-criteria categories (revenue, customer service, profitability, growth, risk), 21 (between 3 and 6 in each category) metrics and 4 ranks (A, B, C, D) is presented in this paper to assist companies with their inventory management process. The framework that is presented has been developed through literature review, surveys, interviews and focus groups with several industry owners, inventory managers and business managers. The interaction with companies led to a set of THREE critical questions:

1. Is there a comprehensive inventory management framework?
2. What inventory metrics should be tracked or monitored on a routine basis?
3. How do implement a multi-criteria inventory classification?

This paper is an attempt to answer these critical questions and provide a framework that is developed by bringing together existing literature available and input/findings from industry executives in the area of inventory management.

Key words: Inventory, Inventory Management, Inventory Classification, Inventory Ranking, Multi-Criteria Inventory Management.


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1. INTRODUCTION

Inventory is a critical asset and resource that is handled extensively by most businesses. Managing inventory effectively has been something that every company strives for; however, it is also an area where companies often have failed and still continue to fail. Companies handle multiple items/products but treat all items equally because the business objective is to serve the customer. As a result they end up having excess inventory of the wrong items. As businesses expand there are so many products in inventory and the company ends up having more stocking inventory for each product or end up investing more in the wrong inventory. Item/inventory stratification is the process of ranking items based on relevant factors applicable to the business environment. According to Pradip Kumar Krishnadevarajan, Gunasekaran S., Lawrence F.B. and Rao B (2015) and Pradip Kumar Krishnadevarajan, S Balasubramanian and N Kannan (2015) you should classify items into a certain number of categories (typically less than five) so that managing them day-to-day does not become unwieldy. This is especially needed when handling several hundreds or thousands of items, where identifying and focusing on the most critical items is of utmost importance to allow resources to be used effectively and efficiently. This stratification process is typically done at a physical location level (at branches or distribution centers) across the entire company, although it could be applied at higher levels (regions or the entire company). The item stratification process is usually not well-defined or given due importance, and it often gets over-simplified. The inventory stratification process should address several metrics and a multi-criteria approach must be taken for effective inventory management. This paper attempts to present a comprehensive framework that could assist companies in choosing the right set of metrics to perform inventory ranking for their business.

2. FRAMEWORK DEVELOPMENT

The process of inventory classification actually begins by developing or choosing a framework that suits the company’s vision and goals. The development process of the proposed inventory framework process took place in two stages. The first stage was to look at existing literature to understand the different factors/criteria that are being used for inventory evaluation by various industries/businesses. The second stage was interaction with companies to gather input, understand metrics used and challenges faced in executing the inventory classification process.
2.1. Literature Review
(Pareto, 1906) observed that about 20% of the population of a country has about 80% of its wealth (also known as the 80-20 rule). This rule holds true for items sold by a firm: about 20% of items account for about 80% of a firm’s revenue.

(Flores and Whybark, 1987) present an inventory ranking model driven by criticality and dollar-usage. The first stage is for the users to rank the items based on criticality, the second stage ranks items based on dollar/currency usage. Based on usage, items are ranked as A, B or C.

(Flores, Olson and Dorai, 1992) propose the use of AHP as a means for decision makers to custom design a formula reflecting the relative importance of each unit of inventory item based on a weighted value of the criteria utilized. The factors applied are – total annual usage (quantity), average unit cost (currency), annual usage (currency), lead time and criticality. They also present a reclassification model based on the following factors and weights: criticality (42%), followed by lead time (41%), annual dollar usage (9.2%), and average unit cost (7.8%).

(Schreibfeder, 2005) recommend a combination model using cost of goods sold (procurement price from supplier, number of transactions (orders or hits), and profitability (gross margin).

(Lawrence, Gunasekaran and Krishnadev, 2009) state that best practices in item stratification are based on multiple factors such as sales, logistics (hits), and profitability (gross margin currency or percentage, or gross margin return on inventory investment [GMROI]) that help to attain the optimal solution in most cases. Companies, however, can include more factors specific to their business environment, such as lead time, product life cycle, sense of urgency, product dependency, criticality, product life cycle and logistics costs. They also present a model to classify items based on demand pattern. A demand stability index (DSI) is established using three criteria – demand frequency or usage frequency, demand size and demand variability.

(Pradip Kumar Krishnadev, Gunasekaran, Lawrence and Rao, 2013) rank items into 4 categories (High, medium-plus, medium-minus, low) for risk management and price sensitivity. Ranking is based on unit cost of the item. Items are also ranked based on annual usage (currency), hits, gross margin (currency) and gross margin (percentage). The final ranks are Critical (A & B items), important (C items) and non-critical (D items).

(Dhoka and Choudary, 2013) classify items based on demand predictability (XYZ Analysis). Items which have uniform demand are ranked as X, varying demand as Y, and abnormal demand as Z.

(Hatefi, Torabi and Bagheri, 2014) present a modified linear optimization method that enables inventory managers to classify a number of inventory items in the presence of both qualitative and quantitative criteria without any subjectivity. The four factors used are ADU (Annual dollar usage), CF (critical factor – very critical [VC], moderately critical [MC] or non-critical [NC]), AUC (Average unit cost) and LT (Lead Time). Items are ranked as A, B, or C.

(Xue, 2014) connects the characteristics of materials supply and the relationship between parts and production, a classification model based on materials attributes. The several criteria applied in the decision tree model are: Parts usage rate, carrying-holding-possession costs, ordering-purchase costs, shortage cost, and delivery ability.
Šarić, Šimunović, Pezer and Šimunović (2014) present a research on inventory ABC classification using various multi-criteria methods (AHP) method and cluster analysis) and neural networks. The model uses 4 criteria – Annual cost, Criticality, Lead Time 1 and Lead Time 2.

(Kumar, Rajan and Balan, 2014) rank items based on their cost in bill of materials (ABC ranking). “A” items -70% higher value of items of bill of material, “B” items – 20% Medium value of items of Bill of material and “C” items – 10% Lower value of items of Bill of material. They also determine vital, essential, and desirable components required for assembly (VED analysis).

(Sarmah and Moharana, 2015) present a model that has 5 criteria – consumption rate, unit price, replenishment lead time, commonality and criticality.

(Pradip Kumar Krishnadevarajan, Balasubramanian, and Kannan, 2015) present a strategic business stratification framework based on: suppliers, product, demand, space, service, market, customer and people.

(Pradip Kumar Krishnadevarajan, Vignesh, Balasubramanian and Kannan, 2015) present a framework for supplier classification based on several categories: convenience, customer service, profitability (financial), growth, innovation, inventory, quality and risk. A similar framework can be extended based on the supplier classification for items or products.

2.2. Industry Feedback

Interaction with companies was performed through surveys, interviews and focus groups with several industry owners, inventory/purchasing managers and business managers. The objective was to get an idea of the metrics being utilized for inventory classification, challenges faced, inventory framework deployed and the effectiveness of their current inventory performance management processes. Key findings from the industry interaction were the following:

- **Lack of a inventory management framework.** Understanding where the process began and where it ended was the key challenge. Who should take ownership of this process in the company? Often, data was missing or currently not captured in the system in order to create various metrics to help with inventory management. Internally, all companies did not have a goal or objective regarding what they would like to achieve with the inventory management process. No concrete data driven discussions or goal setting took place. Most of the inventory ranking was based on experience.

- **What to track?** Companies either tracked too many metrics or did not track anything. Even if they tracked too many metrics most of them were subjective and anecdotal. They lacked a significant number of quantitative metrics to act on something meaningful. Companies wanted a set of metrics they could choose from and then set a process in place to capture the relevant data to compute those metrics. If multiple metrics are used to track inventory performance, is there a methodology to combine various metrics to develop a single rank (ease of decision making) for each item/product?

- **Reporting and Scorecards:** The next challenge was that even if a few companies had the required data and were able to compute the metrics they did not have an effective way of reporting this information back to the purchasing team or anyone who influenced inventory decision. They lacked reporting tools and templates for the performance metrics.

- **Continuous Improvement:** The steps that need to be established to continually improve the inventory management process at the company did not exist. Several
companies had gone down the path of implementing a version of the inventory management but could not sustain the same due to lack of accountability/ownership, failing to change the metrics when the industry dynamics changed, and execution challenges.

The focus of this paper is to propose a simple, yet holistic framework, list of metrics to track and a multi-criteria ranking method for inventory management.

3. INVENTORY MANAGEMENT FRAMEWORK

The approach used to layout an inventory framework is bridging the gap between what was seen in the literature review and the feedback from industry. The key objectives in the framework development were the following:

- Metrics should be quantitative (objective and data driven). There will be only a few qualitative metrics.
- The framework should be holistic and comprehensive at the same time easy to understand.
- Scalability and flexibility of the framework is important as companies adopt it into their inventory management process.
- Apply a multi-criteria approach but provide the ability to get one single final rank (A, B, C or D) for a given item or product so that inventory policies and strategies can be established at a final rank level.
- Provide a starting point for ranking criteria – what determines an A, B, C or D item for each metric used in the framework.

Most companies measure inventory solely based on sales or usage. This is because almost all companies just focus on sales primarily. The proposed framework provides 5 categories based on which items should be ranked (shown in illustration 1). It varies from ‘revenue’ to ‘risk’. These 5 categories have a set of metrics (21 metrics in total), formula to compute the metric and a ranking scale that places each items in one of 4 ranks – A, B, C or D. Companies can choose the categories that are most relevant to their current business priority and then choose a set of factors/metrics under each category to rank their items / products.

Illustration 1: Inventory Classification Categories and Metrics

<table>
<thead>
<tr>
<th>Revenue (Sales)</th>
<th>Customer Service</th>
<th>Profitability</th>
<th>Growth</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales Currency</td>
<td>Hits</td>
<td>Gross Profit %</td>
<td>Growth (Revenue Trend)</td>
<td>Number of Suppliers</td>
</tr>
<tr>
<td>Sales Quantity or Usage</td>
<td>Lead Time</td>
<td>Gross Profit Currency</td>
<td>Gross Margin Trend</td>
<td>Number of Customers</td>
</tr>
<tr>
<td></td>
<td>Number of Stock-outs</td>
<td>Unit Cost</td>
<td>Number of Dependent Items</td>
<td>Criticality</td>
</tr>
<tr>
<td></td>
<td>Inventory Turns</td>
<td></td>
<td></td>
<td>Demand Stability Index</td>
</tr>
</tbody>
</table>
The five categories of the inventory framework address several inventory metrics. The definition of each metric, corresponding formula (calculation method) and the criteria to determine A, B, C and D ranks is listed in Illustration 2. Choosing one metric from each category is recommended. However, companies should customize the framework in alignment with their growth goals and customer requirements.

**Illustration 2:** Inventory Management – Metrics, Definition and Criteria

<table>
<thead>
<tr>
<th>No</th>
<th>Category</th>
<th>Factors / Metrics</th>
<th>Definition</th>
<th>Item Rank (A is better)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Revenue (Sales)</td>
<td>Sales Currency</td>
<td>Total annual sales currency at an item level</td>
<td>A: Top 60%, B: Next 20%, C: Next 10%, D: Others</td>
</tr>
<tr>
<td>2</td>
<td>Revenue (Sales)</td>
<td>Sales Usage or Quantity</td>
<td>Total annual sales quantity at an item level</td>
<td>A: Top 60%, B: Next 20%, C: Next 10%, D: Others</td>
</tr>
<tr>
<td>3</td>
<td>Cost of Goods Sold (Spend)</td>
<td>Cost of Goods Sold (Spend)</td>
<td>Total annual spend currency at an item level</td>
<td>A: Top 60%, B: Next 20%, C: Next 10%, D: Others</td>
</tr>
<tr>
<td>1</td>
<td>Customer Service</td>
<td>Hit Total</td>
<td>Standard deviation of lead time / Average lead time (Calculated for a period of 3-6 months).</td>
<td>A: &lt;25%, B: 25-35%, C: 35-50%, D: Others</td>
</tr>
<tr>
<td>2</td>
<td>Customer Service</td>
<td>Lead Time</td>
<td>Time elapsed between the order date (to supplier) and the order received date (from supplier).</td>
<td>A: 1 Day, B: 2-3 Days, C: 4-5 Days, D: Others</td>
</tr>
<tr>
<td>3</td>
<td>Customer Service</td>
<td>Lead Time Variability</td>
<td>Standard deviation of lead time / Average lead time (Calculated for a period of 3-6 months).</td>
<td>A: &lt;25%, B: 25-35%, C: 35-50%, D: Others</td>
</tr>
<tr>
<td>4</td>
<td>Number of Stock-outs</td>
<td>Number of times this item / product stocked out when the customer requested items.</td>
<td>It is computed over a 6 month period.</td>
<td>A: 2 stockouts in 6 months, B: 3 - 4, C: 5 - 6, D: Others</td>
</tr>
<tr>
<td>5</td>
<td>Inventory Turns</td>
<td>Inventory Turns</td>
<td>Computed as a ratio of Cost of Goods Sold/ Average Inventory Currency</td>
<td>A: &gt; 6 Times a Year, B: 4 or 5 times, C: 2 or 3 times, D: 1</td>
</tr>
<tr>
<td>1</td>
<td>Financial</td>
<td>Gross Profit %</td>
<td>Annual profit percentage of each item.</td>
<td>A: &gt;25%, B: 20-25%, C: 15-20%, D: Others</td>
</tr>
<tr>
<td>2</td>
<td>Financial</td>
<td>Gross Profit Currency</td>
<td>Total annual profit currency (percentage of the total company profit) provided by each item.</td>
<td>A: Top 60%, B: Next 20%, C: Next 10%, D: Others</td>
</tr>
<tr>
<td>3</td>
<td>Financial</td>
<td>Gross Margin Return On Inventory Investment (GMROI)</td>
<td>The ratio of profit currency and the average inventory currency over a specific period of time (6-12 months), represented as a percentage.</td>
<td>A: &gt;200%, B: 100-200%, C: 50-100%, D: Others</td>
</tr>
<tr>
<td>4</td>
<td>Growth</td>
<td>Unit Cost</td>
<td>Cost of each item (Currency)</td>
<td>A: &gt;500, B: 250-500, C: 50-250, D: Others</td>
</tr>
<tr>
<td>1</td>
<td>Growth</td>
<td>Growth (Revenue Trend)</td>
<td>Computed as the increase or decrease in revenue from the previous year / current year revenue.</td>
<td>A: &gt;25%, B: 15-25%, C: 5-15%, D: Others</td>
</tr>
<tr>
<td>2</td>
<td>Growth</td>
<td>Growth (Gross Margin Trend)</td>
<td>Computed as the increase or decrease in gross margin currency from the previous year / current year gross margin.</td>
<td>A: &gt;15%, B: 10-15%, C: 5-10%, D: Others</td>
</tr>
<tr>
<td>3</td>
<td>Product Life Cycle</td>
<td>Product Life Cycle</td>
<td>The life cycle of the product or the number of years the product has been in the market</td>
<td>A: 1 Year, B: 2, C: 3, D: Others</td>
</tr>
<tr>
<td>1</td>
<td>Risk</td>
<td>Number of Suppliers</td>
<td>Number of customers for the product indicates the risk associated with this item.</td>
<td>A: &lt;5, B: 5-10, C: 10-15, D: Others</td>
</tr>
<tr>
<td>2</td>
<td>Risk</td>
<td>Number of Customers</td>
<td>Number of customers for the product indicates the risk associated with this item.</td>
<td>A: &gt; 50 Customers, B: 25-50, C: 15-25, D: Others</td>
</tr>
<tr>
<td>3</td>
<td>Risk</td>
<td>Pricing Variability</td>
<td>Ratio of standard deviation of item price points to the average of the price points. High variation (decrease) indicates that the product is moving toward commoditization.</td>
<td>A: &lt;25%, B: 25-35%, C: 35-50%, D: Others</td>
</tr>
<tr>
<td>4</td>
<td>Risk</td>
<td>Number of Dependent Items</td>
<td>Number of other items that are dependent on this product - assembly or purchased together</td>
<td>A: &gt;15 Items, B: 10-15, C: 5-10, D: Others</td>
</tr>
<tr>
<td>5</td>
<td>Criticality</td>
<td>Criticality</td>
<td>Criticality of the item based on need (flagship product), customer critical or customer specific inventory</td>
<td>A: Very High, B: High, C: Medium, D: Low</td>
</tr>
<tr>
<td>6</td>
<td>Demand Stability Index (DSI)</td>
<td>Demand Stability Index (DSI)</td>
<td>Based on demand pattern of the item and how easy or predictable is the item demand (forecast)</td>
<td>A: Highly Stable, B: Stable, C: Moderate, D: Unstable</td>
</tr>
</tbody>
</table>
3.1. Final Item Rank

Various metrics that could be applied to determine item ranks (across 5 categories) were addressed in the previous sections. Decision-making process becomes challenging when there are multiple ranks (while using multiple metrics across the 5 categories) pointing in different directions. In this situation, a weighted stratification matrix helps determine a final rank for each item (Lawrence, Krishnadevarajan, Gunasekaran, 2011). The final item rank depends on three factors:

- **Weights given for each factor:** This input captures the importance of each factor. Weights may vary depending on the environment, but an example when a company applies 5 metrics to rank their items could be: Sales currency = 25%; Hits = 20%; GMROI = 20%. Number of customers = 20%; and Pricing variability = 15%. If a company chooses to include additional factors, the weights may be distributed accordingly.

- The relative importance of A, B, C, and D ranks: Example: A=40; B=30; C=20; and D=10

- Score the range for the final score: The above weights are converted to a scale of 10 to 40, resulting in a best score of 40 (ranked A in all categories) and a least score of 10 (ranked D in all categories). The 30 points in the range of 10 to 40 is divided into four groups. Example: A=32.6 to 40; B=25.1 to 32.5; C=17.6 to 25; and D=10 to 17.5.

With these parameters, a final rank can be determined for a given item. If an item is ranked as B, C, A, B and D according to sales currency, hits, GMROI, number of customers and pricing variability respectively; this item’s final performance score is computed as follows:

Final supplier score = \[(25\% \times 30) + (20\% \times 20) + (20\% \times 40) + (20\% \times 30) + (15\% \times 10)\] = 27

This score falls between the ranges of 25.1 to 32.5, so this item gets a final rank of “B”.

3.2. Summary of Item Ranking

The various steps that are involved in the ranking of items can be summarized as follows:

- **Step 1:** Customize the framework according to the company’s requirement. This includes both the categories as well as the metrics under each category.
- **Step 2:** Determine the cut-off values for each metric – the criteria that ranks items as A, B, C or D. This is a very important step.
- **Step 3:** Choose key metrics that will determine item ranks.
- **Step 4:** Rank the items for each metric using company-specific cut-off values.
- **Step 5:** Assign weights to each factor.
- **Step 6:** Compute final rank for each item.
- **Step 7:** Using a cross-functional team to determine inventory policies and strategies for A, B, C and D items based on the final rank.
4. CONCLUSION
The proposed inventory framework provides a guideline for companies with their inventory management process. Determining the right items to stock (inventory investment) and managing them effectively is key to good customer service and business sustainability. Measuring items on data driven objective criteria is critical to maintaining profitable-sustainable business relationships with customers and suppliers.

REFERENCES


