ISSN (O) 2321-2004, ISSN (P) 2321-5526

IJIREEICE

**International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering**

Vol. 9, Issue 12, December 2021

DOI: 10.17148/IJIREEICE.2021.91218

Leveraging Cloud Computing and Big Data Analytics for Resilient Supply Chain Optimization in Retail and Manufacturing: A Framework for Disruption Management

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Abstract: The optimization of supply chain architecture is essential for sustainability among industries. Dynamic evolutionary events such as natural disasters, pandemics, terrorism attacks, political unrest, and cyberattacks have severe implications that disrupt the operations incurred by an unplanned event or attack and economic losses that reduce the agility and resilience of supply chains. Organizing initial inventory stock to meet uncertain customer demand is a primary action to counteract uncertainties during the onset of the crisis. Traditional supply chain models may not be effective enough considering past order and demand patterns, incorporate time-dependent fixed-up and shut-down costs, and respond slowly toward uncertain demand due to dissemination issues. Cloud computing, sensor, and network technologies, and distributed intelligent systems provide a universal and economical information and communication technology infrastructure for supply chain entities to share supply chain information, big data analytics, decision support tools, and systems through the Internet regardless of time and place. This innovative approach leads to create a consolidated Virtual Supply Chain (VSC) based on cloud models that associates and connects, in a dynamic fashion, any supply chain entity capable of storing, sharing, and processing information to support multiagent, collaborative, ubiquitous, instantaneous decision-making and recommending answers. The use of advanced cloud computing, the Internet of Things, and data analytics technologies provides the supply chain actors with capabilities of forecasting demand, managing risks, and optimizing supply chain design, planning, and operations in a collaborative, efficient, aligned, responsive, resilient approach. Considering that customers have become the driving agents and have the power to make a difference concerning final demand, this chapter proposes a demand perspective for modeling, optimizing, and managing the VSC by developing an advanced commercial agent-based simulation model.

Keywords: Supply Chain Optimization, Virtual Supply Chain, Cloud Computing, Internet Of Things, Data Analytics, Demand Forecasting, Supply Chain Resilience, Risk Management, Inventory Management, Agent-Based Simulation, Distributed Intelligent Systems, Big Data Analytics, Collaborative Decision-Making, Ubiquitous Computing, Crisis Response, Real-Time Information Sharing, Supply Chain Disruptions, Dynamic Supply Chain Design, Customer-Driven Demand, Multiagent Systems

I. INTRODUCTION

The current global economic landscape is witnessing profound disruptions, with the pandemic serving as a stark revelation of the vulnerabilities inherent in contemporary supply chain systems. These systems, characterized by their progressively intricate and extensive networks, demonstrated a marked susceptibility to disturbances, causing delays and deficiencies in product availability across multifarious sectors. Consequently, organizations have been prompted to reflect upon their strategic planning methodologies, especially concerning resource allocation and investment in supply chains. A prevalent recommendation is to prioritize adaptability, flexibility, and resilience over conventional efficiency metrics.

In an age defined by the demand for real-time connectivity and unprecedented scrutiny from stakeholders, the integration of emerging technologies such as cloud computing and big data analytics into conventional supply chain processes has become indispensable for ensuring an agile and synchronized supply chain infrastructure. The synergy of these advanced technologies facilitates the accumulation of copious amounts of operational data, transcending the limitations of organizational memory and rendering feasible the implementation of concurrent real-time planning and execution.

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Despite the growing interest in and adoption of these technologies by companies, their practical utilization in the domain of supply chain design remains limited. Through this research, we endeavor to explore the potential of these technologies in improving supply chain design decisions. In doing so, our objective is twofold: firstly, to evaluate the state of knowledge regarding the influence of these technologies on the capabilities and decisions of supply chain design, and secondly, to identify and delineate the research gaps that need to be addressed to advance the subject within a sustainable paradigm.

1.1. Overview of the Study

The studies on cloud computing and big data analytics have been flourishing and have gained considerable support from scholars and practitioners alike to date. The cloud enables organizations to execute big data analytics in a cost-effective and time-efficient manner and commonly supports their adoption. Big data analytics supports monitoring and controlling activities of the supply chain at supply chain nodes. It's also been used for analyzing the values and reactions of customers, competitors, suppliers, etc., and aids with predicting future requirements. Researchers have found wide-ranging evidence in support of their utility in the performance-enhancing context. Their impact on manufacturing as well as service organizations is analyzing and modeling the flow of goods, services, internal operations, as well as financial parameters to anticipate future risks and predict future events. Despite the promise of improving efficiency, responsiveness, adaptability, and reliability, there are challenges associated with their adoption and implementation.

Thus, the objective of this text is to provide insights about these technologies which are significantly impacting the landscape of supply chain optimization in a way that makes it more resilient and helps improve performance. Although the presence of other types of advanced technologies, autonomous robotics for example may provide similar capabilities over a different time frame. We hope to accomplish the objective through a literature review followed by qualitative interviews with industry executives. Our specific contribution lies in generating insights about cloud computing and big data technologies for resilient supply chain optimization. We provide guidance regarding the application of these technologies, considerations associated, challenges involved, and areas for future research. These insights should serve as a primer for industry executives as well as guide researchers in casting their nets while investigating allied areas for the generation of new knowledge and conducting empirical studies.

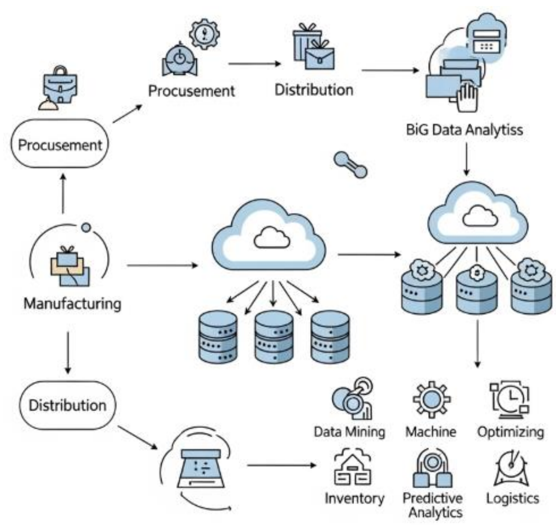

Fig 1 : Cloud Computing: Diverse Applications and Industries

II. BACKGROUND AND LITERATURE REVIEW

All organizations develop capabilities to cope with potential supply chain disruptions, but those capabilities need to be correctly utilized, and for that, information is the lifeblood of an organization. Cloud computing and big data can indeed provide a wealth of information to accomplish this optimization process. A brief examination is made in this section of the concepts and terms associated with cloud computing and big data analytics, as a basis for further discussion on supply chain

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management – past, present, and future, as well as studies on supply chain resilience. Next, the main works regarding the possible effects and the tradeoffs among implemented resilience capabilities are explored. Finally, insights are provided based on the potential use of cloud computing and big data analytics for managing supply chain resilience.

Cloud computing is an Internet-based computing platform that remotely provides customizable services, mainly in the form of standard system applications, computing, or data storage to diverse groups of customers. Some of the services offered are storage of data, e-mail, document production and sharing, and enterprise resource management. After having spent enormous resources to develop, enhance, and operate IT systems, many companies have started using cloud computing. Cloud customers do not incur heavy up-front hardware and software costs. In return, cloud computing eliminates the need for internal operating staff and capacity planning, shifts IT spending from capital expenditure to operational expenditure, and offers lower storage costs for very large-volume users. As a major advantage, cloud computing provides interoperability and standardization of services for small and medium enterprises, similar to those provided by large companies through their proprietary systems.

$$\mathrm{SCRS} = \frac{R_d \cdot C_f}{S_v + L_d}$$

Equation 1 : Supply Chain Resilience Score

where

SCRS = Supply Chain Resilience Score

R_d = Recovery Duration (post-disruption response time)

C_f = Cloud Flexibility (scalability, failover capacity)

S_v = Supplier Volatility Index

L_d = Logistics Disruption Frequency

2.1. Cloud Computing in Supply Chain Management

The dependence of supply chains on high-speed connectivity has increasingly pushed supply chain managers to take advantage of externally hosted suppliers for their information technology, applications, and services. A shift like this is good from a capabilities standpoint since such services are available instantly from anywhere and do not require capital investment. Organizations can use services like information/data backup, website hosting, and webmail, without needing to operate, maintain, or even have the underlying hardware and software. The service provider is solely responsible for hosting, managing, and maintaining the cloud infrastructure and services it delivers to the customer. Such service providers offer easily configurable, queryable online applications for data storage, data collection, and communication, which organizations can develop, customize, and fine-tune based on their needs. Though we can trace the roots of this technology back to the 1960s, cloud computing started to gain popularity in the 1990s with the emergence of the internet. Cloud computing improves business agility, allowing organizations to focus on other aspects of their supply chain rather than the costs and time associated with hardware and software ownership. Cloud computing has also been influential in enabling the deployment of data analytics by providing access to the hardware, infrastructure, and tools needed to extract insights. This emerging trend is particularly evident in how companies are making use of the data deluge generated by customer-facing applications in an exchange, social media, and various enterprise applications such as enterprise resource planning, customer relationship management, or logistics and warehouse management systems.

2.2. Big Data Analytics in Retail and Manufacturing

In the past ten years, retailing has evolved dramatically with the proliferation of social media and online shopping. Online retailing is now a crucial channel for both large and small brand marketers. It's fundamentally changed the sales floor into a virtual one. Online shopping is increasingly becoming an avenue for marketers to explore new aspects of branding, sales, and consumer relations that might not have been previously possible. In the face of ubiquitous computing with high-speed Internet, such an evolution is expected. Besides, this evolution is continuously reshaping the competition landscape across the world, presenting new challenges to both consumers and companies. Big data analytics are discussed as a potential solution for capitalizing on this evolution in consumer behavior. Retail companies possess vast amounts of unstructured data.

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This data partly contains the activities of each customer transaction that occurs on their websites. Using precise big data analysis methods, these retailers can uncover meaningful insight and provide superior customer value.

Establishing mutual value relationships with consumers is not an easy task. Companies might consider using remarketing providers to assist them in capturing the value of consumers for all their marketing activities. Big data analytics can also help retailers in several areas such as merchandise assortment planning and targeting market-based pricing. However, these are not the only focus areas and effects retailers might consider when building a big data-driven retailer technology platform. Previous years have shown that retailers are querying the broadest possible set of customer transactions, purchasing, and behavioral data across both online and brick-and-mortar channels. Consumers increasingly wish to be treated individually by the activities retailers direct to them.

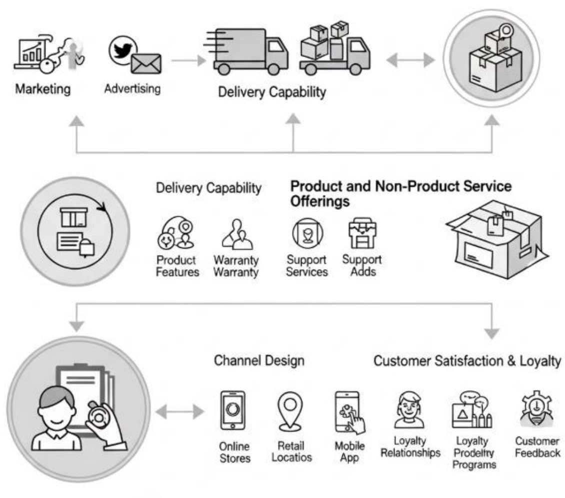

Fig 2: Customer's Journey

2.3. Resilience in Supply Chains

Natural and manmade disasters can disturb the flow of products through supply chains and can have disastrous effects on economies and societies. Disruptions in supply chains are everyday occurrences; the media frequently reports about such disruptions. Products sold through grocery stores can be manufactured in foreign countries and disruptions due to disasters in those countries can lead to shortages in national grocery chains. Disruptions have led to manufacturing interruptions for companies in other countries.

What can companies do to minimize the risk of these disruptions in practice? How should the supply chain design be planned to better withstand the risk of disruptions? Fail-safe design principles have been developed that can be used in an effort to better minimize the chances of disruptions or at least avoid small disruptions turning into huge catastrophes. Mitigation strategies or tactics aim at avoiding supply interruption in the first place or at reducing the size of product shortages during a supply interruption. Contingency plans can help companies to avoid shortages during a disruption or to alleviate the effects of disrupted supply flows. Supply chain researchers have developed frameworks to help guide the process of planning supply chain strategies that account for the potential risk of supply chain disruptions.

2.4. Disruption Management Frameworks

Management of supply chain disruptions can be achieved via supply chain disruption management frameworks; nine disruption management frameworks have been identified in the literature review. Some of them are listed below with their focus and assumptions: the disruption management roadmap aims to create an adaptive system that can anticipate and adapt to changing environments by following a cyclical process; the root cause analysis enables the understanding of a supply chain's micro-behavior contributing to disruption consequences; risk management approaches provide variations that help to prepare for, detect, respond to, recover from, and learn from disruptive events across the supply chain. Varying from traditional risk approaches (mainly avoidance and mitigation), the proposed shifts include supply chain resilience and

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recovery strategies utilizing innovation and communications. The structural collection of capabilities enables the configuration of systems that can more effectively deal with potential disruption events.

The preparedness framework allows patterning of ongoing survival-level or defensive efforts during stable, non-disrupted periods to cope with responses and recoveries during uncertain disrupted periods. The general double-loop learning model enables simultaneous or sequential exploration and exploitation during pre-disrupted, disrupted, and post-disrupted periods. A capability-building framework concentrates on the stage-gate building of strategic-stage capabilities converging successful reactions to historical supply chain disruption events from business-as-usual to risk-hedging. Three areas have been detected that provided friction on the adaption road. Based on insights from existing disruption management literature, a disruption management control tower architecture has been proposed as a comprehensive data aggregation system that enables support functions and applications necessary for efficient disruption management performance in the supply chain context. These support functions include disruption detection, visibility, planning, monitoring, communication, decision support, and speed. Hence, even though we can say that there are many different ways of setting up a disruption management framework, the ones mentioned represent quite an overview of the approaches available, and the decision to choose one approach over another could be based on what you want to achieve.

III. METHODOLOGY

1. Research Design
The study reflects qualitative and quantitative paradigms. Its approach is exploratory, descriptive, and causal, with both primary and secondary data sources. Its stage is cross-sectional and longitudinal, with data collected through surveys. Three unstructured interviews were conducted, one with a cloud computing expert and a second on big data analytics with a member of the decision-making and intelligence unit of the Brazilian Ministry of Finance, both in December 2020 and another on logistics with a specialist of a multinational logistics company in June 2020. The surveys were sent out in December 2020 to various organizations and their respective societies.

2. Data Collection Techniques
The study used semi-structured surveys and unstructured interviews focused on the participant's areas of expertise in cloud computing, big data analytics, logistics alliances, resilience, and resiliency. The participants are among the world's main economic development, international organizations, port, maritime transport, and diplomacy decision-making agents. Their relevance increased from the pandemic, which compressed automatic transport supply and demand through restraints, lockdowns, and financial assistance, which induced companies to protect their cash flow and transport budgets, dragged their working capital down, and postponed their imports and exports. The guides' questions were focused on organizations' motivation and support for investments in cloud computing and big data analytics, which not only help them acquire more capacity at lower prices and mitigate demand volatility and severity, but also suppress operational costs through performance monitoring; to sustain improvement initiatives; and stakeholder engagement, empathy, and responsiveness to events.

3.1. Research Design

In today's turbulent environment, resilience is the most crucial attribute in the supply chain sector. To achieve resilience, we consider a specific Supply Chain Network (SCN) design problem. The issue we focused on consists of determining the number, location, and capacitating of supplier, plant, and distribution center facilities and the logistic modes selected to establish the links between pairs of SCN facilities, within the uncertainty of product demands, transport times, and costs. The Strategic SCND problem has gained attention in the last decades since a wrong design of the SCN may lead to severe economic losses. Big Data enables the user to break through the informational barriers and push the SCND decision-making down to the tactical level by monitoring, measuring, and controlling processes via supply chain information collected through Big Data. Among the several objective functions to minimize considered, to achieve alignment in Supply Chain (SC) strategic decisions, we minimize the supply chain total cost. Challenges concerning Sustainable Decision-Making in SCN Design or Supply Chain Strategy are increasingly gaining focus in the Big Data and Supply Chain Management literature. Resilience is identified as a key attribute in SCN Design.

Despite this increasing research interest, parallels settled with Big Data or taking into account the new Technological Transition, and disrupting SCN Design, are still rarely developed. We aim to first consider a sustainable decision objective that estimates the SC carbon footprint and considers the Big Data, Technological Transition, and the Fourth Industrial Revolution aspects in a Tactical SCN Design problem.

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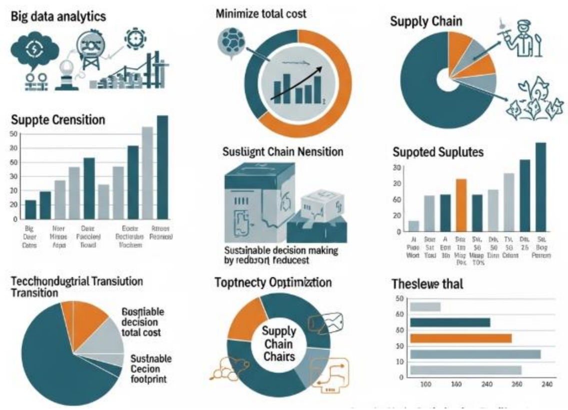

Fig 3 : Design Challenges of a Resilient Supply Chain Network (SCN)

3.2. Data Collection Techniques

The chapter discusses the data collection techniques employed in this research work. The study utilized both primary and secondary data sources to derive results. The primary data was gathered through a survey from 156 organizations operating in the supply chain and logistics sector, as well as financial sector enterprises. The issues pertaining to the use of Cloud and Big Data technology were addressed in a comprehensive manner in the research. The respondents comprised operational management experts and senior management officials from the logistics and supply chain sector, spanning not less than 56 logistics and supply chain companies, and 100 companies from the financial sector, who had prior knowledge of Cloud and Big Data analytics technology and its application in managing the organizational supply chain and operations activities and decisions.

The investigation of the nature of the applied work helped to explore the data collection techniques used in the study. The prime objectives of the research work were to analyze the impact of exposure to Cloud technology on organizational performance, precipitate a model considering the construct operations flexibilities, and focus on the control mechanism as a link between Cloud technology and organizational performance. A quantitative approach using the survey questionnaire technique was engaged to obtain the required data to realize the research objectives. Questionnaires were designed with embedded links circulated to potential respondents via e-mail and social media. The sample consisted of 749 industrial managers and heads of firms from various industries in developing economies currently implementing Cloud technology. Convenient sampling was followed in this study based on the unavailability of respondents during interviews and the wide-ranging geographical dispersion of potential respondents.

3.3. Analytical Tools and Techniques

Data analytics is a very important step in research because without the results from applying the analytical tools set up by the researcher, no validation of the research model is achieved and thus no conclusions can be drawn. The conclusions from the research should be valid and reliable to help any decision-maker. In the case of the current research study, the researcher conducted the current study to answer questions that were exploratory in nature, where the researcher used PLS-SEM for the estimation of the parameters. SEM has become a widely used modeling approach to test whether the data fits predicted models since its introduction. SEM allows having multiple dependent variables in a single model, thus freeing up researchers from the constraints of univariate approaches like ANOVA and regression analysis which assume normality and independence of errors. The added advantage of SEM is that it estimates required path weights from covariance estimates based on factor analysis. The use of factor analysis before arriving at a structural equation model is increasingly being questioned as factor analysis involves a high degree of subjectivity and may produce results that do not correlate across studies.

The results of SEM suggest that H2b, H3b, H7b, H8, H9a, and H9b show significant and positive associations. These hypotheses posit that supply chain resilience improves customer satisfaction, customer trust, and customer loyalty toward green products and lessens the risk perception of green products. Among the factors, customer loyalty is reported to show the strongest association with supply chain resilience. Since customer retention toward green products is the objective of supply chain partners, supply chain partners should be proactive in enhancing supply chain resilience.

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IV. CLOUD COMPUTING FRAMEWORK

This section provides the underlying framework for deploying the various applications proposed in this report. We are working on platforms that fit under the umbrella of cloud computing. A new computing model, called cloud computing, has been developed to provide high-performance computing at a low cost. Cloud computing allows an organization to avoid the costs and hassles of owning and maintaining their own computing infrastructures or data centers. Cloud providers are able to create enormous economies of scale by delivering better and cheaper services in the areas of computing, storage, networking, and applications.

Cloud infrastructure provides resources that include processing, storage, and applications delivered as services to external customers over the Internet. These resources are leased or rented on-demand, providing businesses with a new approach to accomplishing their mission objectives with less investment and operating costs. The advantages of cloud-computing infrastructure over traditional computing infrastructure can be summarized as follows: scalability, elasticity, lower cost, no management, and pay-as-you-go. There are three basic categories of cloud services offered by a cloud provider: Infrastructure as a Service, Platform as a Service, and Software as a Service. Infrastructure as a Service provides remote hardware resources like servers, data storage, etc. Operating systems and runtime environments with the ability to build applications on the user remotely accessible hardware provided are offered by Platform as a Service. Software as a Service provides the owner of cloud services the ability to offer remote service solutions for computers using the internet.

4.1. Infrastructure as a Service (IaaS)

The term cloud computing refers to a model that is intended to provide on-demand resources, such as networks, servers, storage, applications, and services, that can be rapidly provisioned with minimum effort and management effort. Resources are conventionally served over the Internet. An important element of cloud computing is that the resources are shared and therefore, utilization is not fixed, but more dynamic, and thus, it is a more economical model.

Cloud computing uses Remote-Access and Remote-Capture technology models and utilizes Utility as a Financial Model. The functionality modules of cloud computing are Data as a Service and Security as a Service. The three models of cloud computing are Infrastructure as a Service, Platform as a Service, and Software as a Service. The central objective of cloud computing is to provide an IT platform as a service for new computing architectures. Information Technology platforms can be thought of as integrated systems that are used during the development, deployment, or use of applications.

Infrastructure as a Service is a complete offering of all the physical hardware and associated software that is necessary to run client software on the Internet. Its essential component is a cloud infrastructure of servers, storage, networking, and software that enables those components to be accessed and used by clients. Infrastructure as a Service solves some of the important infrastructure deployment problems. A specific project can be initiated and completed without the need to engage in purchasing, commissioning, and installing new IT equipment. New problems, such as projects or temporary spikes of processing needs, can be addressed quickly and efficiently.

$$\mathrm{PDAI} = \frac{A_p \cdot D_v}{T_d + N_o}$$

Equation 2 : Predictive Disruption Agility Index

where

PDAI = Predictive Disruption Agility Index

A_p = Accuracy of Predictive Models (for demand, weather, risk)

D_v = Data Volume Across Nodes

T_d = Time Lag in Detection

N_o = Noise in Operational Data

4.2. Platform as a Service (PaaS)

PaaS services are designed to support the complete lifecycle of building and delivering cloud-based applications — from the design and development stage to deployment and maintenance. Using cloud-based services that are hosted on a lightweight

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environment shortens the time required to develop an application and provides easy access to storage and other fundamental building blocks. PaaS offerings are used by development teams who face the challenges of delivering software against the competitive pressures of the cloud era. Software development is inherently collaborative and rapid, and software projects can expand horizontally in ways that are unstructured and unpredictable. PaaS providers offer to ease the pain of software development by providing services that facilitate teamwork, automate repetitive tasks, and enhance security, compliance, and deployment to production.

With PaaS, developers build software through the abstraction and encapsulation of underlying infrastructure. They don't need to worry about provisioning servers, installing and configuring middleware, or enriching their applications with security, reliability, and scalability best practices. These are handled by dedicated PaaS services: for example, using features for availability monitoring, backup, and data recovery on cloud storage to secure data, or providing usage controls around tenant identity and authentication to meet security and regulatory requirements. Unlike IaaS, where developers are focused on building, running, and managing their applications, with PaaS, much of that work is handled by the PaaS itself. For instance, PaaS offers developers easy access to the additional services required to build an application — database management, messaging, application monitoring, content delivery, and authentication among them.

4.3. Software as a Service (SaaS)

SaaS, also called Web-based Software as a Service, is one of the newest and quickly evolving cloud computing models, offering a powerful alternative to traditional packaged software. Technically, SaaS is a software distribution model in which applications are hosted by a service provider and made available to customers over the Internet. Customers do not buy the software and install it on their own PCs, as has been the way with conventional software licenses. Rather, they access the application via an Internet connection, either free or at a low cost per use. Such software/applications reside on the provider's server, rather than running locally on users' desktops. SaaS somehow limits the user's interaction with the software because it does not allow the level of customization that conventional software does. However, it relieves businesses of the maintenance and support associated with conventional software. Because the software is administered centrally, corporations using it take advantage of immediate updates and patches. Hosted software can require less hardware and no additional servers. SaaS applications can also take advantage of a larger shared database for all users, thus allowing them to compare their operations against the best uses. Application service providers introduced application hosting and remote access a decade ago, but they never achieved serious traction. However, within the last few years, a burgeoning array of companies, from established enterprise vendors to nimble startups have launched a new generation of SaaS offerings. Easy-to-use SaaS applications are now available for many functions: Sales force automation, help desk, marketing services, accounting, analytics, online document collaboration, and business productivity, among others. SaaS terms, including utility pricing and pay-for-use, are also changing the way enterprise software is sold. Some industry insiders believe that scaling software into multi-tenant hosted applications may be one of the best opportunities for growing software vendors, indeed this may be the only way some new applications can economically be developed and marketed.

Fig 4 : Software as a Service

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V. BIG DATA ANALYTICS TECHNIQUES

Big data technologies are contributing significantly to the world of supply chain analytics, as they allow for the capture and storage of explosion of data in an efficient manner and at a low cost; whereas traditional systems would struggle to filter, model, and process the data, advanced systems can bring sense to the chaos and use intelligent algorithms to build relationships, detect patterns, and perform more innovative analytics. New and advanced analytics techniques and advanced analytics tools need to be developed that cater to the complexity and high dimensionality of big-data environments in order for organizations to derive value and insights for better decision-making. Organizations are now shifting from merely reporting to predicting future events and automating decisions. While predictive analytics predicts prior unknown future events/actions/prospective customer behavior, prescriptive analytics leverage technology to help choose the best possible outcome while using algorithms and mathematical modeling to develop future predictive probabilities. The intent is to start thinking about new advanced principles to create automated analytics and help organizations use tools to create a prescriptive engine without human sensors and intervention.

By understanding past transactions and current trends of customers, descriptive analytics provides insights into how making sense of clients what report data and looking events have led to these transactions. Predictive analytics predicts from the past how many, what type, and when demand comes for a specific product, and prescriptive analytics, complex optimization models use advanced algorithms for real-time visibility of data and what it means, matching supply with demand for optimizing their systems and resources and offer a quick response. While descriptive and predictive analytics are enabled through Business Intelligence solutions, prescriptive tools reside within specific functions such as inventory mapping, forecasting, decision support, inventory optimization modeling, revenue optimization, process simulation, and asset recovery.

5.1. Descriptive Analytics

The fundamental objective of descriptive analytics is to provide clear descriptions, such as for what, to whom, where, and when, of certain phenomenon patterns. Traditional data mining, data visualization, and OLAP are all significant techniques of big data descriptive analytics, which create several descriptive models that provide estimates for specific random variable characteristics. For example, decision trees output a set of simple rules that can explain how to describe the different classes of a response variable based on the values of some explanatory variables; clustering outputs a set of clusters that describe the groups in which the data items can be partitioned; frequent pattern mining outputs a set of frequent item sets that describe the set of items that frequently occur together in transactions or sequential pattern analysis; ontology generation provides ontologies that help to describe the concepts and their relations that exist in a particular domain; and information extraction abstracts certain information from unstructured data.

One currently common descriptive model is the iDoc, which is an intelligent document that summarizes the significant features of a data set and indicates the specific aspects of the data set that may require further exploration. In object-oriented databases, iDocs can be used for data summarization, for the contents of the objects, and for the different object classes, hierarchies, and relations. Because of the inherent characteristics of big data, particularly the wide availability and accessibility of data from a variety of heterogeneous and distributed sources; increasing availability of inexpensive storage, computation power, and bandwidth; and the paralleled nature of many basic machine-learning techniques, three main characteristics differentiate big data descriptive analytics models from traditional descriptive models. First, the scale of the data that can be mined for the construction of the models is significantly larger. Second, big data descriptive analytics models can be constructed much faster because of their paralleled nature. Third, these models are inevitably more approximate than traditional models because of the enormous volume of the data.

5.2. Predictive Analytics

Predictive analytics uses a combination of statistical and machine learning techniques to construct the predictors or predictive models that describe the causal structures or functional relationships in the underlying data-generating process. These models enable the decision-makers to forecast future outcomes or hidden characteristics. Predictive models based on historical or current data have been developed for predicting various outcomes in business based on the available predictor variables. Decision trees, generalized linear regression, and neural networks are three commonly used predictive analytics methodologies in business applications. Predictive analytics has been used extensively in a number of supply chain management applications for tasks such as demand and inventory prediction, production planning and control, prediction of supply disruption and recovery time, and prediction of customer order reasons and return behavior. Predictive analytics

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models can be used to forecast supply chain performance for different future periods. For example, the prediction models of demand may be used to forecast the demand valued 4 or 8 weeks ahead. Similarly, lead time and forecast error variance models, which essentially predict the supply chain lead time and forecast error variance, can be used to forecast the behavior of these metrics at different time horizons. Further validation may be required to understand how far ahead these metrics' acceptable or optimal values can be forecasted. Depending on the availability and maturity of the key operational policies, particularly the effect of lead time policy on the quality of demand forecast, the forecast horizon for which the above key metrics can be predicted may differ.

5.3. Prescriptive Analytics

Prescriptive analytics feeds data or insights into a model to arrive at optimal solutions to the problem based on certain objectives or goals. Supply chain networks are usually designed for optimization with the help of mixed-integer linear programming or network flow models to determine the best configuration or behavior of networks. Initially, the most basic models for modeling supply chain networks consider a multi-period static setup, and assume that demand for retailers is deterministic and its distribution is either uniform or based on chance-constrained programs. However, many additional complexities have been added to model supply chain networks, primarily to make them deterministic. Among these are: network disruption and contingency generation leading to vulnerability, risk, and resilience; capital budgeting and financing, liquidity and cash flow; uncertainty in costs, lead times, and demand; prediction or forecasting of these uncertainties; multiple functions other than transportation and warehousing being included in the network for many-to-many flows; network uncertain capacity and cost multichoice; full lagged demand; facility location, selective and transshipment policies; planning horizon and timescale; trade-offs among cost, delivery time and quality; and many others.

Access to hosted large-scale complex mathematical modeling optimization tools in the Cloud has enabled companies to solve their supply chain problems at micro as well as macro levels frequently and cheaply, and at very fine time resolution. While preparatory modeling is still substantial, as it involves demand, lead time, and cost prediction and forecasting, the return on optimizations using such tools is incredibly high. The best known of these tools is the Decision Optimization Services. They can be seen as company-specific implementations of prescriptive collaborative planning tools which are major players in the prescriptive analytics space.

6. Supply Chain Optimization Strategies

Supply Chain Optimization (SCO) is a combination of multiple processes and methods that seek to reduce the cost and time taken to acquire, manufacture, and distribute products to deliver the right products to the right customers at the right time in the right quantity. SCO often involves coordinated planning and execution of procurement, production, inventory, sales and operations planning, warehousing, and logistics. SCO sits at the intersection of operations management, logistics, economics, and applied mathematics. Companies cannot afford to have sub-optimal performance at any point along the supply chain as it can cost them much more than what they save. SCO is valuable for all kinds of products, but it is even more crucial for products with short life cycles, such as consumer electronics and foods, and those like automotive and aerospace which are very expensive and highly desired by many consumers. Traditionally, supply chain professionals have sought to minimize the operating costs of the supply chain. However, with increased competition, organizations have realized that SCO should be expanded to include delivery performance, flexibility, product quality, inventory, and product variety. The importance of SCO is likely to increase in the future because of the rapid trends toward globalization and alliances. Companies must manage their supplies in a more collaborative and coordinated manner to remain competitive. Furthermore, trends such as shrinking cycles, increased uncertainty and volatility, increased outsourcing activities, higher risk for supply disruption, and increasing focus on sustainability and corporate social responsibility are putting pressure on supply networks.

Some of SCO strategies include Inventory Management, Demand Forecasting, and Supplier Relationship Management. Inventory management is the process of ordering, storing, tracking, and using a company's inventory: the raw materials, components, and finished products it has on hand. Inventory optimization is the work of ensuring that you have sufficient inventory on hand to satisfy your customers' needs but not so much that it cuts into profits. Inventory optimization gives an organization control over its product availability while minimizing investment in product inventory. Storage cost incurs carrying the unused items. Capital lost due to overstocking must be taken into account.

ISSN (O) 2321-2004, ISSN (P) 2321-5526

IJIREEICE

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 9, Issue 12, December 2021

DOI: 10.17148/IJIREEICE.2021.91218

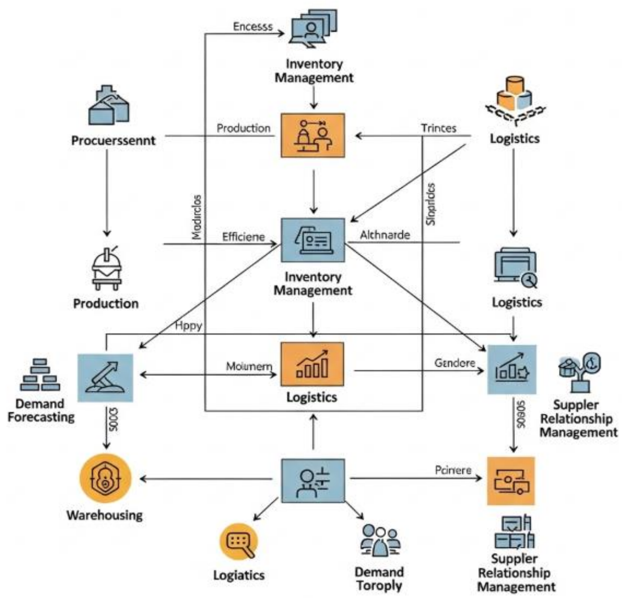

Fig 5 : Supply Chain optimization (SCO)

6.1. Inventory Management

Supply Chain Management is an essential function that helps organizations achieve increased profitability and greater customer satisfaction. Over the past couple of decades, interest in Supply Chain Management has steadily grown. As third-party logistics providers have matured and companies have sought competitive advantage through lowering costs and improving customer service, the interest in Logistics Management has also grown. Simply stated, Logistics Management is the organization and implementation of all activities involved in the flow and transformation of goods and services, which includes the movement and storage of raw materials, work-in-process, and finished goods from the point of origin to the point of consumption. In manufacturing, the goal of Logistics Management is to ensure that the right product is at the right place at the right time and the right cost.

Inventory being an active or passive machine ignores nothing and it repeats processes – failure to reduce or sustain inventory at the correct level incorrectly increases supply chain costs. The struggle to lower inventory levels never ceases and is always cluttered with subsequent stockouts threatening to cripple flow. Lower inventories bring closer cooperation with suppliers and highlight areas of concern, such as quality. One fruit of efforts to reduce funds tied up in inventory is the “Just-In-Time” movement. The concept proposes lowering operating costs by eliminating wasteful work processes. Purchasing just enough supplies when they are needed heavily supports this JIT concept. However, just-in-time control requires accurate supplier performance. If the material or supplies are not delivered as promised, it may be necessary to stock statewide inventory – and pay for stock never supposed to exist.

Maintaining optimal levels of raw materials, work-in-process, and finished goods is the foundation of any successful logistics operation. Although the focus in this module is on end-product inventories, the same principles apply to the other categories. Setting optimal inventory levels involves the examination of both the fixed and variable costs of carrying products in inventory and the service level expected. Costs of carrying inventory are often broken down into four categories: Cost of capital – the interest or opportunity cost associated with putting funds into inventory; Cost of storage – the costs associated with utilizing space to hold stock; Cost of obsolescence – the costs of losses due to deterioration or the inability to sell outdated products; and Cost of handling – the expense of moving goods into and out of storage.

6.2. Demand Forecasting

Demand forecasting - the act of predicting future product demand - is an important activity in many businesses. Accurately predicting demand allows organizations to make key decisions regarding supply chain activities on manufacturing strategy,

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capacity planning, production scheduling, inventory management, and logistics and distribution. For example, accurate demand predictions can help managers determine staffing needs for production and distribution operations, time the hiring (or layoffs) of employees to avoid excessive costs for unneeded staff, determine what-level safety stock to carry, or time markdowns to minimize losses from excess inventory. With real-time and predictive analytics, organizations can meet their goals of improving service levels while at the same time reducing the costs associated with logistics and distribution.

Demand forecasting has been studied with both qualitative and quantitative approaches. The qualitative approach relies on estimates while the quantitative approach uses statistical or time-series models. Both approaches have limitations in accuracy and reliability. For example, qualitative techniques are subjective and may not fully utilize external information. The quantitative techniques require a long period of data before the technique is useful. The existing demand prediction models are prone to errors and do not take into account external data, such as the customer, product, and/or market segments, or important triggers such as holidays and special events that may disrupt the information such as product promotions, special discounts, and product introductions. These disruptions are common in today's world and make it more challenging for organizations to accurately predict demand. This suggests the need for a collaborative approach to demand forecasting, even for products or services in highly competitive markets. With collaboration, demand patterns can be better predicted, and promotions can be better managed to minimize the risk of stockouts and excess inventory.

6.3. Supplier Relationship Management

Supplier Selection and management is a crucial aspect of the supply chain as supplier ability directly affects quality, lead time, cost, and ultimately customer satisfaction. Optimal supplier selection in an uncertain business environment is a challenge for organizations. Researchers have recently recognized the importance of big data sources in enhancing supplier selection and management. Suppliers can be evaluated, ranked, and selected for more detailed negotiation and more integrated collaboration. The selected suppliers can be segmented into different categories based on the strategic importance of a supplier category on business objectives. Supplier relationship quality in critical product categories must be well managed for superior firm performance with careful consideration of possible risks of over-dependence.

A proper Balanced Scorecard approach is needed to build a list of strategic measures to interface with the supplier's financial performance. The measures must be sensitive enough to reflect the financial picture of the supplier. The supplier's original equipment manufacturing profit margin must be examined for presence/absence and data availability/credibility, supplier's market share, corporate sales growth, advertising presence, and advertising-to-sales ratio. Strategic Alliance partners for outsourcing product categories must be carefully selected to avoid the penalties of low buyer dependence power. Relationship commitment and joint venture cloak of joint decision ability, supplier's financial exposure, and product replacement risk of buyer firm must be carefully considered. Each outsourcing partner in the crucial category must have clear risk acceptance criteria. Product technology development standards for long- and short-term must be transparent. If the quality of the supply base forming inputs is fatally weak, the quality of outputs may result in poor customer satisfaction or product liability litigation.

$$\text{R-SCR} = \frac{I_r \cdot C_a}{B_w + D_c}$$

Equation 3 : Real-Time Supply Chain Responsiveness

where

R-SCR = Real-Time Supply Chain Responsiveness

I_r = Inventory Reallocation Speed

C_a = Cloud Analytics Processing Rate

B_w = Bandwidth Constraints in Distribution Systems

D_c = Data Consistency Delay Across Platforms

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VI. CONCLUSION

The key findings of the study provide a great understanding of how Cloud Computing and Big Data Analytics affect Resilient Supply Chain Optimization. Cloud Computing has shed light on the issues of the trade-off between centralized and decentralized approaches. A major incentive for Cloud Computing deployment is the availability of scalable resources and more efficient analytic algorithms for Big Data. On the other hand, the major disincentive for Cloud Computing is the concern about the security of supply chain data hosted in the Cloud environment. Moreover, Cloud enables Supply Chain Analytics to be used by firms of any size. Among these advancements, Big Data Analytics affects supply chain management more positively than negatively. However, while Cloud Computing eases the deployment of these rapidly developing approaches and techniques for Big Data Analytics, more care needs to be exercised in using Cloud Analytics to alleviate the instability of services provided by Cloud Computing. To realize these and more similar advancements, strategic partnerships appear to be one of the promising directions. Future research may best address many of the directions presented in this study by modeling the developing issues of Cloud Computing and Big Data Analytics as theoretical models, conducting empirical studies, presenting illustrative cases, and developing relevant technologies.

The increased complexity of Supply Chain Management calls for responsible research to discover how to best manage supply chains for the common good. This study, although brief, illustrates how Cloud Computing and Big Data Analytics can be used in generating these appropriate strategies and policies for resilient Supply Chain Optimization. We hope that our research broadens the interests of researchers towards resilient Supply Chain Optimization leveraging Cloud Computing and Big Data Analytics, considering the multi-objective, multi-layer, and multi-stakeholder attributes considered in our study. In summary, consultants and practitioners need to become conversant with Cloud Computing and Big Data Analytics, as they can ease many challenges faced in Supply Chain Optimization, hopefully to the benefit of society.

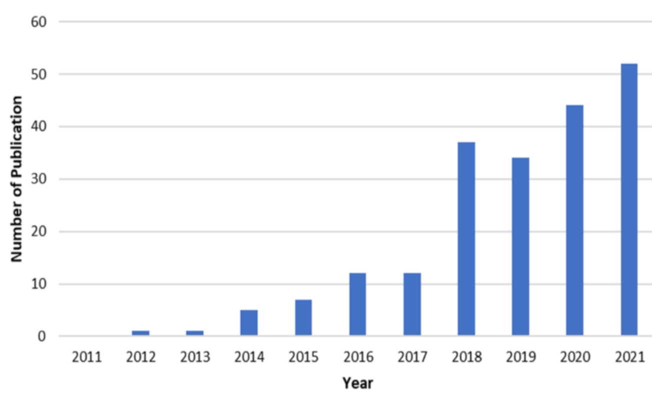

Fig 6: Big Data Analytics in Supply Chain Management

7.1. Summary of Findings and Future Directions

Supply chains are fundamental in channeling products and services from suppliers to customers. Therefore, companies will always seek to enhance their supply chain structures and operations to become a high-performance network. Today, technology plays a significant role in reshaping how supply chains operate. Emerging new risks such as the COVID-19 pandemic, climate change, geopolitical factors, and cyberattacks bring further uncertainty to supply chain operations. While companies invoke the abilities of new technologies to mitigate and grow resiliency against those risks, they also face challenges. Cloud computing and big data analytics are two key emerging technologies that have a deep impact on supply chain structure and performance. This essay explored the implications that applying cloud computing and big data analytics have on the development of resilient supply chains and proposed a research agenda to further guide the academic community toward new research avenues that can help develop better solutions and answers. This research agenda identifies some research ideas that can serve as guidance to any researcher inspired to follow these themes. The intention is not to claim that future researchers should exclusively follow this investigation directive but to provide a sound rationale and background of why these research ideas are relevant to the academic community and society.

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This has been conceived to stimulate researchers' interest in more studies regarding the themes of combined cloud computing and big data analytics technology usage in supply chain management. The majority of the ideas presented strive to understand and design solutions for the management of cloud-enabled supply chains, focusing on the optimization and control of these with the objective of increasing supply chain resilience. It can be concluded that, as with any new technology, the implementation of cloud computing and big data analytics in supply chains poses challenges and hurdles, but if well framed and crafted, new research avenues can help the entire society move toward a more resilient and efficient way of using natural resources.

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