Chapter

Big Data Analytics and Its Applications in Supply Chain Management

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Abstract

In today's competitive marketplace, development of information technology, rising customer expectations, economic globalization, and the other modern competitive priorities have forced organizations to change. Therefore, competition among enterprises is replaced by competition among enterprises and their supply chains. In current competitive environment, supply chain professionals are struggling in handling the huge data in order to reach integrated, efficient, effective, and agile supply chain. Hence, explosive growth in volume and different types of data throughout the supply chain has created the need to develop technologies that can intelligently and rapidly analyze large volume of data. Big data analytics capability (BDA) is one of the best techniques, which can help organizations to overcome their problem. BDA provides a tool for extracting valuable patterns and information in large volume of data. So, the main purpose of this book chapter is to explore the application of BDA in supply chain management (SCM).

Keywords: big data, analytics, supply chain analytics, manufacturing, finance, healthcare, demand planning, procurement management, customized production, inventory management

1. Introduction

Big data are characterized as the gigantic or complex sets of data, which usually encompass extend of more than exabyte. It outstrips the traditional systems with limited capability in storing, handling, overseeing, deciphering, and visualizing [1]. Nowadays, data are expanding exponentially and are anticipated to reach zettabyte per year [2]. The scholarly world and professionals concur that this surge of data makes modern opportunities; subsequently, numerous organization attempted to create and upgrade its big data analytics capabilities (BDA) to reveal and gain a higher and deeper understanding from their big data values. The study of big data is persistently advanced and extended, and the most properties of big data are presently extended into "5 V" concept containing variety, verification/veracity, velocity, volume, and value [3, 4]. Akter et al. recommended BDA as one of the most important factors affecting organizational performance [5]. By progressing BDA, organizations could make better understanding from their customer's needs, provide suitable service to satisfy their needs, improve sales and income, and penetrate into new markets. Several research studies indicated the big data applications in various sectors such as financial services sector, marketing, bank industry, insurance industry, logistics, and manufacturing [6]. However, the present book chapter indicates the benefits of big data application in extracting new insights and creating new forms of value in ways that have influenced supply chain relationships. Regarding this purpose, first, the authors defined the key concepts of BDA and its role in predicting the future. Second, the authors paid to the role of statistical analysis, simulation, and optimization in supply chain analytics. Third, the authors had a review on application of BDA in supply chain management areas. Forth, the authors provided a brief information about application of BDA in different types of supply chain. Fifth, the authors presented some insight into future application of BDA in supply chain, and lastly, the book chapter ends with the conclusion, some managerial implications, and recommendations for future research.

2. BDA capabilities

To fully understand the impact and application of BDA, we first need to have a clear understanding of what it actually is. As a simple definition, big data refer to large quantity of data. Big data specifically refer to large data sets whose size is so large that the quantity can no longer fit into the memory. These data can be captured, stored, communicated, aggregated, and analyzed. As the volume of data has grown, the need to revamp the tools has used for analyzing it. These data do not ought to be set in neat columns and rows as traditional data sets to be analyzed by today's technology, not at all like within the past. Big data appear completely in different kinds of data. They incorporate all types of data from every possible source. They can be structured, semi-structured, or fully unstructured. As another categorization, big data consist of numerical data, image data, voice, text, and discourse. They can come in the form of radio-frequency identification (RFID), global positioning system (GPS), point-of-sale (POS), or they can be in the frame of Twitter feeds, Instagram, Facebook, call centers, or customer blogs. Today's progressed analytical technologies empower us to extract knowledge from all kinds of data. Analytics is a mix of math and statistics to large quantities of data. BDA mean using statistics and math in order to analyze big data. Big data without analytics are just lots of data. The authors have been accumulating a lot of data for years. Analytics without big data is simply mathematical and statistical tools and applications. Companies can extract intelligence out of these huge amounts of data. This is made possible through today's massive computing power available at a lower cost than ever before. However, combining the big data and analytics makes the different tools that help decision makers to get valuable meaningful insights and turn information into business intelligence.

3. Supply chain analytics

The supply chain is the number of firms from raw material suppliers to producer/central organization, wholesalers, retailers, customers, and end users. The supply chain not only includes physical flows involving the transfer of materials and products but also consists of information and financial flows. Supply chain analytics (SCA) means using BDA techniques in order to extracting hidden valuable knowledge from supply chain [7]. This analytics can be categorized into descriptive, predictive, and prescriptive analytics [7, 8]. Well-planned and implemented decisions contribute directly to the bottom line by lowering sourcing, transportation, storage, stock out, and disposal costs. Hence, using BDA techniques in order

Category	Features
Descriptive Analytics What happened and	• Foundational • Filters big data into useful nuggets and interpretable information • Provides a historical summary of what happened in the past • Focus on minimizing bias Example: providing historical insights regarding the company's production, financials, operations, sales, finance, inventory, and customers.
Predictive Analytics What might happen?	• Insightful • What-if analysis • Forecasting supply chain requirements • Focus on minimizing the combined bias and variance Example: Analyzing past trends to estimate future needs, supply and demand, set accurate delivery time and etc.
Prescriptive Analytics What should we do?	• Strategic • Scenario and knowledge based • Optimization and automation of decisions Example: optimizing production, scheduling and inventory.

Table 1.
Features of descriptive, predictive and prescriptive analytics.

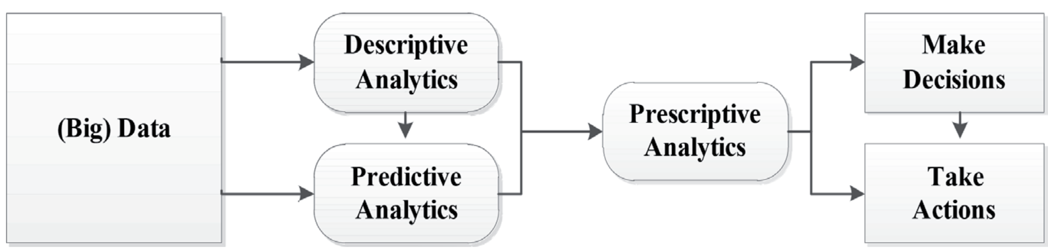

Figure 1.
Using descriptive, predictive and prescriptive analytics to make decisions and take actions.

to solve supply chain management problems has a positive and significant effect on supply chain performance. For a long time, managers and researchers have used statistical and operational research techniques in order to solving supply and demand balancing problems [8, 9]. However, recent progress in the use of analytics has opened new horizons for managers and researchers. The summary of the challenges and features of the three types of analytics is shown in **Table 1**. Also, the relationships among descriptive, predictive, and prescriptive analytics to make decisions or take actions are shown in **Figure 1**.

The different potential advantages that can be achieved utilizing data-supported decision making have incited academicians and researchers to pay attention to the possible integration of big data in SCM. This has resulted in the number of scholarly articles on this topic, which has risen precipitously in recent years. The importance of using BDA techniques in SCM is true to an extent that organizations will not stand a chance of success in today's competitive markets. Since 2010, numerous articles have been published, which emphasized on the application of BDA in SCM and their major achievements [2, 3, 10–13]. Since 2011 to 2015, Mishra et al. identify the influential and prominent researchers and articles with most citations carried out a bibliographic analysis of big data. The results indicated that the number of articles in the field of BDA has increased [14]. Barbosa et al. conducted a systematic literature review to investigate the application of BDA in SCM areas. The results indicated that BDA techniques usually use the predictive and prescriptive approaches rather than descriptive approach [10]. Dubey et al. carried out a research in order to identify the effects of big data and predictive analysis on two aspects of sustainability, including environmental and social aspects. Data were collected from 205 manufacturing companies, and using structural equation modeling based on partial least square was analyzed. The results indicated that big data have a positive and significant effect on social and environmental components of sustainability [15]. Gupta et al. carried out a systematic literature review based on 28 journal articles to investigate the impact of using BDA techniques on humanitarian SCM [16]. Gupta et al. investigated the applications of big data in the context of humanitarian SCM based on 28 journal articles. They proposed some important future research directions based on key organization theories such as complexity theory, transaction cost economics, resource dependence theory, resource-based view, social network theory, institutional theory stakeholder theory, and ecological modernization theory. Zhao et al. proposed a multiobjective optimization model for green SCM using BDA approach. They considered three different scenarios for optimizing the inherent risk associated with hazardous materials, carbon emission, and overall costs. They utilized a big data approach to acquire data and manage their quality [17]. Song et al. studied the problems and challenges arising due to big data in the context of environmental performance evaluation along with summarizing latest developments in environmental management based on big data technologies [18].

- In descriptive analysis, the following questions are answered:

What has happened, What is happening, and Why, In this process, visualization tools and online analytical processing (OLAP) system are used and supported by reporting technology (e.g. RFID, GPS, and transaction bar-code) and real-time information to identify new opportunities and problems. Descriptive statistics are used to collect, describe, and analyze the raw data of past events. It analyzes and describes the past events and makes it something that is interpretable and understandable by humans. Descriptive analytics enables organizations to learn from their past and understand the relationship between variables and how it can influence future outcomes. For example, it can be used to illustrate average money, stock in inventory, and annual sale changes. Descriptive analytics is also useful to an organization's financials, sales, operations, and production reports.

- Predictive analytics techniques are used to answer the question of what will happen in the future or likely to happen, by examining past data trends using statistical, programming and simulation techniques. These techniques seek to discover the causes of events and phenomena as well as to predict the future accurately or to fill in the data or information that already does not exist. Statistical techniques cannot be used to predict the future with 100% accuracy. Predictive analytics is used to predict purchasing patterns, customer behavior and purchase patterns to identifying and predicting the future trend of sales activities. These techniques are also used to predict customer demands, inventory records and operations.

- Prescriptive analytics deals with the question of what should be happening and how to influence it. Prescriptive analytics guides alternative decision based on predictive and descriptive analytics using descriptive and predictive analytics, simulation, mathematical optimization, or multicriteria decision-making techniques. The application of prescriptive analytics is relatively complex in practice, and most companies are still unable to apply it in their daily activities of business. Correct application of prescriptive analytics techniques can lead to optimal and

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efficient decision making. A number of large companies have used data analytics to optimize production and inventory. Some of the crucial scenarios that prescriptive analytics allows companies to answer include in the following:

a. What kind of an offer should make to each end-user?

b. What should be the shipment strategy for each retail location?

c. Which product should launch and when?

Statistical analysis, simulation, optimization, and techniques are used to supply chain decision making [19].

3.1 Statistical analysis

Statistical analysis basically consists of two types of analysis: descriptive and inferential. In descriptive statistics, past data are used to describe or summarize the feature of a phenomenon; it uses either graphs or tables or numerical calculations. Inferential statistics are used to deduce the properties of phenomena and predict their behavior based on a sample of past data. **Table 2** shows differences between descriptive and inferential analyses. Both quantitative and qualitative methods can be used simultaneously to take the advantage of both the methods and the right decisions. Statistical analysis is used when faced with uncertainty, such as in distribution, inventory, and risk analysis. Statistical multivariate techniques are also used for supply chain monitoring to effectively manage the flow of materials and minimize the risk of unintended situation [20]. Given the volume, variety, veracity, and velocity of big data, the supply chain needs robust and easy techniques for analysis. Traditional statistical methods are no longer responsive because the massive data lead to noise accumulation, heterogeneity, and so on. Therefore, proposing and applying effective statistical methods are very important, and major attention has been paid to this issue recently. For example, in a research, a parallel statistical algorithm is presented to do a sophisticated statistical analysis of big data. This algorithm uses specific methods such as Mann-Whitney *U* testing, conjugate gradient, and ordinary least squares to model and compare the densities and big data distribution squares [2].

3.2 Simulation

Manufacturers need simulation tools to optimize the product development process and increase the creativity, speed the time-to-market product, reduce the production costs, and create the innovation. Simulation provides many proven benefits for

Basis for comparison	Descriptive statistics	Inferential statistics
What it does?	Organizing, analyzing, and presenting data in meaningful way	Comparing, testing, and predicting data
Form of final result	Charts, Graphs, and Tables	Probability
Usage	To describe the current situation	To explain the chances of occurrence of an event
Function	It explains the data that are already known to summarize	It attempts to reach the conclusion to learn about the population that extends beyond the data availability

Table 2.
Comparing descriptive and inferential analyses.

each stage of the product design and manufacturing process, for example, producing more innovative products with greater efficiency for the customer and creating a better experience for them [21]. For example, when consumer goods giant Proctor & Gamble develops new dishwashing liquids, they use predictive analytics and modeling to predict how moisture will excite certain fragrance molecules, so that the right scents are released at the right time during the dishwashing process. Modeling and simulation techniques should be used to develop the application of large data, for example, simulation-driven product design. In today's competitive environment, the use of simulators to produce innovative products is considered a challenge. Because manufacturers have to continually drive their operational efficiencies, meet the cost, require the time-to-market product, and predict the customer preferences.

Modeling and simulation help developer to run the "what-if" analysis under different system configuration and complexity [22]. Shao et al. developed a simulation model to analyze the huge data collected from the surrounding and shop floor environment of a smart manufacturing system. This model improved the decision making in this production system [23]. For example, as a predictive tool, simulation can help the manufacturers to predict the need for machines and additional equipment based on customer order forecast and learning from other historical data such as cycle time, throughput, and delivery performance. LLamasoft [24] outlined some examples of where supply chain simulation can be used as follows: predicting the service, testing the inventory policy, analyzing the production capacity, determining the asset utilization, and validating the optimization result. SCA provides new methods for the simulation problem with a large amount of data. Nowadays, there are several simulation software that allow to evaluate the performance of a system before its creation. Enterprise dynamics (ED) is one of the strongest and most used software that researchers and practitioners use it to simulate SCM issues.

3.3 Optimization

The optimization technique is a powerful tool for supply chain data analytics [25]. Optimization techniques by extracting the insights and knowledge of the enormous data generated by complex systems that include multiple factors and constraints such as capacity and route can analyze multiple objectives such as demand fulfillment and cost reduction. Finally, using supply chain optimization techniques along with multiuser collaboration, performance tracker, and scenario management enables organizations to achieve their different goals. The use of optimization techniques supports supply chain planning and also increases the accuracy of planning but presents the large-scale optimization challenge [7]. Slavakis et al. [26] have used several signal processing and statistical learning techniques to analytic optimization, principal component analysis, dictionary learning, compressive sampling, and subspace clustering. Based on SCOR supply chain model, Souza explored the opportunities for applying BDA in SCM [8]. BDA play a critical role at all operational, tactical, and strategic levels of the supply chain; for example, in the strategic level, SCA is used for product design, network design, and sourcing; in the tactical and operational levels, SCA can also be used for procurement, demand planning, logistics, and inventory.

4. Application of BDA in SCM areas

In the production department, a large amount of data is generated by external channels and also by internal networks that contain sensor networks or instrumentation on the production floor. Using big data to tighter analysis and integration of these databases, it can improve the efficiency of the distribution and sales process and the continuous monitoring of process and devices. Manufacturing companies need to use big data and analytics techniques to grow their manufacturing sector. Predictive maintenance of equipment is an immediate segment in this sector ripe for growth. Due to the large number of vendors, as well as the variety of their evaluation and selection indicators, the process of selecting the right and optimal vendor for the supply chain is difficult. Applying Cloud Technologies to selecting vendors is making a big impact. With new systems, access and exposure to data are more intuitive and customer focused with the power of APIs and integration to modern big data applications and analytic packages. A review in the literature indicates that BDA can be used in several areas of SCM. In the following sections, an overview of BDA applications in different areas of supply chain is provided [27].

4.1 BDA and supplier relationship management

Supplier relationship management involves establishing discipline in strategic planning and managing all interactions with organizations' suppliers in order to reduce the risk of failure and maximize the value of these interactions. Establishing close relationships with key suppliers and enhancing collaboration with them are an important factor in discovering and creating new value and reducing the risk of failure in SRM. Strategic resources and supplier relationship management (SRM) are the success factors of organizations, which focus on relationship management and collaboration. Using BDA techniques can provide accurate information on organizational spending patterns that help manage supplier relationships [28]. For example, big data can provide accurate information on the return on investment (ROI) of any investment and in-depth analysis of potential supplier. In a study, fuzzy synthetic evaluation and analytical hierarchy process (AHP) were used to supplier evaluation and selection, given the high capacity of big data processing as one of the evaluated factors has been used [29]. The objective is to select supply partner that can adapt to the future challenges from big data.

4.2 BDA and supply chain network design

Supply chain design is a strategic decision, which includes all decisions regarding the selection of partners of the supply chain and defines company policies and programs to achieve long-term strategic targets. Supply chain network design project involves determining supply chain physical configuration that affects most business units or functional areas within a company. In designing the supply chain network, it is important to determine the customer satisfaction and supply chain efficiency. The purpose of supply chain design is to design a network of members that can meet the long-term strategic targets of the company. When designing a supply chain, the following steps must be followed: (1) define the long-term strategic targets; (2) define the project scope; (3) determine the form of analyses to be done; (4) the tools that will be used must be determined; and (5) finally, project completion, the best design.

Selecting the optimal supply chain design and appropriate planning, the company will achieve a significant competitive advantage. Wang et al. (2016b) proposed a mixed-integer nonlinear model for locating the distribution centers, utilized big data in this model, and randomly generated big datasets applied for warehouse operation, customer demand, and transportation. They assumed that the behavioral dataset has been analyzed using marketing intelligence tools. Their findings show that big data could provide all the necessary information about penalty cost data and service level; therefore, it is a very powerful tool for complex distribution network design [30]. A study investigates the application of BDA in design intervention such as healthcare, disaster relief, and education in supply chain [31]. Since humanitarian data have the characteristics of high volume, high diversity, accuracy, and speed, BDA can be used in the humanitarian supply chain.

4.3 BDA and product design and development

One of the major concerns of adaptable product manufacturers is ensuring that these products conform to their customers' preferences. As customers' preferences and expectations change throughout the product lifetime, designers need tools to predict and measure those preferences and expectations. Lack of enough information about customers' preferences and expectations is an important issue in the product design process. If designers continuously monitor customer behavior and access up-to-date information on customer preferences, they can design products that meet customer preferences and expectations. Continuous monitoring of customer behavior, product design, and manufacturing process generated huge data that are considered as big data. Collecting, managing such huge data, and applying new analytical methods to gain insights and useful information and then apply them to decisions can reduce uncertainty [32]. Engineering design is defined as a process of transforming customer needs into design specifications [33]. Data science (DS) is defined as a process of transforming observed world reality data into comprehensible information for decision making [34]. Although different approaches are available for product design [35, 36], all of these methods are common in DS perspective. A schematic view of the design process is shown in **Figure 2**.

Big data are going to impact many industries, and product design is no exception. That is in part because engineers will increasingly design sensors and communication technology into their products. Therefore, in the process of supply chain design, the product specificities of the company must be considered, and all partners and constraints of the supply chain must be integrated at the design stage [37]. Supply chain design according to product design creates competitive advantage and flexibility in the supply chain [38]. Recently, BDA techniques have been used for product design and development, which lead to the production of new products according to customer preferences. Applying BDA to product design enables the designer to be constantly aware of customer preferences and expectations that lead to produce a product according to their needs and preferences [32]. Designers can use online behavior and customer purchase record data to predict and understand the customer needs [39]. Designers can identify product features and predict future product trends by continually monitoring the customer behavior and informing the customers' opinions and needs. In the automotive industry, the importance of big data is derived from the vehicle that shows huge performance data and customer needs [40]. The ultimate goal of companies producing consumer durables is to maintain their competitiveness over the longest possible period [41]. Nowadays, this is facilitated the implementation

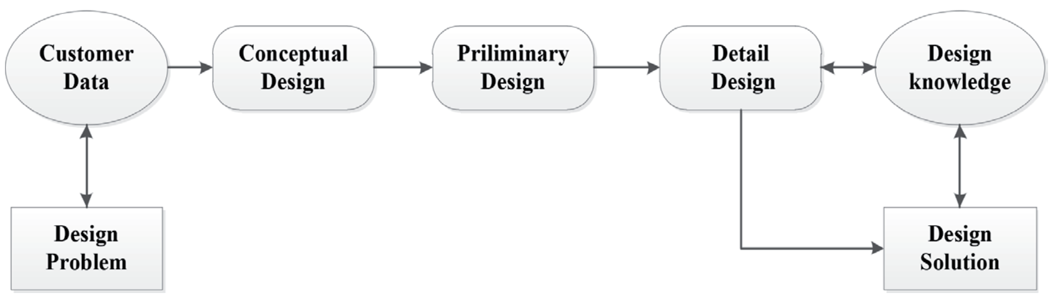

Figure 2.
Design process from data science view [32].

of the concept of (run-time) data-driven design. The recent developments of data analytics and application of data analytics tools have opened up a new path for generating knowledge for product enhancement and achieving their objectives [42]. As one doctrine, product developers can achieve a perpetual enhancement of their products and services based on real-life use, work, and failure data. Though numerous data analytic (software) tools and packages have been developed for extracting product-associated data, exploiting data analytic methods and tools in product enhancement is still in a rather premature stage [43]. Designers still face many challenges and should consider many limitations. Reportedly, choosing the most relevant data analytic tools (DATs) and using them in design projects are not trivial for designers [44].

Here are some other ways the design engineering might change as a result of big data it enables:

- Better-informed product development: How would the way organizations design product's change if they could learn not only how customers are using them, but also where they are having trouble with them and what features they are ignoring altogether? That information is going to be available to organizations soon. Mechanical engineers have the opportunity for product insights that were never possible before. With an Internet of Things (IoT)-enabled device, products can stream usage data back to engineers. Imagine, for example, a bike fork that captures force measurements or a utility cabinet that transmits internal temperature readings.

- More empowered engineering: Traditionally, engineers rely on marketers, customer visits, or their own best guesses to design the competitive products. However, big data could provide volumes of reliable feedback that none of those channels offer. Products are generating a lot of information during their lifecycle, and new trends for Internet of Things will bring even more information to manufacturing companies. A tremendous amount of data will be collected from connected devices, and this can be transformed into consumable information assets. Because products will be able to talk back to engineers, engineers will be empowered like never before to have a direct impact on the competitiveness of their products.

- Faster product development: As much more data reside on the cloud, more people can securely reach information faster (and at a lower cost) compared to working within corporate networks and specific platforms. That may lead to more participants and disciplines involved in the product development cycle early on. The IT infrastructure of cloud computing will enable new approaches for concurrent CAD design and system engineering principles combining mechanical, electrical, and software in product development.

Concluding with all these different disciplines in product design connected and accessing the big data throughout the various phases of the design cycle, the engineers will be confronted with many surprises and few unpleasant shocks as well. The real challenge will lie in solving these minute hassles and in developing better products reaching a new level in the product design as a whole.

4.4 BDA and demand planning

Many supply chain executives are keen to improve demand forecasting and production planning with big data [45]. Accurate demand forecast has always been a major puzzle in SCM [46]. Trace consumer loyalty, demand signal, and optimal price data can be determined by BDA. However, one of the challenges the organizations face is the ability to apply advanced hardware and software and algorithm architecture [47]. BDA allow to identify new market trends and determine root causes of issues, failures, and defects. Data analytics can predict customers' preferences and needs by examining customer behavior, which can drive creativity and innovation in business services [48]. In one study, a model was presented to predict the electric vehicle charging demand that used weather data and historical real-world traffic data. This model enables operators to plan the generation profiles and operation by determining the charging demand [49]. Another study presents a model for predicting demand for air passenger demand, which uses big data to estimate air passenger demand. The results of this study show a 5.3% prediction error [50].

4.5 BDA and procurement management

As tactical and operational decisions, procurement consists of a series of action mechanism and contracting [8]. Logistic organizations, given the high volume of widely dispersed data generated across different operations, systems, and geographic regions, need advanced systems to manage these enormous data, as well as skilled professionals who can analyze these data, and extract valuable insights and knowledge into them in order to apply them in their planning and decisions. In the past, organizations faced laborious processes that took several weeks to gather internal and structural data from the operations and transactions of the company and its partners. But today, at a significant speed, in real time, in many cases, all of the diverse structural, nonstructural, internal, and external data generated from automated processes are made available to these organizations. SCA can be used to manage suppliers' performance and supply chain risk [7]. In one study, external and internal big data have been used to quickly identify and manage the supply chain risk [51]. For example, informing the social media and news about exchange rate movement and disasters affects the supply chain. Applying this framework to identify supply chain risk enables real-time risk management monitoring, decision support, and emergency planning. Schlegel [52] also provided a big data predictive analytic framework to identify, evaluate, mitigate, and manage the supply chain risk.

4.6 BDA and customized production

With BDA, manufacturers can discover new information and identify patterns that enable them to improve processes, increase supply chain efficiency, and identify variables that affect production.

In today's global and interconnected environment, the supply chains and manufacturing processes involve long and complex processes; it should be possible to examine all components of each process and link supply chain in granular detail to simplify the processes and optimize the supply chain. Data analytics enables manufacturers to accurately determine each person's activities and tasks through timely and accurate data analysis of each part of the production process and examine entire supply chain in detail. This ability enables manufacturers to identify bottlenecks and reveal poorly performing processes and components. In the past, centralized production and production at scale were not rational because they focused only on the ordering of a small group of customers, while today's BDA have made it possible to accurately predict customer demands and tastes for customized products. Some studies have investigated the applied techniques of BDA in the production area. For example, Zhong et al. applied RFID-enabled big data to support shop floor logistic planning and scheduling [53]. He then implemented the Physical Internet concept by using the Internet of Things, wireless technology, and BDA to create an RFID-enabled intelligent shop floor environment [54]. Stich et al. have used BDA techniques to predict demand and production levels in manufacturing companies [55]. On the other hand, early additive manufacturing (also called 3D printing) was developed in the 1980s. This new technologies and trends are emerging that will change the rules of supply chain design and management [56]. 3D printing is any of various processes in which material is joined or solidified under computer control to create a three-dimensional object [57]. 3D printing is an innovative technology that makes possible to create a physical object from a digital model. Understanding the uses and implications of big data and predictive analytics will be urgent as additive manufacturing makes traditional models of production, distribution, and demand obsolete in some product areas [58].

4.7 BDA and inventory management

Inventory control is the system that involves requisition process, inventory management, purchase, and physical inventory reconciliation. The following key objectives define the design of inventory control:

- informing the quantity of goods in warehouse and also the amount of goods needed in the warehouse;
- facilitating the requisition process to finish in time;
- automatic recording and backorder serving;
- minimizing the inventory by analyzing previous purchasing and consumption patterns of the organization;
- using the automated tools to facilitate management of the inventory, servicing, and purchasing; and
- improving the financial control of the inventory through a timely and regular checkup of the inventory balances with the physical counts.

Big data by integrating business systems in distribution of nonperishable products improve operational efficiency on a broad scale while also delivering greater profitability. The benefits of using BDA in supply chains are listed below. Below are some ways the big data are changing the way companies manage inventory. Following are a few examples of ways big data manage inventory.

Improved operational efficiency: Due to the possibility of continuous monitoring and analysis of operational data by operational managers and better access to metrics, efficiency has improved, and bottlenecks have been removed. Big data increase efficiency and performance in whole supply chain.

Maximized sales and profits: Using the real-time data, financial managers can continuously monitor and analyze these data and manage the profit margins with greater insights to ensure maximum profitability from their investment.

Increased customer service satisfaction: The access to real-time data and the ability to timely analyze these data provide operational managers with the ability to match their inventory levels with customer orders and tastes, which will increase customer satisfaction. Data analysis techniques can also be used to predict spikes or depressions in customer demand and seasonal trends to accurately inventory planning at different times.

Reduced costs by migrating to the cloud: A Software-as-a-Service (SaaS) approach to IT management means that the cloud-based nature of big data reduces hardware and maintenance costs. It can also be seamlessly integrated to existing systems with a minimum of expense.

There are only two publications in the field of BDA applications in the inventory management in Perish or Publish Software. Big data create significant competitive advantage by connecting and integrating internal production system with external partners (customers and suppliers) in inventory management [59]. With the help of big data, an automated inventory control system can be designed [60]. Data analysis techniques can be used to analyze the data, extract the relationships between them, and predict the optimal rate of inventory ordering [7].

4.8 BDA and logistics

The logistic industry has undergone a fundamental transformation due to the emergence of large volumes of data and devices, emission concerns, complex regulatory laws, changing industry models, talent limitations, infrastructure, and rise of new technology. In this industry, the standardization of structure and the content of data interchanges must be given great importance to improve and facilitate communication and collaboration between different sectors, including shippers, manufacturers, logistic companies, distributors, and retailers, as well as to the creation of new common business processes. However, reducing costs by driving down excessive inventory, both staged and in-transit, proactively responding to inbound and outbound events and sharing assets has become critical in today's supply chain environment.

Today, due to the high volume of data generated from various sources such as sensors, scanners, GPS, and RFID tags, as well as due to integrating business judgment and fusing multiple data sources, powerful techniques are needed to quickly and timely analyze these data and provide real-time insights for a timely and accurate decision making. Given the high volume of orders and massive flow, huge data sets and methods for timely analysis are needed to manage and maintain them. Since high volumes of data such as size, weight, origin, and destination are being generated daily for millions of shipments, there is a huge potential for new business creation and operational efficiency and customer experience improvement. Organizations need data platforms and data analytic processes to pervade their insights into organizations, which are not easy, and it is a new challenge for organizations. Infosys offerings are designed to help logistic companies rethink, evolve, and achieve their vision through a three-pronged strategy:

- Boundary-less information: A strategic alliance has been created among customers, logistics enterprises, and suppliers in the logistic industry, and the huge data set produced by the industry is placed on logistic technologies such as Warehouse Management Solutions (WMS), Transport Management System (TMS), supply chain execution systems, and IOT devices to share and access all members. A platform in the supply chain manages and integrates a huge variety of data created from different internal and external systems and provides the right validations and governance to improve the trustworthiness of the data and make right data available to business users in a self-service manner for exploratory analysis and insight generation.

- Pervasive analytics: An open and adaptive framework is needed to integrate seamlessly the different insights into an organization and to apply them effectively.

- Progressive organization: The dynamic changes in markets and the emergence of advanced data management and analysis technologies as well as "boundaryless" paradigm make organizations to abandon traditional BI analytic methods and governance structures and use new advanced techniques. Organizations will become knowledge-based organizations that utilize powerful horizontal platform and supportive tools that are in line with associated security, next-gen data sets, and business semantic policies.

Many research studies pointed to the application of BDA in the areas of transportation, and logistics. BDA have been used to gain competitive advantage and provide new services in logistics [61]. Maritime companies have also used prescriptive and predictive BDA to solve their planning problems [62]. In another study, we have used big data to share transportation capacity in order to improve the efficiency of urban healthcare services [63]. It is an obvious fact that BDA can support all supply chain activities and processes and create a supply chain strategies/agiler logistics.

4.9 BDA and agile supply chain

The most successful organizations create supply chains that can respond to unexpected changes in the market [64]. Choi et al. argue that big data have significant effects on operation management practices [65]. Gunasekaran et al. further argue that supply chain disruptions have negative effects, and agile supply chain enablers were progressively used with the aid of big data and business analytics to achieve better competitive results [66, 67]. Srinivasan and Swink further argue that although BDA have been using to understand customer intentions/behaviors, the use of analytics for supply chain operational decisions is less understood [68]. Gunasekaran et al. [66] and [67] argue that big data and predictive analytics have positive effects on supply chain performance and organizational performance [67, 68]. Swafford et al. found that IT capability has positive effect on SCA [69]. Srinivasan and Swink noted that supply chain visibility is a prerequisite for building data analytic capability and vice versa [68]. Supply chain visibility and BDA are complementary in the sense that each supports the other [66, 67]. Supply chain visibility is a desired organizational capability to mitigate risk resulting from supply chain disruptions [70]. Following Srinivasan and Swink's arguments that organizations investing in building supply chain visibility capability are likely to invest in BDA [68], Dubey et al. found a positive impact of supply chain visibility on SCA [15]. By accurately anticipating consumer trends based on historical data, real-time data, and future predictions, organizations can put that knowledge to work to become more agile, efficient, and responsive.

Some other studies have been done to examine BDA that support the advanced supply chain agility [71]. Many parts and processes of the supply chain BDA have been widely used; however, publications regarding data analysis applications in the supply chain remain limited. Many parts and processes of the supply chain BDA have been widely used; however, publications regarding data analysis applications in strategic sourcing and inventory management are still limited. People working in this area should be able to extract knowledge and insight into the enormous data available and use it in their planning and decisions, and this is a challenge for them. Big chain analytics will help optimize decision making by aligning organization's strategy to the sourcing strategies and providing proper insights [7]. BDA also improve inventory decision through a better understanding of uncertain customer demand [72].

4.10 BDA and sustainable supply chain

Although sustainable SCM has been discussed in corporate offices for some time, actually implementing the sustainability phenomenon in the extended supply chain has proved difficult [73]. Nevertheless, large corporations perceive sustainability efforts as long-term investments aimed toward building strategic resources [74]. Corporations are increasingly interested in using BDA in their sustainable efforts, which in turn give them a strategic edge [75]. According to a Mckinsey survey report, companies using BDA are able to predict the 65% of customers that make repeated purchases through shop alerts and 75% of those customers reported that they are likely to use the service again [76].

Several scholars acknowledge sustainability (environmental, social, and financial) as an emerging area for BDA applications in business [77, 78]. Therefore, BDA techniques should be applied throughout the supply chain in order to achieve full benefits [79]. As decision making in organizations has been based on data, organizations must change their strategic capabilities, which affect sustainability. Given the growing importance of sustainability and BDA, organizations must integrate these two areas to achieve sustainable competitive advantage [78, 80]. Despite the pressing need to integrate data analysis with sustainability and supply chain measures, little progress has been made so far [81]. Few scholars have addressed this issue that to achieve strategic and competitive advantages, BDA and sustainability must be integrated [78, 80]. Today's organizations must use methods to analyze high volumes of data to gain insights and knowledge in order to achieve the three dimensions of environmental, social, and economic sustainability [82].

Some studies have used big data analysis to predict natural disasters to take preventive action against them, and simulation has been used reduce the effects of these environmental hazards [83]. Big data are also collected for melting glaciers, deforestation, and extreme weather through satellite images, weather radar, and terrestrial monitoring devices. Such data are used to comprehensively study global climate change and assign specific causality [21]. Big data have also been used for community health and welfare. For example, BDA have been used in Europe and USA to identifying and predicting prostate cancer biomarkers to take preventive measures at the right time [84, 85]. Another study applied policy-driven big data to support and improve sustainability measures in various operations. For instance, to protect the environment and take the sustainable measures, computer platforms are used to collect and share environmental data (i.e., big data), and such data have used for government-led publication of data on medical records for risk mitigation and research, among the other applications [86]. However, literature on the application of BDA for supply chain sustainability has been much less explored. Thus, scholars acknowledge the need for further exploration in this domain [75, 77, 87, 88]. Furthermore, for the supply chain to be sustainable, the potential risks disrupting operations must be identified and predicted. In the next section, the authors explore the literature related to supply chain risk management.

5. Application of BDA in different types of supply chain

In the current years, BDA practices have been extensively reported. One of the main reasons is to make full usage of the data to improve productivity, by providing "the valuable right information, for the right user, at the right time." In this section, an overview of BDA applications in different companies including manufacturing, finance, and healthcare is provided.

5.1 Application of BDA in manufacturing

Despite the importance of big data in today's world, many organizations overlook the importance of using big data for their organizational performance. Proper application of BDA techniques can be used to track, analyze, and also share employee performance metrics. BDA techniques also are used to identify employees with poor or excellent performance, as well as struggling or unhappy employees. These techniques allow organizations to monitor and analyze continuously real-time data, rather than just annual investigations based on human memory. In today's world, the manufacturing industry must use advanced data analytic technologies to gain competitive advantage and improve productivity in design, production, sales, and timely product delivery processes. Approximately, manufacturing industry stores 2 exabytes of new data in 2010 [89]. Since in production lines and factories, various electronic devices, digital machineries, and sensors are used, and a huge amount of data is generated. Therefore, BDA can be used to build intelligent shop floor logistic system in factories [54, 90]. A huge amount of data also creates from design and manufacturing engineering process in the form of CAM and CAE models, CAD, process performance data, product failure data, internet transaction, and so on. Data analysis techniques can be applied to defect tracking and product quality and to improve activities of the product manufacturing process in manufacturing [91].

Data analysis techniques can also be used to predict customer demands and tastes. Raytheon Corp manufacturing company has develop smart factories through the powerful capacity of handling huge data that collect from various sources including instruments, sensors, CAD models, Internet transactions, digital records, and simulations that enable the company in real-time control of multiple activities of the production process [92]. General electric creates innovative and efficient servicing strategies by continuous observation and analysis of huge data obtained from various sensors in manufactured products including in GE's case, jet engines, locomotives, medical imaging devices, and gas turbines [93]. Schmitz Cargobull, a German truck body and trailer maker, uses sensor data, telecommunication, and BDA to monitor cargo weight and temperatures, routes, and maintenance of its trailers to minimize their usage breakdown [94]. Toyota Motor Corporation to dramatically improve its data management capabilities launches Toyota Connected as their Big Data Business Unit. Toyota also uses vehicle big data collected from connected car platform to create new business and service such as adding security and safety service and to create mobility service, traffic information service, and feedback to design [95]. The integration of BDA into manufacturing system design should move from a descriptive to a predictive system performance model over a period of time, such as using what-if analysis, cause-effect model, and simulation [96].

5.2 Application of BDA in finance

Maintaining the sustainable competitive advantage and enhancing the efficiency are important goals of financial institutions. In order to achieve sustainable competitive advantage and stay afloat in the industry, these institutions must continually use big data and appropriate analytic techniques into their business strategy. In recent years, there has been a great deal of improvement in big data and analytic techniques, and there has been a lot of investment in them. Banks and financial service organizations using big data and analytical techniques gain valuable knowledge and insights that can be used in continuous monitoring of client behavior in real time, predict their wants and needs, and provide the exact resource and service according to customer's requests and needs. Using the findings of this real-time data analysis and evaluation result in turn, it enhances overall profitability and performance. After the 2008 global financial crisis, financial institutions need to use big data and analytic techniques to gain competitive advantage [2]. Due to the high volume of financial transactions and activities, the application of big data and analytic techniques is very necessary and important in most of the financial organizations such as asset management, insurance companies, banks, and capital market. Organizations need to be able to manage their huge data and extract the knowledge and insight contained in these data and then use them in all their business processes and decision making. Bean reported that 70% of global financial service organization thought BDA was important and 63% has applied big data in their organizations [97]. According to Technavio, costs of big data technology in the global financial industry will grow by 26% from 2015 to 2019, which suggests the importance of big data in this industry [98]. BDA techniques provide important insights through continuous monitoring of customer behaviors and data analysis, which improve customer intelligence such as customer risk analysis, customer centricity, and customer retention. BDA is applied to all transactions and activities of the financial service industry, including forecasting and creating new services and products, algorithmic trading and analytics, organizational intelligence (such as employee collaboration), and algorithmic trading and analytics. BDA is also used to support risk management and regulatory reporting activities [99]. Chief Financial Officer (CFO) should use analytic techniques to analyze data of big data and extract knowledge and insights into them and then use information and knowledge in their strategic decision making. Therefore, Chief Financial Officer (CFO) can apply a business analytics and intelligence tool to improve data accuracy, make better decisions, and provide greater value [100]. Data analysis techniques can also be used in financial markets to examine the market volatility and calculate VPIN [101]. Financial institutions can use real-time decision making and predictive modeling to gain a competitive advantage in the dynamic financial markets [102]. The Barclays Finance Company has widely used big data to support its operations and create and maintain primary competitive advantage. They apply big data in many areas such as financial crime, treasury, financial crime, risk, intelligence, and finance [103]. Deutsche Bank also has applied the big data in their businesses. Deutsche Bank has set up a Data Lab that provides internal data, analytics consultancy, test-out business idea, and technology support to other division and business function [104].

5.3 Application of BDA in healthcare

In the health industry, a large amount of data is generated to control and monitor the various processes of treatment, protection, and management of patients' medical records, regulatory requirements, and compliance. Big data in healthcare are critical due to the various types of data that have been emerging in modern biomedical including omics, electronic health records, sensor data and text, and imaging, which are complex, heterogeneous, high-dimensional, generally unstructured, and poorly annotated. Modern and strong techniques are needed to quickly manage and analyze these data. "Big data" in the healthcare industry include all data related to well-being and patient healthcare. According to the report of US Congress in August 2012, big data are defined as "large volumes of high velocity, complex, and variable data that require advanced techniques and technologies to enable the capture, storage, distribution, management, and analysis of the information." Big data in healthcare encompass such characteristics as high-dimensional, variety, heterogeneous, velocity, generally unstructured, poorly annotated, and, with respect specifically to healthcare, veracity. Big data in the healthcare industry include these characteristics of high-dimensional, variety, heterogeneous, velocity, generally unstructured, poorly annotated, and, with respect specifically to healthcare, veracity. Application of analytical techniques in Medical Healthcare System includes image detection, lesion detection, speech recognition, visual recognition, and so on. Existing analytical techniques can be applied to the vast amount of existing (but currently unanalyzed) patient-related health and medical data to reach a deeper understanding of outcomes, which then can be applied at the point of care. A large amount of diverse healthcare data from personal medical records to radiology images, laboratory instrument reading, and population data is, and human genetics currently being created, requiring robust, modern systems for protection and maintenance. Big data reduce healthcare costs and also improve the accuracy, speed, quality, and effectiveness of healthcare systems. Bort reported on combating influenza based on flu report by providing near real-time view [105]. Other big data initiatives were to monitor inhaler usage and reduce the risk of the asthma attack and cancer [106]. BDA can also help health insurance companies to identify fraud and anomaly in a claim, which is difficult to detect by the common transaction processing system [107]. Big data application has many values in healthcare including right care, right living, right innovation, right provider, and right value [108]. Big data can be used to population health management and preventive care as a new application of Huge Data in the future [106]. Despite the high potential of using massive data in healthcare, there are many challenges, for example, improving the available platform to better support the easy friendly package, a menu driven, data processing, and more real times. There are also other challenges in using big data in the healthcare industry including data acquisition continuity, ownership, standardized data, and data cleansing [109].

6. Analytics in supply chain

Big data create different capabilities in the supply chain that provides networks with greater data accuracy, insights, and clarity and also create a greater e-contextual intelligence shared across the supply chains. Big data are a powerful tool for solving supply chain issues and driving supply chains ahead. For example, currently, BDA techniques have applied in the retail supply chains to observe customer behaviors by accurately predicting the customer tastes and preferences. Supply chain decision makers to succeed in today's competitive markets must always seek ways to effectively integrate and manage big data sources to gain more values and competitive advantage. The effective and appropriate use of big data sources and techniques resulted in enormous improvements in processes of supply chain:

- Building agile or responsive supply chains through predicting and gaining a better understanding of the market trends and customer expectations and preferences. BDA can facilitate the real-time monitoring of supply chain and managing of data that enhance the speed, quality, accuracy, and flexibility of supply chain decision. Utilize a wide range of data from news, social media, weather data (SNEW), and events as well as direct data inputs from multiple static and dynamic data points provide the capability to predict and proactively plan all supply chain activities.

- Building reliable and intelligent supply chains through the application of Internet of Things (IoT), machine learning, and deep learning techniques in each supply chain activities. For instance, IoT can provide real-time telemetry data by the real-time monitoring of supply chain to reveal the details of production processes. Machine learning algorithms that are trained to analyze the data can accurately predict imminent machine failures. Deep learning techniques can also be used to accurately predict customers' demand and their preferences and expectations.

- Supporting the creation of sustainability in SCM. BDA undoubtedly will enhance social, environmental, and financial performance measures. For example, detailed planning for timely delivery of the product can be done by analyzing the real-time traffic data provided by the GPS that reduces production of carbon emission and the cost of fuel consumption.

- Enabling global supply chains to adopt a preventive rather than a reactive measures to supply chain risks (e.g., supply failures due to natural hazards or fabricated, contextual and operational disruptions). In a more complex global supply chain, BDA techniques can help supply chain managers to predict external future events and adopt a proactive against them.

BDA can also be applied across the end-to-end supply chain. For instance, the points of sales (POS) data on retailers provide real-time demand data with price information. It gives the signal for replenishment such as in the vendor managed inventory system. RFID data provide automated replenishment signal, automated receiving and storing information, and automated checkout data, which inform the real-time inventory status. Supplier data provide important data about suppliers and ordering processes that can help the supplier risk management and better coordination with supplier processes. Manufacturing sensor data provide real-time monitoring of manufacturing equipment and identify an inevitable problem. During the delivery process, GPS data provide real-time inventory location data and help in finding optimal routes and reducing inventory lead times and fulfillment [110].

Despite the potential use of big data, many supply chains are unable to harness the power of BDA techniques to generate useful knowledge and insights into available data for their businesses. The underlying reasons are due to the lack of ability to apply appropriate techniques for big data analysis, which result in significant cost reduction [110]. Therefore, the efforts to strengthen the BDA capabilities in supply chain are considered as an important factor for the success of all supply chains [2].

7. Conclusion and managerial implications

BDA have become an important practical issue in many areas such as SCM. There are many scopes for advancement in the application of appropriate analytic techniques in this area. As stated in previous literature [7–9], there are a variety of techniques and fundamental applications in the SCM (e.g., predictive, descriptive, and prescriptive). This chapter tries to demonstrate some of the most fundamental and recent applications of BDA within the SCM and also notice some of these techniques in SCM that are critical for managers. BDA have important applications across the end-to-end supply chain. BDA have many important applications across the end-to-end supply chain. For example, this is applied in various areas of SCM including the demand data at the sales department, retailer data, delivery data, manufacturing data, and until supplier data. BDA are also used in various supply chain activities and support them, including supplier relationship management, product design, development, demand planning, inventory, network design, production, procurement, until logistics and distribution, as well as the reverse. Applying big data sources and analytics techniques have led to many improvements in supply chain processes. Furthermore, BDA can support the development and improvement of responsive, reliable, and/or sustainable supply chain. BDA can able to manage and integrate huge sets of diverse data in a complex global supply chain. Many researchers have applied various techniques of BDA across different industries including the healthcare finance/banking and manufacturing. Other industries such as hospitality, technology, energy, and other service industry will also take advantage of BDA techniques. Depending on the contexts used and the strategic requirements of organizations, different techniques of BDA are applied. The culture, politics, environment, and the management team within the organization are very critical factors in decision making. Since, sufficient resources with analytic capabilities become the biggest challenges for many today's supply chain. Supply chain has to establish close and continuous links between data experts and their business function and also apply appropriate BDA techniques according to the context of their application in their decision making, processes, and activities to answer the question of how data can help drive supply chain result. Hence, mutual coordination and cooperation between different supply chain units must be established, use BDA techniques to link these units, and exist an ability to share and access data and information throughout the entire supply chain.

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