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Innovative Techniques for Optimizing Supply Chain Operations

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Abstract

Supply chain management is an approach used by firms to ensure that their business can be highly effective, and profitable and that operations run smoothly. This involves managing the movement of raw materials inwards and finished goods outwards. Logistics is a key component of this. It also involves managing the flow of products between companies, which can involve the movement of products between a manufacturer, a wholesaler, and a retailer. Supply chain management is therefore the integration of these flows between companies. Several innovative techniques can be used to optimize supply chain operations, particularly given recent advances in information technology. The function of logistics is known as activities that are related to the flow of products between companies, such as the transportation and warehousing of goods. Activities that take place within companies, such as inventory management and materials handling, are not considered to be logistical activities but part of the supply chain. The level of interest in supply chain management has risen quite dramatically over the last few years. This is partly due to advances in information technology, which have enabled closer integration of the supply chain. As well as increasing competition between companies, on both a national and an international level, has led to an increasing emphasis on the need for companies to concentrate on their core competencies, and to look to outside suppliers to provide other goods and services. This has led to the increased use of external suppliers.

Keywords: Innovative Techniques for Optimizing Supply Chain, Industry 4.0, Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML), Smart Manufacturing (SM)

1. Introduction to Supply Chain Optimization

Optimization of the operations across the numerous supply chain processes and modules is a very challenging task. The ever-changing market dynamics, customer requirements, introduction of new products, lead time variability, production constraints, transportation difficulties, price fluctuations, and many other external and internal parameters adversely affect the operation of the supply chain. For several years, there has been a growing interest in the use of advanced optimization tools and techniques to improve and cope with the different types of problems encountered in the supply chain. The development of such innovative techniques for supply chain operations is the primary focus of this special issue. Different classes of optimization (metaheuristic, deterministic, discrete-event, etc.) and advanced techniques, identified to be useful for solving a wide range of supply chain problems, are presented.

The supply chain is a network of organizations that are involved through the different upstream and downstream link processes and activities required to create and deliver value in the form of products and services to the end customers. The ultimate aim of

each supply chain is to meet the market requirements at the lowest possible cost while maximizing the profit of each of its members. A supply chain generally involves the flow and transformation of the material from the initial raw material supplier to the manufacturer, and from the manufacturer to the customer at the other end. In addition to the flow of material, the supply chain also involves the flow of information and money. Small disturbances in one of the flows can have a significant effect on the performance of the entire chain. The inherently dynamic nature and the ever-changing market, production, and distribution environment cause the lead times to be uncertain and highly variable. This, in turn, leads to operational difficulties and the sub-optimization of the various entities of the supply chain.

1.1. Definition and Importance of Supply Chain Optimization

A supply chain consists of all parties involved in fulfilling a customer request, which encompasses the flow of materials, information, and finances. The importance of supply chain management has grown due to larger customer involvement and demands, global trade, and competition. To remain competitive, companies must innovate by continuously improving their supply chain operations. Supply chain optimization enables companies to improve their operations by gaining more control, increasing visibility, taking advantage of opportunities, and ultimately making better and timelier decisions. A key aspect of optimizing the supply chain is the coordination of activities involved in the flow of materials, information, and finances from suppliers through factories and warehouses to the end customer.

Supply chain optimization is the application of different techniques to improve the value that supply chains generate in their entirety. These techniques can be employed at different levels: strategic decisions are used to shape the structure of the supply chain over a long-term horizon, tactical or planning decisions are used to implement the strategy over a medium-term horizon, and at an operational level, day-to-day decisions are used to guide the activities within the supply chain. Optimal operational decisions help synchronize the flow of materials, information, and finances so that products are delivered at the right time, to the right place, and at the right cost. Properly implemented optimization techniques can help companies reap the benefits of lower costs, better responsiveness, and higher customer satisfaction. As a result, supply chain optimization can be seen as a powerful concept to innovate a supply chain's operations and drive a company's competitive advantage.

FIG 1:Deviation driven development

2. Traditional Techniques in Supply Chain Optimization

Supply chain operations reference three flows related to the movement of physical goods (product flow), the transfer of information (information flow), and the exchange of finances (financial flow). Supply chain optimization (SCO) represents the application of various processes, activities, and techniques to improve and develop the entire supply chain system to satisfy the final customers at the lowest possible cost. Usually, the main area of concern for company managers is related to reducing the supply chain costs. Several traditional techniques are presented in the literature to support and help these companies achieve their supply chain objectives. These techniques include Just in Time (JIT), Total Quality Management (TQM), Materials

Requirement Planning (MRP), Enterprise Resource Planning (ERP), Dynamic Programming (DP), and Linear Programming (LP). Small, medium, or large-scale companies apply these techniques to optimize their supply chain operations. However, in the case of some companies, the results obtained are not successful, creating the necessity of using new, innovative techniques that take into consideration the changes that appear in the global economy.

In the last decade, the performance of the supply chains that implement traditional techniques has been poor, due to many factors such as increased competition at a global level, globalization of the economy, shortening of product life cycles, cross-functional nature of supply chain management, rapid advances in information technology, and industrial networks linked around the world. These networks are subject to political and social instabilities, and vulnerability to natural and man-made disasters. Consequently, the concept of risk management needs to be introduced to the supply chain. Additionally, a trend towards mass customization represents a challenge for supply chains that traditionally optimize mainly in the cost area, utilizing the efficient frontier. Since the mass customization area is mainly in the low volume high price spectrum, the opposite area of the efficient frontier, this trend calls for a new balance between the conflicting objectives of cost, responsiveness, and flexibility. Consequently, a new generation of innovative techniques that address all these supply chain objectives needs to be developed.

2.1 Inventory Management

Inventory management is an essential element in any supply chain design. It accounts for a considerable portion of the supply chain operations. To minimize the overall cost of the supply chain, the number of warehouses must be reduced, while the quantity of stock in those warehouses is increased. This points to the conflicting nature of inventory management at different levels in the supply chain.

At the operational level, inventory management is concerned with deciding how much stock should be held at each stocking point in the supply chain. It involves the determination of the stocking levels for the different products to be able to fulfill the demand under the lead time uncertainties. If the stock level is set too high, the operational costs of the system increase. However, if the stock level is set too low, the level of service provided to the customer degrades, and there is a loss in the sales profit.

The complexity of inventory management in a distribution system can be attributed to the relatively high proportion of the total logistics cost. For a typical manufacturing or distribution company, these costs can be as high as seventy percent of total logistics costs. The high percentage reflects the cost associated with the construction of warehouse space. Today, it is widely recognized that the cost of holding inventory in a warehouse is not only associated with the value of the item itself but also with handling, storage, and other related costs.

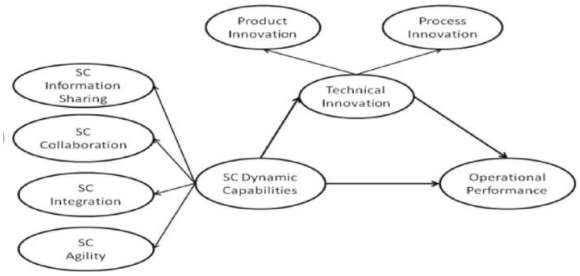

FIG 2: relationship between supply chain dynamic capabilities

2.2.Forecasting and Demand Planning

The cornerstone of any supply chain operation is ensuring that the right product is available at the right time and in the right place. Achieving that goal without creating a surplus of inventory requires increasingly sophisticated planning. A necessary first step in the supply chain process is demand forecasting. A forecast is an estimate of average consumer demand. The purpose of forecasting is to

make sure that appropriate inventory management, production planning, transportation, and distribution planning occur in sufficient time to facilitate timely product flow in the necessary quantities. As a result, the forecast is the key input to all supply chain planning processes and is critical over both the long and short term.

Traditionally, retail sales data have been the most important input to the demand forecasting process. These data generally move through the collection, processing, and analysis stages of the retailer's inventory control system before being used by manufacturers to produce and deliver new stock-keeping units (SKUs). Retailers collect cash register data at the point of sale, usually daily, and transmit these data to their central offices, where they are used for various inventory control functions, as well as for sales analysis and planning. In addition to data on current sales, these systems may also provide information on current inventory levels (through perpetual inventory records), prices, in-store promotions or special displays, and other factors that might affect consumer demand. Many retailers use electronic data interchange (EDI) to transmit sales data to manufacturer-suppliers.

3. Innovative Techniques in Supply Chain Optimization

This paper reviews some of the innovative techniques that have been employed to address supply chain decisions such

as production planning, inventory management, and transportation. These include (1) optimization techniques that combine several objectives, possibly in a fuzzy framework, or over the long and short term, possibly using a bi-level approach; (2) meta-heuristic techniques that search for better solutions, exploiting problem-specific knowledge; (3) game-theoretic approaches that model the interactions among several decision-makers involved in the supply chain; (4) revenue management techniques that address demand management in the face of limited capacity; (5) risk management techniques that address the risk of disruptions in the supply chain, employing possibly robust optimization approaches; and (6) behavioral techniques that make managerial recommendations accounting for the bounded rationality of humans. The paper also discusses several areas of future research in supply chain optimization.

Supply chain management and optimization are becoming increasingly important. As technology advances, products are getting more complex, and firms are focusing on their core competencies while outsourcing the rest. Globalization is leading to a broader and more disaggregated network of suppliers, manufacturers, distribution centers, retailers, and customers. These factors are making the management of a supply chain more challenging. The present work discusses several innovative techniques that have been proposed over the last years to address the challenges. These techniques operate at different levels - strategic, tactical, and operational - and address different decisions such as production, inventory, transportation, and location. The techniques are appropriate for a variety of supply chain structures - for example, with single or multiple products, single or multiple facilities, single or multiple periods, and single or multiple objectives. Rather than focus on one narrow type of optimization technique, this paper reviews several types. The paper does not attempt to review all possible techniques or models; instead, it provides a diverse but sufficiently detailed discussion of the key characteristics of each type of technique. The review pays particular attention to the mechanism by which each optimization technique operates.

3.1.Artificial Intelligence and Machine Learning Applications

Supply chain and logistics operations have been revolutionized in the digital era through the development and implementation of novel techniques. The sheer vastness of data that is available within the supply chain environment has driven the creation and enhancement of various decision support tools. Artificial intelligence, in

particular, machine learning, is offering smarter solutions to reduce complexities, optimize operations, cut costs, and reduce waste. Different products require different techniques, especially considering the competitiveness of the market and the 'time to market'.

Machine learning can facilitate smoother supply chain operations by predicting future events and possible outcomes. It can help transform reactive decision-making into proactive decision-making. Inventory management, transport and warehousing, production and scheduling, quality inspection and traceability, sales and operations planning, and transformation and change management are the main supply chain processes that can be optimized through machine learning applications. The drawbacks of traditional intelligence systems can be resolved by integrating multiple artificial intelligence techniques. Such hybrid intelligent systems can enhance supply chain performance. The trajectory of artificial intelligence advancement promises great innovations and a breakthrough shortly.

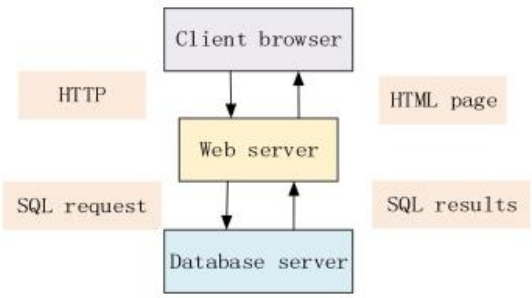

FIG 3: Design of SCM System

3.2. Blockchain Technology in Supply Chain Management

A modern definition of blockchain is that of a distributed ledger that uses a chain of blocks to provide a permanent and secure record of transactions. Although the concept of blockchain was identified with its first practical application (the virtual cryptocurrency Bitcoin), this technology can be disassociated from currencies and used in a variety of other applications. A blockchain is open when anybody can participate in the network and execute consensus algorithms and permission when the participants in the network need to be identified and given access rights. In the supply chain, a blockchain can be used to register the transfer of assets between companies, to record purchase orders, receipts of goods, and invoices and payments, and to execute smart contracts that implement the business rules for the supply chain.

A permission blockchain can help mitigate the issues related to the sharing of sensitive commercial information with unauthorized stakeholders in an uncommissioned blockchain. Several blockchain platforms, like MultiChain, Hyperledger Fabric, or Quorum, support permissioned blockchains, and some of them allow to definition of different channels inside the network, which are visible only to a defined group of participants. Blockchain technology can add value to supply chain management in several ways. First, blockchain can help to increase the trust between the involved companies. The fact that the data in a blockchain is virtually impossible to tamper with and that the smart contracts can ensure that all the entities participating in a transaction agree on its execution can help to solve the trust issue that plagues conventional supply chain management systems.

4. Case Studies of Successful Supply Chain Optimization Implementations

At Procter & Gamble, a best-in-class global supply chain translates not only into bottom-line results but also into offering three times more user-preferred new products and maintaining three times more market share versus nearest competitors. P&G's supply chain is designed to collaborate with its key customers. It has deployed joint-planning processes and tools to remove non-value-added costs and activities from the value chain. The company's efforts resulted in dramatic improvements in merchandising and promotion effectiveness with several key customers. P&G is recognized as a supply chain innovator and leader. Its supply network is among the most extensive in the world.

They service over 5 billion consumers through more than 300 brands.

Traditionally, most consumer goods companies have organized their supply chain around manufacturing products in large quantities and with a long lead time to be placed in inventory. It was then the distributor's responsibility to service the retailers from this inventory. The world is changing, and consumer goods customers are demanding more responsiveness. Retailers are on the front lines servicing the consumer and are making increasing demands on manufacturers for better service. Manufacturers are being asked to deliver smaller quantities more frequently, improve delivery reliability, and respond faster to changes in demand. In addition, new product introduction (NPI) cycles must be compressed, and promotional product activity must be supported with the highest levels of in-stock product availability.

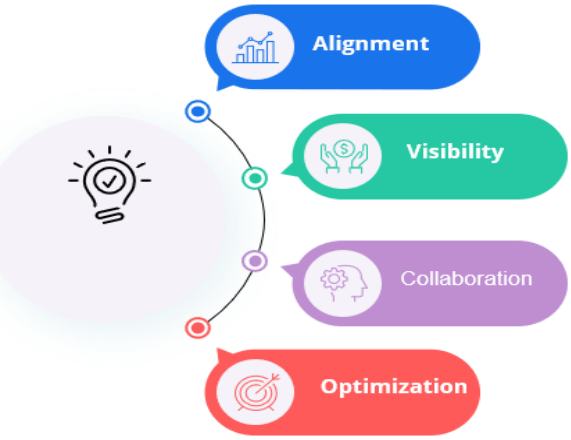

FIGURE 4: Supply Chain Optimization

5. Challenges and Future Directions in Supply Chain Optimization

Supply chain optimization is gaining high momentum in the industry and also in the academic research community, thanks to the wide scope and a large number of emerging challenging problems. Several problems are yet to be addressed or studied in the literature. In this chapter, we have discussed some challenges and the future directions of research in the domain of supply chain optimization.

In this book, we have attempted to present state-of-the-art supply chain modeling and optimization techniques. The aim is to provide comprehensive coverage of different aspects of supply chain optimization and to act as a repository for supply chain models and techniques. Supply chain optimization involves the design, planning, execution, control, and monitoring of supply chain activities to create net value, build a competitive infrastructure, leverage worldwide logistics, synchronize supply with demand, and measure performance globally. The exploding growth in e-commerce and the accompanying proliferation of virtual enterprises emphasize the ever-increasing importance of supply chain management. However, it is a complex process, especially in the modern-day scenario of multi-echelon, multi-product, multi-plant/distribution centers, and constantly changing dynamic demand situations.

6. Conclusion

The emergence of new technologies such as the Internet of Things, Big Data, and blockchain has transformed the modern supply chain from a linear into a digital, interconnected system. To optimize supply chain operations, enterprises need to develop and deploy innovative techniques derived from the new technologies. In this chapter, we discussed several key areas of supply chain operations, including demand forecasting, inventory management, transportation management, and warehousing, as well as decision-making across multiple functions, such as sales and operations planning. For each area, we identified the primary objectives and described the conventional techniques. We then introduced several innovative techniques and methods leveraging new technologies, analytical modeling, and AI to address the challenges and help optimize supply chain operations. Finally, we summarized the key concepts, techniques, and implications of the digital supply chain and outlined future research directions.

In this book, we have described several supply chain challenges that companies face today, and we have highlighted some of the advanced technologies companies are using to address these challenges. Although we are confident these technologies can help solve supply chain problems, the definition of a supply chain—to deliver a product from the supplier to the customer—remains deceptively simple. In this chapter, we present an optimistic view of the future of supply chains. We believe that once we reach the technological frontier, the supply chains will need to manage will become even more interesting and rewarding. The reason for our optimism is rooted in the practice of business itself. Over time, businesses have found new methods to do things better, smarter, and more efficiently. We believe the future will be no different.

6.1. Future Trends

Many sectors are likely to witness an increase in customer-specific production. Large-scale production assemblies, such as automobiles, are likely to be broken down into smaller and more flexible units, which can be easily transported and quickly assembled close to the customer site. The production at the customer's site is likely to grow in importance and the distinction between the producer and the seller of a product may largely disappear. Consequently, many supply chains will reverse direction, moving from distribution to production. The power of IT is likely to increase further with more and more companies specializing in IT-related services. It is expected that in many sectors the development of market links will become more important than production-friendly links.

In the coming years, mass-produced, low-tech products are likely to face severe competition from developing countries. The future lies in high-quality, customer-specific products, innovative designs, and fast introduction of new products. As global competition increases, the role of efficient supply chain management will be crucial for Western companies. Already, some companies in the USA have moved in the direction of specialized design and marketing activities, with production being carried

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