Big Data Enabled Healthcare Supply Chain Management: Opportunities and Challenges

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Abstract. It is estimated that healthcare spending in the world's major regions will increase from 2.4% of GDP to 7.5% during 2015 to 2020. Healthcare providers are required to deliver high quality medical services to their customers. Since most of their budgets are spent on high cost medical equipment and medicines, there is a pressing need for them to optimize their supply chain activities such that high-quality services could be provided at lower costs. Relatedly, medical equipment and devices generate massive amounts of unused data. Big data analytics is proven to be helpful in forecasting and decision-making, and, hence, can be a powerful tool to improve healthcare supply chains. This paper presents a review on the use of big data in healthcare supply chains. We review the various concepts related to the topic of this paper including big data, big data analytics, and the role of big data in healthcare, and in healthcare supply chain management. The opportunities and challenges for big data enabled healthcare supply chains are discussed along with several directions for future developments. We conclude that the use of big data in healthcare supply chains is of immense potential and demands further investigation.

Keywords: Big data · Data analytics · Healthcare · Supply chain management

1 Introduction

The healthcare sector is considered one of the main economic pillars worlwide, to which significant proportions of countries' budgets are allocated. It is estimated that healthcare spending in the world's major regions will increase from 2.4% to 7.5% of GDP between 2015 and 2020 [1]. Despite this massive expenditure, healthcare organizations are required to deliver high-quality medical services at lower costs to their patients. However, spending hundreds of millions does not alone guarantee high quality services. Hence, most of healthcare organizations nowadays are faced with incremental challenges, including limited budget, daily increases in patient numbers and increasing costs of medical equipment and pharmaceuticals [2]. As much as 45% of a hospital's typical total operating expense is committed to its supply chain, including suppliers, drugs and consumables.

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The healthcare supply chain is an essential area that should be considered and improved. It would be incorrect to understand it as only relating to purchasing and managing contracts, as it is a very complex concept, and could free up huge revenues within healthcare sectors once managed properly [3]. Consequently, healthcare organizations will likely increasingly need to employ recent technological developments to deliver efficient services at lower costs and high quality. Moreover, such improvements are required to reduce the waste and loss that threaten sustainability.

In the current era of increasingly advanced technologies in medical devices and medical equipment, the size of data generated by their use is growing exponentially. The immense growth in the volume of electronic medical records (EMRs) stored by healthcare organizations is also significant and undeniable. Exploring the possibility of investing this big data in improving services has become attractive to researchers and practitioners. A lot of fruitful business applications and network search engines have been developed using Business Intelligence (BI) for extracting knowledge from big data [4]. Some researchers have been investigating how to transfer and where to store this amount of data, while others have been focusing on big data utilization. Big data utilization involves analysing it to seek a solution for existing issues, exploring trends, and supporting decision-making.

A plethora of literature has been produced that explores to what extent big data can be beneficial in the healthcare industry. Malik and his colleagues [5] noted that big data analytics seems to have been frequently used for the diagnosis, prognosis or planning of treatment, for example, disease management for oncology to anticipate heart attacks and identify and classify at-risk people. However, a very limited work has been done in applying big data to healthcare supply chains. Existing published survey papers focus on reviewing the significant applications of big data to supply chains in manufacturing generally.

In this paper, our main aim is to review the use of big data in the healthcare supply chains. To the best of our knowledge, only three peer-reviewed works have been published on this topic. We will investigate the opportunities, challenges and future directions of big data in this field.

The paper is organized as follow: Sect. 2 gives brief definitions for the basic concepts that are mentioned in this paper. Big data analytics in supply chain and healthcare opportunities and challenges are discussed in Sect. 3. Section 4 concludes the work and suggests possible future directions.

2 Background

This section introduces the work by defining the basic terminologies that are mentioned in this paper. Supply chain, big data and big data analytics are illustrated based on the reviewed references. Then, some examples of how the big data been used in healthcare and supply chain individually are given in the last two sub sections below.

2.1 Supply Chain

Malik et al. define the supply chain process as "having the right item in the right quantity at the right time at the right place for the right price in the right condition to the right customer" [6]. In the meantime, supply chain managers can legitimately claim to have played a major role in spreading the information technology revolution. E-SCM (e-supply chain management) was a great transformation as supply chain activities were integrated with the Internet [7]. Smarter supply chains [8] and smart factories [9] are further examples of intelligent systems developments. Sustainability (triple bottom line, TBL) has become a crucial consideration in business, government and academia. Therefore, the concept and practice of green or sustainable supply chains have become a vital part of industrial and government operations, see e.g. [10, 11].

2.2 Big Data

According to [4], big data refers to "the datasets that could not be perceived, acquired, managed, and processed by traditional IT and software/hardware tools within a tolerable time". However, researchers and scientists have defined the term "big data" according to several different aspects. Apache Hadoop in 2010, defined big data as "datasets which could not be captured, managed, and processed by general computers within an acceptable scope."

In 2011, an IDC report characterized big data as "large information innovations depict another era of advancements and structures, intended to financially extricate an incentive from substantial volumes of a wide assortment of information, by empowering the high-speed catch, disclosure, as well as examination". Big data technologies have also been defined as "the emerging technologies that are designed to extract value from data having four Vs characteristics; volume, variety, velocity and veracity." [12]. Accordingly, the key attributes of big data can be outlined as the 'four Vs', i.e., Volume (extraordinary volume), Variety (different modalities), Velocity (quick era), and Value, as shown in Fig. 1.

2.3 Big Data Analytics

Big data analytics has become a key buzzword these days. It is not just a buzzword but is making a fundamental impact on all spheres of our life, transport [13], planning and operations [14, 15], smart cities [16], teaching and learning [17], to name but a few. According to Feki and Wamba [18] and Hogarth and Soyer [19], the term 'analytic' can be defined as transforming big data into meaningful intelligent information. This transformation of big data is usually done using two main steps: Data management, then Data Analytics using specific techniques [20]. Data management implies "processes and supporting technologies to acquire and store data and to prepare and retrieve it for analysis" while analytics means "techniques used to analyse and acquire intelligence from big data" [18].

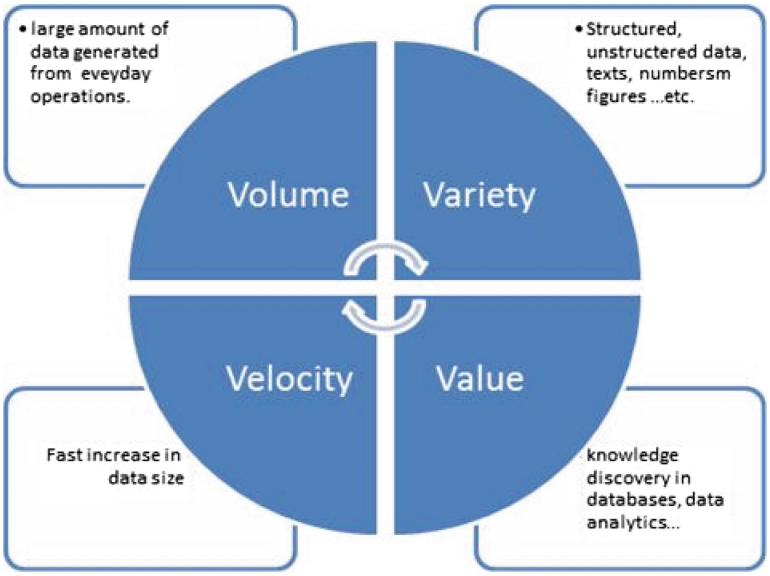

Fig. 1. Big Data Characteristics.

2.4 Big Data in Supply Chain Management

Big data has been widely used in supply chain management in many industries. According to Waller and Fawcett [21], despite the operational influence of big data in supply chains, traditional approaches and standard activities are affected, too. They identified the potential opportunities that big data could offer in enhancing supply chain processes.

Carriers, manufacturers and retailers, the main users of logistics, are also the main beneficiary of big data. They could obtain actionable information about many of their daily activities, such as inventory, transport, and human resources management. DHL and UPS, two leading companies who are pioneer investors in big data initiatives to enhance their services and increase their profits [22].

2.5 Big Data in Healthcare

The use of big data is not limited to industrial fields. It is playing a key role in enhancing critical service sectors such as healthcare. Healthcare systems and applications have long been considered computationally intensive [23]. However, the focus on data—i.e., big data—has only began in the last few years. It As noted in [12], "the cost of healthcare, according to World Health Organization is mostly due to system and operational inefficiencies, and missed disease-prevention opportunities. Big data analytics can minimize these efficiencies and improve the clinical processes resulting in better, preventive, personalized healthcare; estimated to save billions in the healthcare sector alone with virtually unquantifiable impact".

Collaborations between big data platform providers and scientific research centres have generated remarkable and noticeable successes. In Australia, two innovative applications for big data have been developed by Srinivasan and Arunasalam [24]. They have utilized the massive data extracted from hospital discharge reports and insurance claims to detect fraud, abuse, waste and errors in insurance claims.

Similarly, in 2014, Raghupathi and Raghupathi [25] reported that in healthcare more than $300 billion could be saved annually through big data analytics utilization, as estimated by McKinsey. Big data utilization could be applied in two vital areas: Clinical Operations and Research & Development [26]. A practical example of using big data analytics has been undertaken by developers [27] in US health care sector. They built predictive systems based on big data that could help in early identification of six critical cases: high cost patients, readmissions, triage, decompensating (once a patient's situations get worse), adverse events, and treatment optimization for diseases affecting multiple organ systems.

Several works exist that use big data to improve healthcare ICT systems efficiencies. For example, the use of cloudlets and big data to improve mobile healthcare systems response and experience is proposed in [28, 29]. A capacity sharing model for healthcare using big data is proposed in [30]. The use of big data to improve the performance of networked (integrated) healthcare systems is proposed in [12].

3 Big Data in Healthcare Supply Chains

In this section, we demonstrate the possible opportunities of using big data as a solution in healthcare supply chains. The opportunities are summarized based on the previous works that have been published. Unfortunately, very limited work has been found. However, the application of big data in this regard is unlimited and further investigations are required. In the last sub section, the challenges that might be considered are listed.

3.1 Opportunities

Nowadays, big data has in many ways become a solution looking for a problem to solve. Rozados and Tjahjono saw that "Major business players who embrace Big Data as a new paradigm are seemingly offered endless promises of business transformation and operational efficiency improvements" [31]. This has attracted researchers and practitioners in many industries to explore the possibilities of using big data. Abundant research has been done in both healthcare and in supply chain management generally. The healthcare industry is considered as an essential and critical sector within services, but there is a lack of information about the current state of research into healthcare operations management (OM) and supply chain management (SCM) [32]. At the time of writing this paper, only three peer reviewed papers have been found in this area, and we can summarize the opportunities of using big data in healthcare supply chains as follows.

Demand Forecasting. At management level in many industries, demand forecasting is widely used in order to decision-making reinforcement and to promote other management tasks. In China, historical recorded data from transaction datasets has been successfully used to build a predictive model based on data mining algorithms [33]. This model is supposed to work as a prediction tool to estimate future needs within the healthcare supply chain process in China. They used real datasets from 2014 to build the prediction tool, to predict the next year's needs. Since the nature of the collected data set is heterogeneous, and in order to empower the prediction tool, they combined a classification decision tree and regression algorithm in CRT modelling. The efficiency of their model was proven and gained better results than other traditional statistical approaches.

Improving Safety and Quality Assurance in the Pharmaceutical Supply Chain. In the pharmaceutical industry, counterfeiting and illegal export and import of medicines is a major issue. Moreover, transferring medicines and medical equipment in inappropriate environmental conditions, such as at high temperature and humidity, can affect quality. Thus, the challenge is to guarantee the delivery of shipped medicines safely. Further, medical care providers (hospitals, clinics etc.) need to verify that they have obtained the right medicine from the right source. In Germany XQ in [2] made use of the data stored by their RFID-based system about tracked and traced shipments, such as ID, location, temperature, humidity etc. Tracking and tracing are widely-known terms in the supply chain management context, which may offer opportunities to ensure quality of medicines and prevent counterfeiting.

Indoor Monitoring. For healthcare organizations, the benefits of track and trace systems are not limited to ensuring medicines' quality. Data generated from these systems can also offer an opportunity to improve the safety of special needs patients and new-born babies. A healthcare unit's administrators can retrieve real time locations and other necessary information, such as vital signs for Alzheimer's patients, at any moment, to ensure that they are safe. Intelligent applications can offer monitoring without restricting patients' movements. Also, new-born babies can be saved from kidnapping and theft. A real application for this opportunity was delivered by Sultanow and Chircu [2] when they launched the track and trace system and reported its significant benefits.

3.2 Challenges

While big data could offer a wide range of opportunities, it has characteristics that could be considered as important challenges, both generally as well as in the case of healthcare, specifically. The criticality of the healthcare industry and its standards of confidentiality might create difficulties too. The key challenges of applying big data in the healthcare supply chain can be summarized as follows.

Data Related Issues. Due to big data's characteristics, such as data volume, variety, and heterogeneity, some issues may arise. According to Tan et al. the variations of data require finding special techniques for handling and storing, as claimed by Burghin et al. [34]. Moreover, the traditional data mining techniques may not be longer sufficient for

such kinds of data [35]. Alongside (and sometimes as a result of) the variety and volume, incompleteness, incorrectness and uselessness are also commonly reported difficulties.

Healthcare Related Issues. The main resources of big data in the healthcare industry are electronic medical records (EMRs) [25]. Practitioners use EMRs to record patient's medication histories every time the patient visit the clinic. According to [6], data ownership, governance and standardization are the main challenges that should be considered in this area.

Knowledge Related Issues. Deep knowledge is needed in order to understand the variety of data forms and analyse the relationship between different kinds of data [24]. Moreover, the topic is complexly multidisciplinary, since sufficient knowledge of big data analytics techniques, healthcare data and supply chain processes are required, too.

4 Conclusion and Future Research Directions

In conclusion, healthcare supply chains are an essential area that should be considered and improved. Healthcare organizations will likely need to employ recent developments in technology to deliver efficient services at reasonable cost and high quality. Improved data analysis is also required to reduce the waste and loss that threaten sustainability. Big data analytics is a powerful tool that is usually concerned with large-scale data and high-performance computing environments; it has emerged as a revolution that is able to contribute in different ways to many field, such as through data analysis, knowledge extraction, and advanced decision-making. We recommend some future directions for the use of big data in healthcare supply chains in the following.

1. Data driven inventory can enhance prediction tools through several optimization methods. This includes studying how to get benefits from "data patterns" that are extracted at the analysis step, and how to use them to support decision-making.
2. Further reviews of how big data is used in manufacturing, unrelated to patients, is another possible direction, informing how we might use patient-centric data in estimating hospitals' needs or logistic operations such as scheduling, staff scheduling, resources allocation, and hospital design layout.
3. Using social media in addition to EMRs can assist in determining the best locations for future clinics and services.

An important step to enable optimised supply chains in healthcare sector would be the networking and integration of healthcare and other smart world systems [28]. Such integration would give rise to a plethora of useful data where the systems integration would allow automatic collection, storage, and analyses of data. Moreover, the integration would also enable optimised decisions to be taken and enforced automatically leading to optimised supply chains in the healthcare sector.

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