Excess inventory management based on AI: an exploratory case study

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Abstract:

The paper aims to demonstrate how artificial intelligence (AI) could be used in the field of inventory management, including excess inventory reduction. The paper shows several cases in various industry and reveals the trends in the topic. With the evolution of information technology, many actors in this area forecast that these problems in future will be addressed with the help of artificial intelligence. This paper is aimed at an overview of the concept of inventory management and AI. We focus on practical aspects of AI in inventory management. The results demonstrate a conceptual idea regarding how AI can support managing excess inventory.

Keywords: Supply Chain, Inventory, Inventory Management, Artificial Intelligence (AI)

1. Introduction

In today's challenging times bringing a variety of disruptions and lengthening of lead times across the whole business value chain, organizations are seeking to reduce inventory carrying costs, since the closing margin gaps force businesses to seek for optimization opportunities to stay within targeted profitability. Along with it, the growing consumer expectations require to maintain the gained momentum in improving service levels which brings up the dilemma on how to deal with these objectives especially today.

The companies formulate objectives and group them in the following way:

1. Capital utilization
- Decrease working capital
2. Operational efficiency
- Improve operational cost structure
- Positively impact overall company cash flow
3. Customer service
- Improve service level
- Reduce lead time and increase responsiveness of supply chains

However, to meet these objectives requires answering a variety of complex questions:

How much inventory should be held and in what location?
- What should safety stock levels be?
- Where should pull processes be used?
- What replenishment strategies should be used?
- What is the optimal inventory cost to achieve required service levels?

To successfully answer these questions, businesses need to recognize the challenges the inventory management process bring up today:

1. Siloed inventory management. Planners across the supply chain do not consider the impact of their decisions on the following echelons of the network. There is a lack of centralized inventory governance that manages inventory considering the whole picture.
2. Lack of inventory visibility. Data need to evaluate inventory performance and to take optimized inventory decisions is spread all over isolated systems across the company. Without the right data available, it is hard to make informed data driven decisions.
3. Increasing supply chain complexity. Businesses face higher pressure for high service levels and shorter delivery times alongside with steadily increasing product portfolio

to manage. There are emerging more diverse demand needs and channels with steadily widening structure of suppliers.

4. Multi objective problem by nature. There is not a single right inventory to hold, but an inventory that represents an overall balance between inventory holding costs, service level and sourcing/production capacity and costs.

To systematically address these inventory management challenges, one needs to elaborate a structured multi-horizon strategy to be able to put the right capability at the right time of the planning process. The strategy needs to be divided into three categories of the planning horizon:

1. Strategic planning (9-18 months). The necessary steps include: 1) Supplier sourcing decisions evaluation, 2) Push/Pull and postponement strategies analysis, 3) Re-positioning Inventory strategies.

The key implied outcome: Achieving Optimal stocking points in supply chain of the business.

2. Tactical planning (3-9 months). The necessary steps include: 1) Inventory segmentation and stocking policies redefinition, 2) Inventory target levels definition, 3) Inventory service-levels and costs optimal balancing, 4) Inventory drivers evaluation (e.g. sourcing decisions, forecasts), 5) Service times commitment evaluation.

The key implied outcomes: 1) Optimal replenishment policies in every location of the supply chain, 2) Optimal inventory parameters (Safety stock levels, Reorder Points, Optimal batch/lot sizes etc.). 3) Optimal service levels definition.

3. Operational planning / execution (0-3 months). The necessary steps include: 1) Targets deviation prediction and root cause analysis, 2) Re-optimization of MEIO parameters, 3) Inventory re-balancing across the supply chain, 4) “What-if” scenarios evaluation and comparisons (e.g. evaluation of service level changes impact on inventory etc.).

The key implied outcomes: 1) The definition of inventory alerts and root cause capabilities, 2) Adjusted inventory parameters.

2. Main body of the paper

The approach being suggested has stem from the concept of artificial intelligence, which has gained increasing attention in the recent time. According to, AI normally refers to the ability of machines to learn from experience, adjust to new inputs and make decisions on series of performance as a human with intelligence [Duan et al., 2019]. Based on modern cases and studies, there are four main areas of implementation of AI [Helo, Hao, 2021]:

1. Learning systems that can adapt behavior according to dynamically observed data.
2. Situation-aware systems which can understand the prevailing conditions, and adjust behavior according to modes and situations
3. Autonomous decision-making systems which can execute decisions.
4. Systems that are able to process streaming images, video, audio and non-structured text type of data

Nowadays AI has a big impact on inventory management. Implementing up-to-date IT solutions in the sphere of management of inventory is very important as it has been shown by Soegoto et al. [Soegoto et al, 2020].

The reason of implementing AI is that this technology could find a better balance between service level and inventory cost in the circumstances of increasing complexity and volatility of supply chain and operations management.

Many key players have tried already to benefit from implementing AI for improving inventory management systems, for instance Amazon, Walmart and eBay. The tasks of such advanced systems may include, but not limited to, monitoring inventory levels in real-time and reordering materials when they reach a threshold. There is a variety of software vendors providing specialized IT products in this area, for example - PTC (Servigistics), Oracle and

Syncron in the manufacturing service inventory systems, and Scandit and Logility in the fashion industry.

As demonstrated by Chowdhury on example of pharmaceutical industry, AI can be used in each of the stages of the entire supply chain of a firm. [Chowdhury, 2021]

3. Method (including sample and measures description)

The approach to implement this structured strategy includes three consecutive stages:

1. Inventory diagnosis
2. Inventory optimization pilot
3. Use case scaling with ongoing monitoring

All cited stages imply the use of Applied Intelligence approach which enables to complete design and implementation of Intelligent Supply Chain by means of AI technologies.

In accordance with established practice, the results achieved through the implementation of this approach create added value and provide multiple pay backs:

1. 10-30% reduction in inventory and working capital through decrease of ordering cost and optimized stock
2. 10-30% improvement of asset utilization through increased availability and capacity utilization
3. 2-10% increase in service levels through defined inventory policies
4. 2-10% reduced operational costs enabled through improvement of global coordination across supply chains.

The cited stages are disclosed in detail in the following passages.

Stage 1. Inventory Diagnosis.

To implement the stage, one needs to acquire the following groups of data: 1) Historical demand data, 2) Forecast data, 3) Material supply and costs data, 4) Historical inventory levels, 5) Inventory planning parameters, 6) Location data

The stage includes three consecutive steps:

1) As-Is visibility on the main inventory position KPI to identify potential paint points: inventory volume variance, safety stock coverage, service level delivered, low performance alerts.

2) Segmentation: the classification of each SKU according to its supply and demand behaviour to assess which corrective actions may be applied. There are different ML-based segmentation algorithms: DBSCAN as a density-based concept, K-means as a standard non-hierarchical concept, separate hierarchical concepts. AI tools today can select already the segmentation method itself.

3) Value targeting including segment (cluster) specific analysis to evaluate the main drivers and actions that can help improve the performance of the overall inventory (e.g., SLOB analysis, production policies analysis, inventory drivers' analysis).

Stage 2. Inventory optimization pilot.

The pilot implies the usage of AI approach and includes several steps.

1. Unitary Costs Modelling. The step includes building a reliable cost function which truly represents the current supply chain costs.
2. Segmentation. A definition of "a priori" inventory policies and target service levels as well as an identification segments eligible for MEIO (Multi-echelon inventory optimization).
3. MEIO Baseline Run & Validation trough Digital Twin. The step includes building a validated digital twin which represents the supply chain processes of a company in a reliable way.

A digital twin is a virtual supply chain replica that represents hundreds of assets, warehouses, logistics and material flows, and inventory positions. Using advanced analytics and artificial intelligence (AI), the digital twin simulates the supply chain's performance, including all the complexity that drives value loss and risks. By means of Digital Twins one is able to consider supply chain processes' uncertainty and simulate them for the right risk assessment and automatically set self-learning intelligent inventory triggers through mathematical optimization and ML.

4. MEIO Optimization. The step includes finding the optimal inventory parameters across the network minimizing the overall costs at targeted service level. To complete the step, the simulation-based optimization is used to determine the "to-be" supply chain network of the company. MEIO is used to determine the optimal combination of threshold (ROP) and order quantity (ROQ) for each line item to minimize overall costs. To optimize costs (or PROFIT) through inventory management, all company costs in terms of SKU (Stock Keeping Unit) are divided into three mutually affecting blocks: storage costs, order costs, losses from shortages. The revenue side may be also taken into account thus transforming the initial problem into maximizing the overall profit at each echelon by using the optimal combination of ROP and ROQ.

First, the optimization engine run takes place including:

- Genetic Algorithm used for the intelligent selection of inventory parameters to simulate scenarios
- Global optimization minimizing the objective function of Total supply chain cost (i.e. holding, ordering, backlog and lost sales cost etc.) at targeted service level.

Once the optimization inventory parameters defined, the output from the scenarios is translated into simulation engine as a second step. The simulation experiments include several steps:

- Simulation of the as-is or to-be network to test what the real behaviour would be for a specific scenario
- Testing of stochasticity of the real supply chain by simulating lead times, forecast error and demand based on the historical distribution
- Stress-testing of network capacity availability on multiple scenarios including testing of the robustness of the system as well as the risk associated to each solutions undertaken

5. "What-If" Scenarios modelling to assess potential impacts of various operational and strategic decisions on the state of the supply chain network (e.g. forecast accuracy variations, network changes etc.)

The cited steps give a huge support in a successful transformational journey of the company towards resilient and agile supply chain network.

To enable a successful implementation of the Inventory optimization pilot it is necessary to support the optimization/simulation engines with high-quality data:

- Material and Locations Master data
- Transportation & Manufacturing Lanes for Theoretical Lead Times, BOM & Costs
- Real Replenishment Lead Times (Purchase orders, Work orders, Stock transfer orders)
- Independent Demand & Forecast data (sales orders, forecast data)
- Auxiliary data:
- Stock Units of Measure (SUOM)
- SUOM Material Dependant
- Currency data
- Time Units of Measure

Stage 3. Use case scaling with ongoing monitoring

In this stage it’s crucial to set up the continuous monitoring of performance with customized dashboards:

- Inventory view
  - Visualize overall health of inventory across all networks (On Hand and Projected) with ability to drilldown to BU and Product Family level
  - Comparison of actual inventory vs forecast/budget
  - Inventory projection based on the on-hand inventory, expected receipts and demand.
- Lead time health and variability
  - View of lead time from raw material to finished good, incl. details on each step of the value chain (e.g., production, quality, transportation, warehousing)
  - For each product and each step in the value chain a user can identify lead time outliers (actual vs. planning lead time)
  - Lead time health parameter comparing the actual vs. planned lead time & lead time variability.
- Early warning system
  - Safety stock alarms enable to quickly identify the products which have excess safety stock or risk of future stock out.
  - Identify the % of the total stock available for use and % of blocked, under quality or in progress(semi-finished)
  - Identify the % of stock ageing due to shelf-life issues and take action to e.g., avoid write-offs or allocate to different markets.
- Executive alert management dashboards
- List of alerts including their criticality to work by exception, incl. future stock outs / over stock, write offs, stock at risk due to shelf-life ageing alarms.

4. Empirical results and conclusions

Amidst COVID-19 pandemics Amazon faced a challenge of increasing inventories. As a result of agile monitoring, it begun tempering inbound shipments to their DCs with a focus on prioritizing high demand products such as household staples and medical supplies. Such quick re-shift allowed to satisfy increased demand and avoid significant working capital “stuck“ in stocks. At the same time Amazon adjusted the way sellers operate, they changed how restock limits work. Amazon allowed to re-stock in limited quantities per category (regular items, oversize footwear, apparel to name a few). This use case does seem relatively simple unless we take into consideration the network behind: Amazon operates >175 fulfilment centers around the world in >46m square meters of space that process and store the products of >6.3m sellers. To manage such complexity, there is a proprietary set of AI algorithms starting from demand forecasting models to inventory management tools. These algorithms are working both ways: top-down from Amazon to the seller and bottom-up from seller to Amazon meaning that sellers can actually review and adjust parameters and outcomes through a specifically designed seller portal. As an example, the inventory performance dashboard sends an alert when stock quantities are running low and provides demand planning and forecasting to suggest recommended optimum inventory levels and shipment timelines.

2. Another good example is a healthcare company that developed a proprietary tool for demand planning, forecast accuracy improvement, transportation costs reduction, lead time reduction, and safety stock reduction. This tool allowed to assess the stock levels in the near real-time and simulate safety stock impact based on consumer behavior changes. Within the heart of this modelling is an interesting AI algorithm that leverages decision trees and

random forests based on dynamic factors including but not limited to lead times, actual & lost sales (3-year history), deals win-loss history, historical stock levels and even weather. By piloting this tool in selective European countries more than 10% of safety stock was reduced without changes in the service levels.

3. Excess inventory management can be also targeted using AI-algorithms: one of the European-based industrial manufacturers faced a problem of high inventory costs and decided to apply an AI-based algorithm. The algorithm is linking the turnover & stock analysis to sales recommendations. On the 1st step open orders volumes from each ERP system and existing stocks by SKU by warehouse are passed to the algorithm to update distributions, recalculate turnover and classify whether this SKU is in high / medium / low demand. On the 2nd step SKUs that are classified as being in low demand with high stocks and low turnover are provided back to the sales managers with a threshold-based discount system. The lower the turnover is, the higher usually the discount is. Discount size also takes in consideration profit function: storage and transportation costs are assessed to limit discounts that can be provided. Also for each type of the SKU there is a minimum order quantity that do not allow sales managers sell below specified limits. Interesting to add that SKUs that are in high demand and usually ran out of stocks are also part of the algorithm: for them the recommended price is increased to potentially balance turnover.

Further investigation should be done though to detect the benefits and costs for using AI in excess inventory management, especially what is concerned to the accurate data problem. Case analysis for some particular firm that uses AI in inventory management would be beneficial for this further study in the field.

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