International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

Optimal Inventory Allocation in Supply Chain Using Decision Optimization

S Suraj[1], Dr. K Badari Nath[2]

[1]B.E Student, Department of Computer Science and Engineering, RV College of Engineering, Bengaluru, Karnataka, India

[2]Assistant Professor, Department of Computer Science and Engineering, RV College of Engineering, Bengaluru, Karnataka, India

Abstract: ***The success of a business primarily depends on the efficiency of its supply chain. An enterprise with a well-organized supply chain may significantly reduce majority of the expenses connected to that chain, which contributes to a greater profit and customer satisfaction. Existing systems mainly stress on delivery time and order management systems to ensure smooth running of a supply chain. However, when optimization starts at the inventory level, based on forecasted or available demand and customer data, the functioning of the supply chain can be made more efficient. The utilization of Machine Learning and Decision Optimization has helped in further improvement in the field of inventory optimization.***

Keywords: Decision Optimizer, Inventory Allocation, Inventory Allocation, CPLEX, Supply Chain

1. Introduction

Inventory optimization in the supply chain is focused on improved planning and stocking of inventory to deliver the desired level of customer service at minimal cost within any limits or restrictions that exist [1]. Quantities and delivery priorities are to be fixed in accordance with factors such as customer priority classes, type of customer domain and other such real time requirements. Optimization brings all those considerations together in a comprehensive plan that delivers the desired performance at minimal cost.

1.1 Decision Optimization

Decision Optimization is a mathematical approach to solve problems that require critical decision analysis subject to rules and constraints. It deals with maximizing the output from a large number of input variables that exert their relative influence on the output. The part played by the technology of Decision Optimization in rocketing the advancement of Machine learning deserves a definite mention. Decision Optimization technology uses advanced mathematical and artificial intelligence techniques to solve decision-making problems that involve millions of decision variables, business constraints and trade-offs. Decision Optimization evaluates a wide variety of alternatives to choose from and tried to tender the best possible solution that satisfies the given targets and constraints. Linear and non-linear programming is utilized by Decision Optimization to find solutions to such problems. Hence, this specimen may or may not be considered as data mining or machine learning technique, depending up on other factors that are involved in solving the problem.

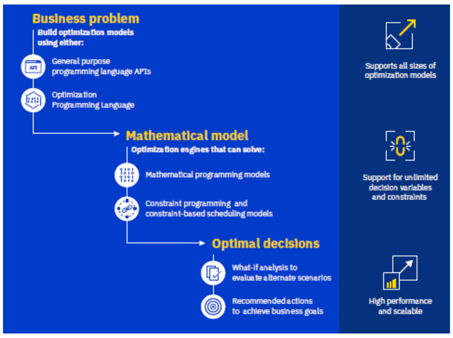

Figure 1: Working of Decision Optimization

1.2 Optimization Technologies

Optimization techniques use optimization technologies to solve optimization problems. An optimization problem, as stated earlier, deals with the task of finding the best solution from all other alternative solutions. Optimization problems can be solved by making use of optimization models.

The CPLEX optimization engine is the best-known technology for the purpose of solving optimization problem. It provides a very convenient framework for solving multi-variable linear as well as quadratic equations without the need of manually performing tedious mathematical calculations. CPLEX is a very high-performance mathematical programming solver for linear programming, mixed integer programming and quadratic programming [2]. It provides a technology that assists in boosting profitability, reducing cost and increasing efficiency. Its fundamental algorithms include a parallel distributed algorithm for mixed integer programming to form a leverage over numerous systems to solve problems that are difficult. These algorithms are robust enough to solve problems involving millions of variables and constraints. The solver delivers the adequate needed to solve large, real-time optimization problems. At the same time, it also delivers the speed required for the interactive decision optimization applications of today. The main challenges of decision optimization problems are:

- Enormous number of possible solutions.
- Lack of sufficient number of constraints to solve for the variables.
- Gruel and time-consuming methods of manual calculation.
- Programming such problems using native language statements leads to inflexible solutions.

These above challenges can easily be tackled using Decision Optimization Technology effectively. Thus, the CPLEX optimizer can be used to solve a wide variety of decision optimization problems with multiple constraints and variables. An Optimization model is to be created to make sure that the CPLEX optimization engine knows how to solve the right problem. Such model is characterised by the following terminologies:

- A set of constraints, decision variables and an objective function.
- An optimization engine for the purpose of solving the instance of a model.
- The data to create model instance.

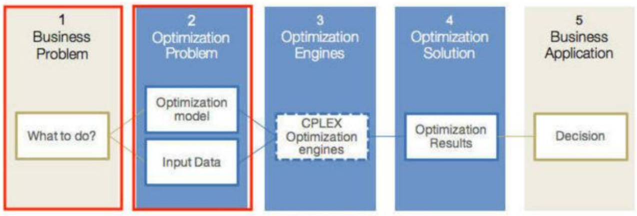

Figure 2: Process to solve a business problem using optimization engine.

Enumerating the terminologies:
1) Objective function represents the entity that is trying to be solved. This involves some sort of a maximization/ minimization function that can be expressed in terms of the decision variables.
2) A constraint is a mandatory criterion that the problem must satisfy to arrive at the final optimal solution. These constraints are imposed on the decision variables.
3) The quantity that is controlled by the decision maker is called a decision variable. The result of the optimization problem is obtained as the values of the decision variables.

The key to the solution lies in expressing the problem in hand in terms of an optimization problem stated above, so that the problem can then be solved by designing a dedicated Decision Optimization model.

1.3 Inventory Optimization

The basic idea behind inventory optimization is simple: control inventory levels to fulfil set service levels while reducing the amount of working capital held in inventory that is not being used efficiently.

Lead time, shipping, daily usage, and economical reorder numbers are all factors to consider. To ensure proper stock availability, supply chain managers use this data to compute ideal stock levels and reorder points. They can also use techniques like the ABC analysis approach to categorise inventory selectively, which sets inventory levels based on sales volume and value.

The ultimate goal of any inventory optimization model is to achieve the prescribed customer demand satisfaction level by incurring minimum expense on the supply procurement and supply chain. This optimization is achieved in terms of demand satisfaction, cost minimization and profit maximization.

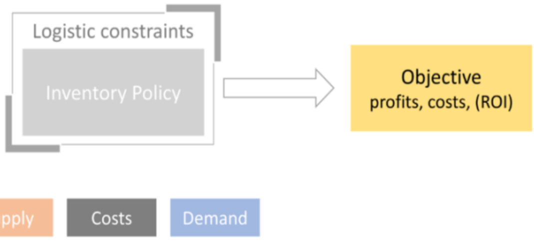

Figure 3: Inventory Optimization Overview

In supply chain terminologies, the environment is described by using three terms:
1) **Supply**: The expected supply lead time and its accounted variability.
2) **Demand**: Two aspects are to be focused. The expected demand is a forecast of how much demand can be expected. The other demand is how long the customers are willing to wait for the products.
3) **Costs**: These are the expenses incurred by the supply chain owner in running the distributed network. Optimization in terms of cost is a business objective and is essential for the survival of the supply chain. These costs may include purchasing costs, holding costs, transfer costs, expiration costs, shortage costs, etc.

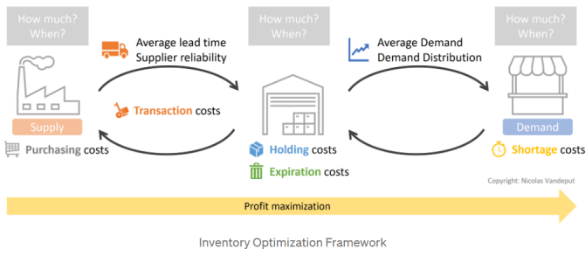

Figure 3: Inventory Optimization Framework

If the aim is just to attain some specific service levels, assessing supply variability and demand would be sufficient. In cases where the aim is to attain profit maximization, costs incurred by the supply chain must also be taken into consideration.

2. Problems associated with Inventory Optimization

A vast number of challenges hinder the process of inventory optimization. These challenges must be overcome using appropriate technologies and algorithms and sufficient data. Some of the common problems faced include:

- **Fluctuating demand:** The needs of customers are always changing. Having too much inventory could result in an obsolete inventory that cannot be sold, while keeping too little inventory could prevent you from fulfilling customer requests. Ordering tactics for essential items, as well as technologies for creating and executing an inventory strategy, can all help to accommodate for fluctuating demand.

- **Dealing with Customer Groups based on Priority:** Supply chain often have certain groups of customers who may be considered a greater priority over the rest. Such a classification leads to hierarchy of customers with the customer group at the summit of the hierarchy having the maximum need of satisfaction. Thus, there should exist a system such that this is possible.
- **Inadequate Order Management:** Preventing overselling of products and running out of inventory is one of the most prevalent problems to good inventory management. One may reliably estimate client orders by using historical and seasonal data trends.
- **Expansion of Inventory Nodes:** As the supply chain plans to diversify its business, a greater number of inventory nodes start emerging into the picture and it is necessary to extend support to all such nodes.
- **Lack of Sufficient Software:** Inventory management software must interface with existing business process platforms in order to expand to accommodate complicated logistics. Choosing from hundreds of inventory management solutions and understanding a slew of features that necessitate training and continuous assistance is a difficult undertaking.

The above-mentioned challenges form a mere subset of the problems that obstruct the goal of inventory optimization.
The technology of Decision Optimization can find its application in Inventory Optimization. Since the former offers a best-possible solution to a multi-way solvable problem such as Inventory Optimization, by modelling the latter as an optimization problem, an efficient solution can be generated to solve the latter.

3. Using Decision Optimization in Inventory Optimization

The aim here is to club the concepts of decision optimization and inventory optimization such that the former is used to implement a solution for the latter.

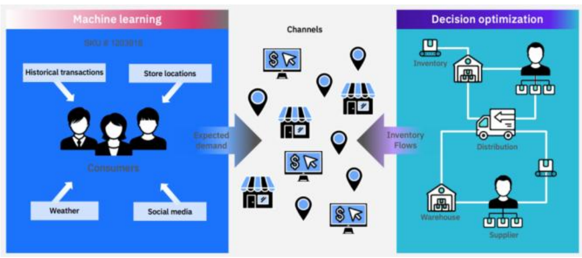

Figure 4: Decision Optimization in Supply Chain

Decision Optimization and Machine Learning work hand in hand in the field of supply chain. While Machine Learning deals with analysing historical transactions, store location details, social media advertisements and responses, weather impacts, etc, Decision Optimization benefits from this analysis performed and uses the results to predict and provide optimal inventory conditions to the supply chain operator. Hence, by stacking together individual Decision Optimizers to solve various specific purposes, an effective model can be created which contributes to the solution of optimal inventory allocation.

The proposed model is a generic one. It aims to achieve optimal inventory allocation of items based on their forecasted demands. These demands are then grouped according to customer priority into customer demand priority classes. This function can be either done manually or done by a Machine Learning model such as customer segmentation/classification model provided that sufficient data is available for such demand forecast and group classification. Once the demand is distributed among the customer classes, each of these customer classes at any node is assigned a priority. This priority signifies the importance and necessity of that particular customer group to the supply chain operator. Higher the priority (1 being the highest priority group), higher is the requirement of satisfaction of such group customers. Consequently, out of the available stock, decision must be taken regarding demand satisfaction such that higher priority groups have a precedence over lower priority groups.

As a result, a Decision Optimizer can be utilized for this purpose, and this is where a bridge can be made between Decision Optimization and Inventory Optimization. The overall procedure to be followed can be briefly stated as:

1) Establish the business rules and constraints that govern the supply chain problem. This is done in consultation with the end users and shall include maximum holding capacity, number of inventory nodes. The system constraints are made as generic as possible such that user with minimal knowledge on supply chain constraints can also utilize the model without any hassles.
2) Aggregate, understand and process the necessary data required to solve the problem. The standard template for the system input is required to be maintained by any interacting user. The range limits of the variables are determined by plant capacities. The data thus acquired is then arranged in appropriate data structures so that it can be directed to the DO.
3) Formulate the decision variables, constraints, and objective function to be solved using the Decision Optimizer.
   - Identify and define the values to be optimized as decision variables of the model. These pertain to the allocations that are to be determined.
   - Impose the constraints on these variables according to the requirement which define the permissible range of values that each decision variable can take. These are determined by the rules and constraints specified in the first step.
   - Formulate the objective function in terms of these decision variables which must be maximized/ minimized. This function is a weighted sum of the allocation to be achieved to each group and its corresponding priority/transfer cost.
4) Separate DO models for each module are then programmed. Modules include intra-node allocation module, inter-node allocation module and transportation

module. These models are then compounded to provide the result along with objective scores and transportation costs.

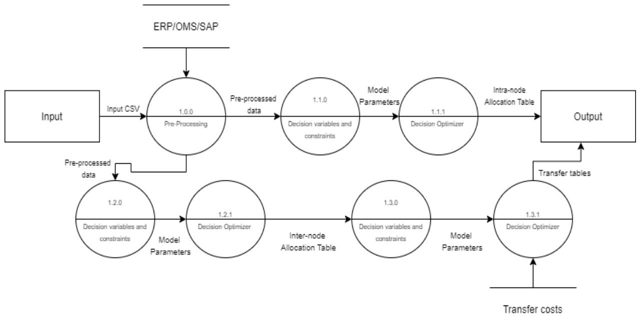

Figure 5: Data Flow Diagram of the Proposed System

The above diagram gives an overview of the system. It is a culmination of 3 decision optimizers where each of them performs their own tasks. After necessary pre-processing of the input data, the pre-processed data is directed to the intra-node followed by the inter-node allocation modules. The former does the allocation ignoring the possibility of transfer between inventory nodes based on customer group demands and priority whereas the latter performs the same function considering the transfer possibilities. Once done, the latter directs its output to the third and final transfer module which calculates the cost incurred and other transfer details to be implemented to achieve the solution of the inter-node allocation module. Each of the 3 modules make use of their own dedicated Decision Optimizer to carry out their prescribed tasks.

4. Benefits of using CPLEX engine

CPLEX is the backbone of the system which does the job of implementing decision optimization. It provides a convenient framework and is easily used in combination with Python language to assist in the process of development. It extends support for:

- Problem modelling: provides a mathematical framework for modelling business difficulties.
- High-performance solver to implement fundamental algorithms.
- Industrial support: IBM offers a high rate of product improvement and a large support staff to assist you.
- Robust Algorithms: Assists dealing with optimization problems involving millions of constraints and decision variables.
- Elimination of the necessity to remember algorithms.
- Ease of programming using Python.
- Delivers state of art speed in computations and hence can be used to solve very large-scale real-world problems.

5. Conclusion

The system does the determination and calculation to determine optimal inventory allocation quantities as per the request of the user. The system thus is very beneficial for planning a supply chain inventory distribution and has support for numerous multiple customer groups with different customer priorities along with support for large number of nodes. The use of Decision Optimizer enhances the solution model and makes it very efficient in terms of performance as well as well as scalability. However, the processing time of the model is subject to the input workload and increases with the size of the data to be analyzed. The model can also serve as the base podium on which further constraints and costs can be inculcated to build a more complex model which can solve a larger problem.

References

[1] Dave Turbide, 'Inventory Optimization in the Supply Chain', December 26, 2018, Available: https://blogs.3ds.com/delmia/inventory-optimization-in-the-supply-chain/
[2] Sajan Kuttappa, 'Decision Optimization and Machine Learning: Complementary techniques for an AI-driven future', February 26, 2018, Available: https://medium.com/inside-machine-learning/decision-optimization-and-machine-learning-complementary-techniques-for-an-ai-driven-future-98f4e4794c5d
[3] IBM® Decision Optimization CPLEX® Modelling for Python (DOcplex) V2.20 documentation, Copyright 2016-2021, IBM®, Available: https://ibmdecisionoptimization.github.io/docplex-doc/mp.html
[4] Nicolas Vandeput, 'A Framework for Inventory Optimization', February 13, 2021, Available: https://towardsdatascience.com/a-framework-for-inventory-optimization-71d4496aec75
[5] Abby Jenkins, '20 Inventory Management Challenges and Solutions for 2020 and Beyond', October 14, 2020,Available: https://www.netsuite.com/portal/resource/articles/inventory-management/inventory-management-challenges.shtml

Paper ID: SR21624203337 DOI: 10.21275/SR21624203337