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Big Data Analytics in Supply Chain Management: Applications and Challenges

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Abstract: **As competition in the business world is getting tougher, many businesses are confronted with the need to effectively manage increasingly supply chain activities beyond their boundaries. This paper is aimed at identifying the applications and challenges of big data analytics in supply chain management. It examined the big data analytics and its processes; supply chain management; big data analytics methods in supply chain management; applications of big data analytics in supply chain management; and challenges of apply big data analytics in supply chain management. The paper revealed that big data analytics has been applied in diverse areas of supply chain management for various tasks of both supervised and unsupervised learning for extraction of insights, patterns, and trends from varied data sources in different formats. Big data analytics has faced a lot of challenges such as complexity of analysis, data quality and integration; and complexity of supply chain considering that supply chain management cut across chain of entities and activities that are connected to one another. Hence there is need for an efficient supply chain data warehousing model for big data analytics for supply chain management that will effectively combine advanced analytics with accessible insights.**

Keywords: **Analytics Challenges and Applications, Big Data, Big data analytics, Data, Supply chain, Supply chain management.**

1. INTRODUCTION

With the technological advancements across the entities of supply chain, data generated is now increasing at a fast rate. The information flow was documented in terms of physical documents until the use of information technology in supply chain. Presently, the majority of the information flow linked to material flow is being documented in the form of digital structured data [1]. As the scope of supply chain is currently worldwide, the volume of data collected from its numerous processes and the velocity at which it is being generated in varied formats of structured, semi-structured and unstructured formats could be referred to as big data. Furthermore, entities such as product research and management, warehousing, production planning and control, sourcing risk management, order picking, logistics/transportation management, demand management, maintenance, and diagnosis are now relying on big data analytics of the unstructured data along with the structured data to gain insights to improve on the cost aspects of supply chain processes [2].

Managing the complexity in supply chain has been of importance to industries that compete in the global market as the complexity in supply chain management is associated with material and information flow between the different supply chain entities considering how information flows in this digital age [3]. Hence; the vast proliferation of data, increased customer expectations and the pressing desire to stay at the forefront of competition has prompted organizations to focus on using analytics for driving strategic business decisions. As a result, competition between companies and their supply

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chains takes the role of business rivalry. In today's competitive market, supply chain specialists are under pressure to manage enormous volumes of data in order to create an integrated, effective, efficient, and flexible supply chain data [4]. This paper therefore will specifically examine the applications and challenges of big data analytics in supply chain management.

2. BIG DATA ANALYTICS AND ITS PROCESSES

Big data, which is recognized by its large volume, diversity, truthfulness, velocity, and high value, has been introduced in the digital era with the expanding pace of data production. Big data has made it more difficult to analyze the data itself, which has forced businesses to adopt new analytical techniques and tools to deal with the complexity and volume of many data categories. Big data analytics is the study and extraction of important knowledge from very big and very complex databases [5, 6]. To find patterns, trends, correlations, and other pertinent information within the data, advanced analytical techniques including statistical analysis, data mining, machine learning, and predictive modeling are used.

In a bid to classify sources of big data across the supply chain into structured, semi-structured and unstructured with the velocity and volume of data generated from over 50 sources, [3] noted that data collected from transactions, RFID, Point of Sale (POS), sensors and social media were ranked highest among other sources for data generation and analytics with a rating of 87%, 42%, 41%, 43%, and 43% respectively.

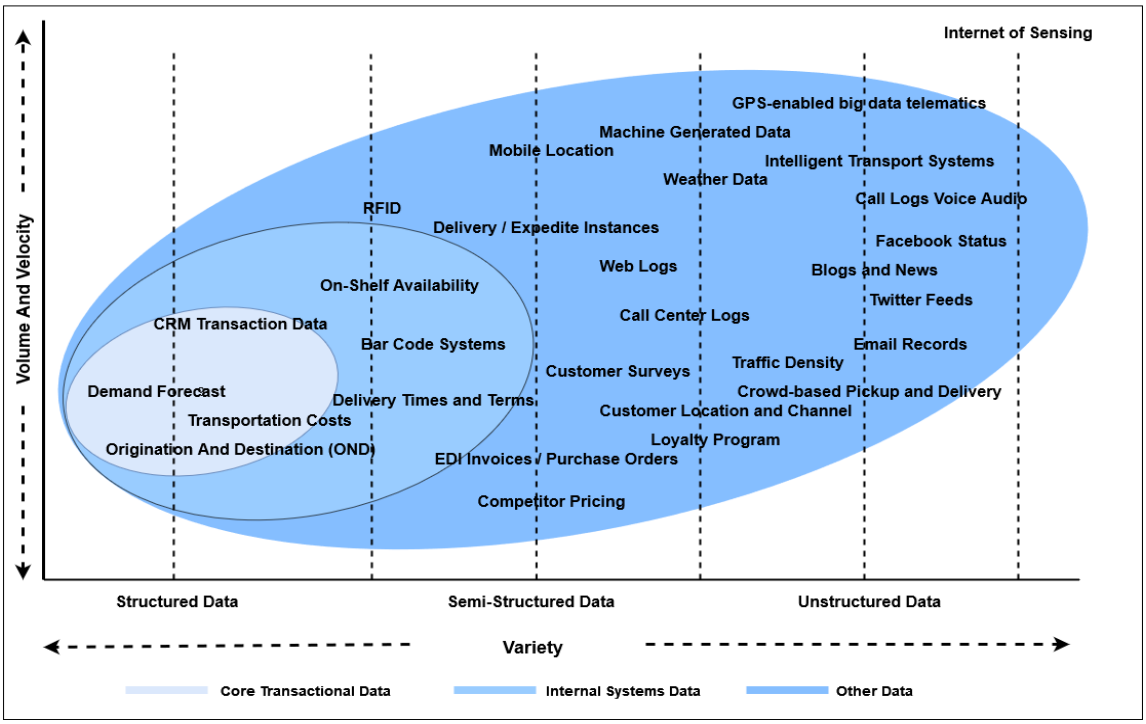

Figure 1: Classification and sources of data [3]

Data collection, storage, and management, data pre-treatment, exploratory data analysis, modeling and algorithm creation, and result visualization are just a few of the phases involved in big data analytics [7, 8, 9, 10]. To [11] big data analytic process typically involves the following stages: data collection, data storage, data processing, data analysis, data visualization, decision making, and continuous improvement. The big data analytics process is iterative, which means that as fresh data is gathered and insights are gained, it may need to be done several times. The procedure may also be altered to accommodate the unique requirements of various business and organizations. Big data analytics can be categorized into four namely [12]: Batch-oriented Processing (always used in time series forecasting when dealing with historical data and generating forecasts for future periods.); Streaming Processing (data is continuously streamed in real time and is evaluated as fast as feasible to produce approximations); Online Transaction Processing (OLTP) (data processing is concentrated on tasks that involve transactions, like online banking and the viewing and updating of customer information by call center agents; and Interactive ad-hoc Queries and Analysis (enables extremely low latency querying of many large scale data sources and query interfaces [13]

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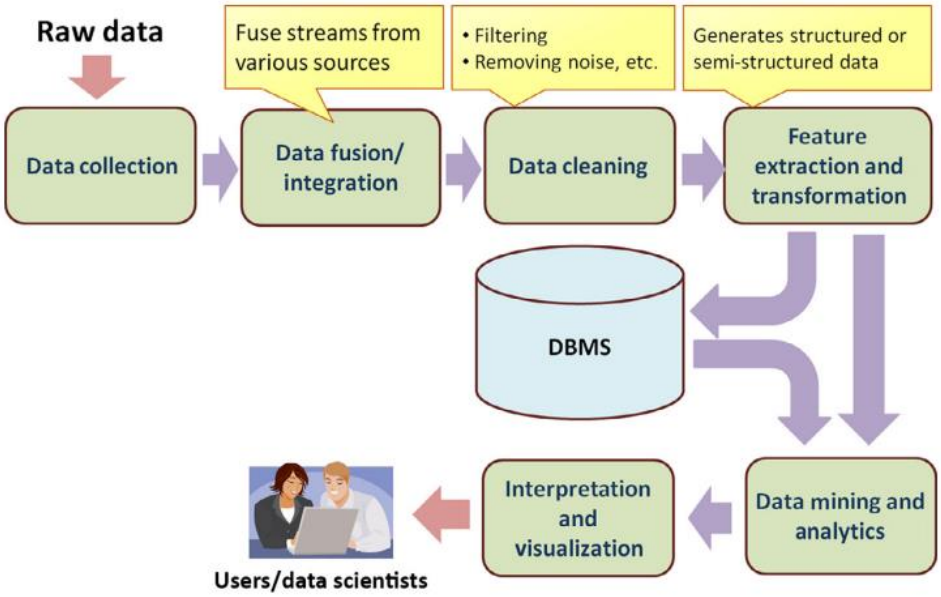

Figure 2: Flow in the process of big data

3. SUPPLY CHAIN MANAGEMENT

Supply chain can be considered as a combination of four independent yet interlinked entities namely: transportation, marketing, warehouse management, and procurement [3]. Supply chain management focuses on flow of goods, services, and information from points of origin to customers through a chain of entities and activities that are connected to one another [2]. The supply chain is made up of various businesses, ranging from producers and central organizations to wholesalers, retailers, customers, and end users. Information and financial flows are included in the supply chain in addition to the physical flows that involve the transfer of goods and commodities [14].

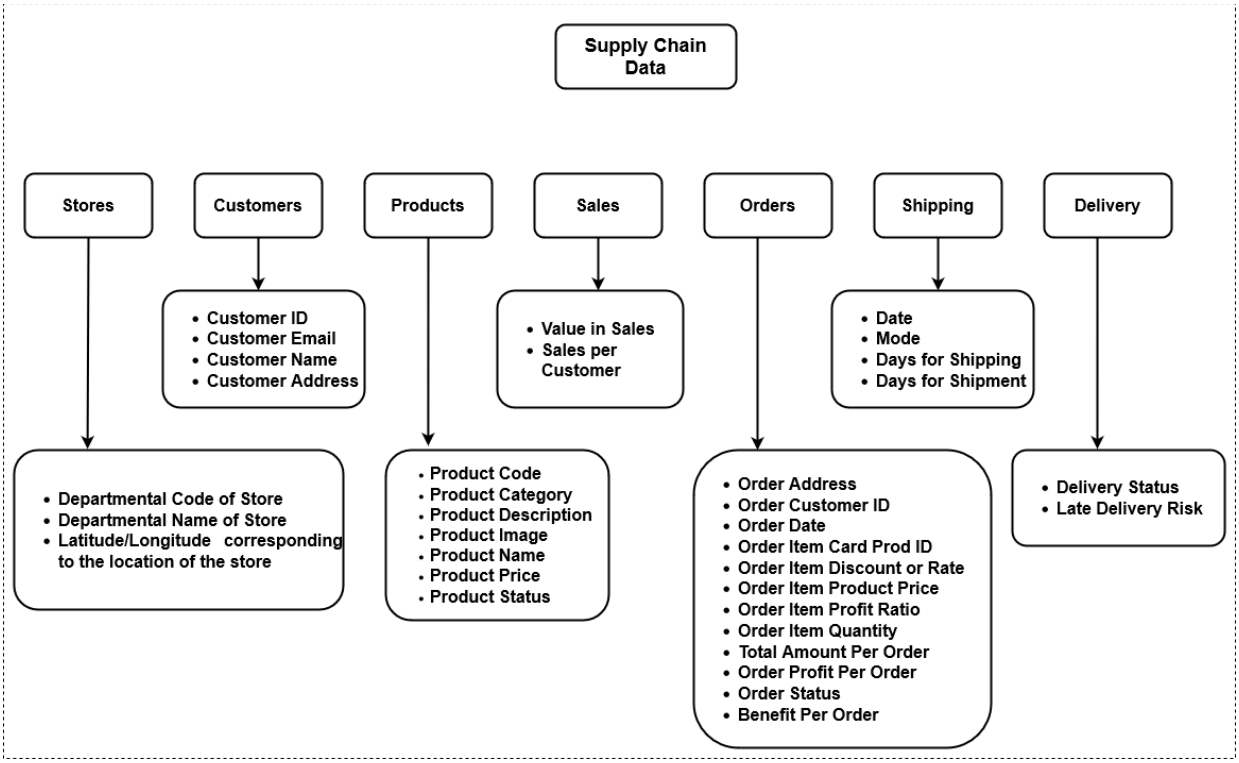

Figure 3: Taxonomy of supply chain data [2]

The characteristics of data in today's ever expanding and sporadic global supply chains has made the adopting of big data analytics and machine learning approaches a necessity in supply chain management. Supply chains are capturing enormous data volumes including varied amounts of unstructured data like videos, images, blogs, files, clickstreams and geo-spatial data, as well as data from sensors, devices, and social networks. Data in the context of supply chain can be categorized into customer, shipping, delivery, order, sale, store, and product data [15]. Supply chain data originates from different and segmented sources such as sales, inventory, manufacturing, warehousing and transportation [2]. There are multiple sources of big data across the supply chains with varied trade-offs among volume, velocity, variety, value and veracity attributes [1]. Thus the combination of data sources with their diverse temporal and spatial attributes places a greater emphasis on the use of big data analytics in supply chain management.

4. BIG DATA ANALYTICS METHODS IN SUPPLY CHAIN MANAGEMENT

Big data analytic approaches/models are complex algorithms and techniques used to extract insights, patterns, and trends from large datasets. They could be referred to as models that are designed to handle and process massive amounts of structured and unstructured data in real-time or near real-time. Big data analytics consist of predictive analytics, prescriptive analytics, and descriptive analytics [16]. Big data analytics consists of five different levels of analytics with each level having different role and desired outcome. The five levels of big data analytics are: descriptive analytics, diagnostic analytics, predictive analytics, prescriptive analytics, and cognitive/self learning analytics [17, 18, 19, 20, 21].

Descriptive analytics has been applied in a wide range of industries and contexts including: marketing, finance, healthcare, retail, sports, manufacturing and education. Some examples of prescriptive analytics include optimization of supply chain operations, fraud detection in financial transactions, demand forecasting, and personalized recommendations in e-commerce [2, 22] ; while Applications for cognitive/self-learning analytics include supply chain optimization, fraud detection, risk management, and customer relationship management [21).

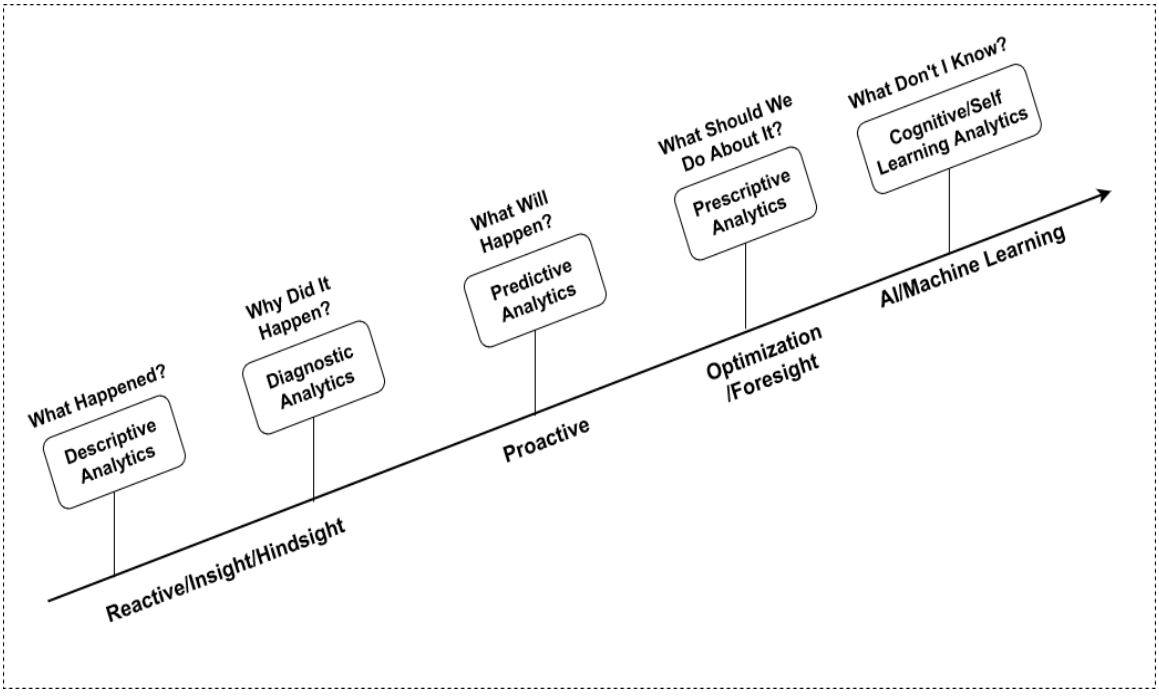

Figure 4: Big Data Analytic Models

5. APPLICATIONS OF BIG DATA ANALYTICS IN SUPPLY CHAIN MANAGEMENT

The big data analytics applications in supply chain management have been reported in both categories of supervised and unsupervised learning [23]. In supervised learning, data will be associated with labels where the inputs and outputs are known [24]. In unsupervised learning, data are unlabeled with unknown output, while big data analytics algorithms try to find the underlying patterns among unlabeled data by analyzing the inputs and their inter-relationships [25].

Big Data analytics can boost the efficiency and effectiveness of supply chain management by enhancing demand management, accelerating the development of new products, improving supplier management, reducing supply chain risk, and developing dependable and efficient supply chain designs. [26] noted that utilizing big data and big data analytics in a supply chain helps firms to function with goals of improving in areas like risk management, prediction of customer needs, reaction time, assessment of supply chain, and efficiency of the overall supply chain.

Big data analytics has reportedly been used more and more in supply management for tasks including order picking, warehousing, logistics planning, product research and development, demand management, demand shipping, procurement management, and sourcing risk management, among others [2]. Big data analytics has been applied in all stages of supply chains such as warehousing, finance, healthcare, manufacturing, procurement, sales management, and logistics/ transportation. [27, 28] identified the following as areas in supply chain analytics: demand management, inventory optimization, warehouse management, order fulfillment, supplier performance analytics, cost analysis, risk management, and performance metrics.

Accurate forecasting with the intention of minimizing the bullwhip effect is the primary use of big data analytics in supply chain management [29]. Supply chain analytics covers a wide range of areas, each contributing to a more informed and optimized supply chain. Big data analytics can be applied in the following supply chain management areas:

Demand Management

Demand management involves predicting future using historical data and market trends. Demand management helps to find out new market trends and root causes of failures and defects, hence one can analyze the requirements from the customer's point of view and proceed according to the needs of customers [28]. Accurate demand prediction has always been a major challenge in supply chain management; tracing consumer loyalty, demand signal, and optimal price can be determined by big data analytics [30, 31]. Incomplete orders can damage the image of every organization, to maintain customer relationship, there is need to offer the right product to the right persons. Through predictive analytics firms can figure out how likely an issue is to arise and what impact it could have.

Logistics and transportation Optmization: Big data analytics has been used to optimize transportation routes, modes of transport, and warehouse locations based on traffic patterns, customer locations among others. Big data analytics have been used to share transportation capacity in health care services [32], and to solve planning problems in maritime industries [33].

Supplier Relationship Management: Big data analytics enable firms to assess supplier performance based on various metrics like quality, pricing, reliability and delivery times. Supplier relationship management relies on big data analytics and machine learning for evaluation, audits, and assessment. Big data analytics has been reported as a technique that can help in providing accurate information on a firm's spending pattern that help manage supplier relationships , return on investment and in-depth analysis of potential supplier [30], and supplier evaluation [34]

Predictive Maintenance: Big data analytics has revolutionized predictive maintenance across various firms by enabling firms to proactively monitor equipment health, optimize maintenance practices, enhance safety, reduce costs, and make data driven decisions to improve overall asset reliability and performance.

Inventory Management

Inventory management system involves requisition process, inventory management, purchase and physical inventory reconciliation. Inventory control is a critical aspect of supply chain management, and is mainly designed to ensure that an organizations inventory is managed efficiently to meet customer demand as well as minimize costs. The objectives of inventory management include: accurate demand prediction, optimal stock levels, minimizing holding costs, customer satisfaction, preventing stock outs, efficient order fulfillment: Streamlining order fulfillment process to ensure that customer orders are processed quickly and accurately by optimizing picking and delivery operations, avoiding stock outs, data accuracy and visibility, and risk management [30, 35].

Quality Control: Big data analytics enables firms to develop risk mitigation strategies by analyzing diverse sources of data to identify potential risks to the supply chain.

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6. BIG DATA ANALYTICS CHALLENGES IN SUPPLY CHAIN MANAGEMENT

Big data analytics, which are seen to be the most crucial stage in big data application processes, face a number of difficulties that make them far more challenging and complex than small data analytics [36]. Big data analytics is the process of examining large and complex data sets to extract insights, patterns, and trends that can help businesses make informed decisions. Massive data build-up has recently emerged as a barrier to the development of successful data-driven businesses and decision-making processes [37, 36].

Big data analytics for industries that rely on data face inherent difficulties, these difficulties include data cleaning and aggregation, scalability in data storage systems, complexity of data, privacy and security, infrastructure readiness, and big data management, among others [9, 38]. To [16] the major challenges of big data analytics are: complex data representation, super- high dimensionality, non-scalable computation ability, and ubiquitous uncertainty. Big data analytics faces many challenges, including how to efficiently collect, integrate, and store massive amounts of data while requiring less infrastructure and software. The enormous volume of data and streaming data [39], are the two largest barriers to big data analytics.

However, big data analytics also poses several challenges. Here are some of the key challenges of big data analytics in supply chain management:

i. Data Explosion: Managing the vast amount of data generated by supply chain can strain infrastructure and analytical tools [40].

ii. Data Quality and Integration: Ensuring that data from various sources are clean, consistent, and integrated is a significant challenge in supply chain analytics [38]; considering that may come from various sources and in varied formats.

iii. Complexity of Supply Chain: Supply chains are highly complicated as it involves multiple suppliers, distribution centres, transportation and regulations.

iv. Achieving simplified deployment and management in big data systems can be complex, costly and difficult.

v. Scalability: Managing and analyzing the massive volume of data generated in supply chain in real time is very challenging. Hence; scalability is important in handling the increasing data volume efficiently.

vi. Complexity of Analysis: Analyzing the multi-dimensional and complex supply chain data may be challenging as it requires sophisticated algorithms and model in order to generate meaningful insights; integrate data analysis into decision making process; as well as translating insights into actionable strategies.

vii. Data Security and Privacy: Considering that supply chain data contains sensitive information; ensuring data security, compliance with regulations, and privacy may be challenging as data will be shared across multiple stakeholders involved in supply chain management.

viii. Predictive Analytics: Predicting future demand, disruptions, and market trends is critical for proactive decision-making in supply chain management. However, building accurate predictive models requires historical data, domain expertise, and advanced analytics techniques.

7. CONCLUSION

In recent years big data analytics has emerged as an interdisciplinary field that combines statistics, machine learning, data mining, and analytics to understand and explain how analytical insights and prediction models can be generated from structured and unstructured big data. Big analytics has been applied in supply chain management in various areas, serving different sectors. It has been useful in predictive maintenance, warehousing, logistics and transportation optimization, supplier relationship management, quality control, demand management and risk management. Big data analytics faces many challenges in handing big datasets associated with supply chain management. Such challenges as identified in the study include data explosion, data quality and integration, data security and privacy, complexity of analysis, scalability, and complexity of supply chain. Hence, there is need for an efficient supply chain data warehousing model for big data analytics for supply chain management. It is hoped that this study on big data analytics and supply chain management will be used as a reference guide for potential research and applications for decision makers, industry, academia, professionals and society at large

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