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The Use of Big Data Analytics in Supply Chain Optimization

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ABSTRACT

In recent years, the adoption of big data analytics has revolutionized supply chain management by enhancing decision-making processes and optimizing operations. This paper explores the integration of big data analytics in supply chain optimization, emphasizing its impact on improving delivery time, cost efficiency, customer satisfaction, and flexibility. The study provides an overview of the foundational principles of big data analytics and its application in supply chain management, highlighting the challenges and opportunities associated with its implementation. Through a comprehensive review of existing literature and case studies, the paper discusses the potential benefits of big data-driven supply chain strategies and outlines future research directions aimed at addressing the dynamic complexities of modern supply chains.

Keywords: Big Data Analytics, Supply Chain Optimization, Decision Support Systems, Supply Chain Management, Industry 4.0.

INTRODUCTION

In the past decade, there has been increasing interest in the rise of big data and its potential advantages and value for firms. This phenomenon has been democratized by fast-growing global web-based social networking, business transactions, electronic mobile devices, and affordable data storage technologies. Additionally, the tools and technologies for data collection, storage, and analysis have become more readily available, enabling many people and organizations to take advantage of big data. Big data has been described as "the new oil." Discovered in the late 1850s, oil - with the necessary tools and technology to extract, refine, and transport it - became a vital raw material for producing electricity and the power and energy to drive the industrial revolution. Big data, with the necessary tools and technology to collect, store, and analyze it, is being increasingly viewed as an essential raw material for producing timely and accurate information that drives rapid decision-making, aiming to achieve a competitive advantage for the firms involved. High-quality information is vital for decision-making by firm managers [1, 2]. That said, the immense and ever-growing data presents a challenge as well as an opportunity for the firm. Given the IoT, sensing devices that monitor and collect data of the environment surrounding the firm's production plants (i.e., beside the machine's raw material usage data) are becoming more commonplace. The complexity and accuracy of the data being collected by firms are increasing. It might be feasible for firms to collect data that was previously unattainable, representing the behavior and usage of products throughout their life cycle (i.e., beside the raw materials and product design parameters). That data can support more accurate and faster decision-making. However, for that data to produce timely and accurate information, the necessary data storage and analytical capabilities must be developed first. Firms lacking the needed capabilities might be paralyzed rather than helped. In a market that is shaped by the rapid growth of readily available big data and intelligence, firms must develop the needed capabilities to sustain their competitive advantage [3].

FOUNDATIONS OF BIG DATA ANALYTICS

Data analytics has become a significant method for using big data. Big data analytics is an essential tool for analyzing big data that can complement and enhance existing decision models, redefine business practices, and create new business-wide opportunities. Big data analytics combined with decision-making models can help firms maintain competitiveness and enhance firm performance [4].

Understanding the decision-making models available for big data analytics and maintaining competitiveness, recent developments in the area of big data analytics and decision-making models are reviewed. Research opportunities are highlighted, and future research directions are suggested. Analytics refers to a variation of statistical procedures used to explore, model, and understand data in the context of business problems. The main purpose of analytics is to use the results of statistical procedures to gain insights about business processes that can support business decisions to improve those processes. They provide historical context and are sometimes prerequisites for more advanced decision-making tools. However, as they do not model future scenarios, they are less suitable for complex and strategic decisions [5]. A classification of strategic decision-making tools for big data analytics is proposed. They are referred to as "decision-making models" since they always have a decision context and model real business scenarios to support decisions. Decision-making models are grouped into three classes according to the nature of the decisions supported: decision support systems (DSSs), forecasting models, and optimization models [6]. A DSS is a computer-based system that supports business process decision-making activities. DSS can be adapted for use with big data. Big data DSS systems designed for supply chain resilience analysis is an example of this adaptation. In this case, the exploratory capabilities of a DSS are complemented with optimization capabilities to recommend decision alternatives [7]. The business problem context is less well-defined than in the case of DSSs. It represents future scenarios based on historical data modeling, and thus the actual business context is excluded. However, they model very important business problems, such as demand forecasting. Strategic decisions are usually high-level, long-term, and often related to gaining a competitive advantage or major investments. They are usually taken by top management and are less frequently revisited than operational and tactical decisions. In the case of big data, there are essential differences in the nature of the data since big data involves significant changes in volume, variety, velocity, and veracity in data handling. These questions are addressed during the development of the classification [8].

SUPPLY CHAIN MANAGEMENT BASICS

Ali and Khan define a "supply chain" as an integrated system of equipment, technologies, policies, activities, resources, procedures, and practitioners involved in materials flow, from suppliers to consumers. Supply chains support a range of compilation activities that govern resource usability. In particular, they include planning, execution, and monitoring of the relevant activities. Figure 4 illustrates the generic structure of a supply chain [9]. Each point of a supply chain network is related to an actor. Actors perform roles in a supply chain network. Supply chain network (the model of trade relations) can be decomposed into resource fulfillment systems associated with distinct actors. Supply chain actors can be distinguished based on resource type relevant to the activities of resource fulfillment systems. In the SCN modeling methodology, lower level abstraction offers a standard set of constructs. The use of each construction can be traced to either one or a combination of fundamental objects [10]. The transactions of resource flow between supply chain actors and the dynamics of these transactions are controlled by a combination of strategies, policies, and agreements. The agreed purpose of transactions comprises a set of fulfilling conditions constraining resource input and output of fulfillment systems. The three basic types of conditions between non-zero fulfillment systems are: (i) "activity condition"; (ii) "logical condition"; and (iii) "temporal condition" [11]. The goal of design, analysis, and re-engineering of SCN is the identification and alternation of improved SCN model (supply chain network) fulfilling given criteria. The SCN model comprises a network structure (set of actors, types of resources, transactions of trade relations) and resource knowledge of actors (ownership, collection, return stochastic policy). Actors perform a series of complex events, changing the state of "owned" resources and modeling SCN dynamics (the transformation of knowledge concerning resource value, state, location). Events of transactions affecting the behavior of actors are either autonomous or externally triggered [12].

CHALLENGES IN SUPPLY CHAIN OPTIMIZATION

Supply chain optimization (SCO) focuses on acquiring benefits in delivery time, cost reduction, customer satisfaction, quality, and flexibility through practical decision-making in interrelated networks consisting of various players with existing company strategies. Here, you find the main algorithms contributing to the SCO solution, representative solution methods, decision variables, and objective functions related to three main SCO categories: single epidemic-based SCO optimization, for-horizon multi-epidemic-based

SCO optimization, and risk-based SCO optimization at the design level. Big data, characterized by the 5Vs, poses challenges in SCO, specifically in storing, managing, processing, integrating, and safeguarding information generated [13]. Within the scope of disaster incidents, non-knowledge of event occurrence, patterns, time, and spreading resistance levels is common, challenging decision-making workflows. There is an urgent need to develop an intelligent decision support system using extensively generated big data to enhance decision-maker knowledge and robustness. Supply chain optimization lacks existing knowledge representation mechanisms that monitor dynamic parameters in decision-making workflows, which big data could readily provide. Considering both the stored and dynamically generated big data in the knowledge representation mechanism is a challenge [14]. With the emergence of Industry 4.0, the demand for connected high-tech assets for big data acquisition and big data management and analysis in the cloud is rising. However, cloud computing systems present availability, performance, and security challenges that induce reliability concerns and affect decision-making workflows. Safety integrity levels assure efficient decision-making workflow safety in supply chain optimization. However, there is no existing safety-inventory level in the literature that assures an efficient safety control level in Industry 4.0-connected supply chains [15].

APPLICATIONS OF BIG DATA ANALYTICS IN SUPPLY CHAIN OPTIMIZATION

In recent years, various big data technologies have been developed to address supply chain issues. However, these technologies are often only observed in limited instances. Using a literature review, practitioners can identify how these technologies can apply to their organizations and help overcome challenges. The adoption of big data technologies to solve internal supply chain issues is not well-studied. A systemic framework of these technologies provides a guideline for practitioners exploring the impact of big data [16]. Matters requiring attention in terms of future research are the potential advantages of integrating big data technologies within supply chains, as well as big data technologies reducing the importance of certain supply chain challenges. The former asks whether the potential advantages, in terms of either legal power or market power, of establishing a supply chain with a central big data holder based on the literature on the "big data marketplace" will advance, if at all, the state of knowledge on supply chain risk management, supply chain management research, and general supply chain research. The latter asks whether and how the rise of big data will affect the need for past workhorse supply chain models on information sharing incentives, obfuscation, and leakiness of information [17]. These two matters together provide a springboard for investigating the implications of big data technologies for the emergence of new types of supply chain configurations least favorable for supply chain challenges. Furthermore, "multicriteria performance measurement models" that address the multifaceted nature of variables such as demand variability and delivery delays hold particular promise in revealing deeper insights into the increasing complexity of balancing supply chains and the increasing complexity of "what-if" evaluations aiding in their design. Herein, "events chain management," an extension of supply chain management that addresses the whole increased complexity of dynamically creating, optimizing, and modifying supply chains becomes of utmost relevance.

CONCLUSION

The integration of big data analytics into supply chain optimization presents significant opportunities for firms to enhance their competitiveness by improving decision-making processes and operational efficiencies. Despite the challenges related to data management, storage, and analysis, the benefits of adopting big data technologies in supply chains far outweigh the obstacles. Firms that successfully leverage big data analytics can achieve superior performance in delivery times, cost management, and customer satisfaction. As the landscape of supply chain management continues to evolve with the advent of industry 4.0 and advanced technologies, further research is needed to develop robust models and frameworks that can fully harness the power of big data, ensuring resilience and agility in supply chain operations.

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