International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 7, 2020
ISSN: 1475-7192

Impacts and Challenges of Big Data: A Review

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Abstract

Data exists in all folds of life. Big Data is a call for change entailing technological improvements that affect trends and lifestyles. Big Data is a valuable asset for businesses and government organizations hence rendering the importance of defining the concept, its main features and the challenges that come with its implementation which commonly involve issues related to technology, organization, process, data management, and skills. This paper thus examines the potential growth of Big Data and its accompanying challenges driven by these three objectives. First is to define Big Data and its characteristics and to summarize the definitions of previous studies; second is to determine the impacts and potentials of Big Data, and third is to highlight the major Big Data challenges and categorize them accordingly.

Keywords: Big Data, Big Data Implementation, Impact of Big Data, Big Data Challenges,

01. Introduction

The McKinsey Global Institute defines Big Data as a large-sized dataset that is beyond the collection, storage, management and analysis capabilities of conventional database software tools [1], [2]. Big Data is generally referred to as "a term that describes 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" [3]. Big Data plans have been the focus of major technology players in recent years including IBM, EMC, Microsoft, Oracle, Google, Facebook, SAS and Amazon. IBM for instance had spent USD 16 billion on 30 Big Data properties. Big Data is deemed as the future of innovation, productivity, competition, and quality by leading corporations such as the SAS Institute, Gartner, IBM and McKinsey [3]–[5].

McKinsey in 2011 had projected that the five domains of Big Data i.e. the public sector, healthcare, retail, manufacturing, and personal location data would generate $223 billion [6]. In 2012, The World Economic Forum named Big Data as the most outstanding technology. Academics too had studied the capabilities of Big Data Analytics (BDA) in improving organizational performance in the dimensions of technology, process, talent, and management [7]. It is crucial for organizations to start investing and leveraging on the multitude forms of Big Data [7], [8].

In recent years, organizations find it more and more crucial to maintain their competitive edge through strategies such as cost minimization, quality improvements, and marketing time reduction [9]. Conventional technologies have become obsolete in the era of Big Data. Proper Big Data management is not only crucial for gaining competitive advantage, but also for ensuring survival in the modern digital market [10]. Organizations should hence transform the focus of their data

collection and analysis from being merely product / service-oriented to being more future-oriented [11]. Organizations should also ascertain critical data sources, structures, skills, and architecture; determine the supporting process infrastructure for Big Data analysis; outline Big Data strategies, and delineate technologies and applications that facilitate the implementation of Big Data [12].

There is very little information about the effects, issues and challenges of Big Data in existing literature [3], [13], which leads to this paper filling that gap. This paper begins with Section 2 which presents the definition of Big Data as indicated in prior studies, followed by Section 3 which delineates the identified characteristics of Big Data. Section 4 presents the impacts and potentials of Big Data whilst Section 5 outlines the major obstacles in implementing Big Data i.e. People, Technology, Organization, Process, and Data Management. Finally, Section 6 summarizes the whole paper.

02. Definitions of Big Data

Big Data is defined differently by scholars, businesses, industries, media, and other stakeholders. As such, Big Data remains as a vague concept [14]. Generally, the term is defined based on the existing software tools and dataset sizes in a certain industry [1]. Big Data has been extensively deliberated by both industry and academia [16], but the concept could be made clearer when grounded upon scholarly readings. A clearer definition of the concept is beneficial for practitioners and scholars alike in developing it further to realize its value creation [17].

In 1997, NASA scientists published a paper explaining Big Data. According to them, large data volumes increase the demand for bigger memory space in the local and remote disks. This need for more resources is described by them as a Big Data issue [18], [19]. Data growth obstacles and prospects are defined to have three dimensions i.e. volume, velocity, and variety [14], [20]. Gartner updated the definition of Big Data as a "high-volume, high velocity and/or high variety information assets that demand cost-effective innovative forms of information processing for enhanced insight, decision making, and process optimization" [5], [18]. Meanwhile, SAS described Big Data as a "popular term used to describe the exponential growth, availability, and use of information, both structured and unstructured" [21]. IBM gave several definitions of the concept: 1) "Data, coming from everywhere; sensors used to gather climate information, posts to social media sites, digital pictures and videos, purchase transaction record, and cell phone GPS signal to name a few"; 2) "Big Data is defined as large sets of data that is very unstructured and disorganized", and 3) "Big Data is a form of data that exceeds the processing capabilities of traditional database infrastructure or engines" [21].

Today, there exist several definitions and theories of Big Data [10]. However, it is commonly defined as large datasets that are beyond the capturing, management, and processing capacities of traditional hardware settings and software tools. The conceptual definition soon entails advanced computational technologies for processing large data volumes. Big Data is mainly characterized and taken from the Business Intelligence and Business Analytics (BI & BA) that enables it to create business value via its predictive analytics and decision support capabilities, and manage data that would otherwise be too complex for conventional methods [22], [23]. Hence, the collective definition of Big Data is "a term that describes 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".

03. Characteristics of Big Data

Prior studies had defined Big Data as advanced technologies and architectures created to extract value from large volumes of data in an economical manner via rapid data capturing, discovery, and analysis [20]. As Big Data is still a fairly new

concept, organizations need to recognize its significance and the actual "Vs" that delineate its main features [24] particularly because earlier studies had been inconsistent in doing so [25].

The three features of Big Data are volume, velocity, and variety. Large volumes of data are unmanageable by conventional technology because they are produced rapidly via online streaming and other sources including sensors, transactional systems, web platforms, product/service instrumentation, and social media [25]. The 3Vs of Big Data namely; Volume, Velocity and Variety are the dimensions that make up its data management [26]. IBM soon added 'Veracity' to the list. Oracle did not employ these dimensions to define Big Data and instead highlighted that it entails value derivation from conventional database-driven business decision-making, developed using new unstructured data sources [13].

The studies by [1], [12], [29], and [38] had defined Big Data using the 4V model i.e. volume, variety, velocity and value while some others added veracity to the list. Specifically, Volume entails the amount of data; Velocity entails the speed or rate for the generation or processing of the data; Variety entails the data types and sources, whilst Veracity entails the accuracy and authenticity of the data and the result of its analysis. Meanwhile, [27] and [28] characterized Big Data by volume, velocity, variety, and value i.e. insights derived from a Big Data organization which necessitates both scalability and enhanced strategies and operational procedures [27]. Similarly, [29] too used the 5Vs i.e. Volume, Velocity, Variety, Veracity, and Value [29], [30]. For [31], their use of the 4Vs i.e. volume, variety, velocity and value is supplemented by "complexity". "Management" and "security" were added to the 3Vs of volume, variety and value identified by [33] which necessitates further technical studies.

Nowadays, Big Data is defined in terms of Validity, Variability/Volatility, Virtual, and Visualization/Visibility [34]. According to [2], velocity, variety, value, veracity, and variability imply data heterogeneity and fickleness whilst the seventh feature i.e. visualization implies the data's descriptiveness. In sum, the most common Vs are volume, velocity, variety, veracity, and value, and their specific features are the distinction between conventional data and Big Data [2], [17].

04. Impact and Opportunities of Big Data

All Internet-related activities, phone calls or card-based purchases create a recorded data that can be stored and analysed for business purposes [10]. Big Data transforms industries considerably. Through the use of Big Data technology, large amounts of data created through daily rampant transactions allow marketers to identify the lifestyle patterns and requirements of consumers [23]. Remaining competitive in a rapidly changing marketplace requires the integration of Big Data in organizational decision-making so as to generate value addedness for the business [35]. McKinsey & Company found that Big Data technology added massive values to the US healthcare industry, the EU public sector administration, retail industry, global personal location data, and global manufacturing in terms of improved economic utility, productivity and competitiveness for the organizations and considerable benefits for consumers [16].

Industries and government agencies are now planning to harness the massive potentials of Big Data by accelerating all related studies and applications [16]. The use of Big Data in many industries is growing rapidly. Big Data investments in the public and private sectors are advantageous for both businesses and the public through improvements in services, effectiveness and efficiency [18]. Big Data allows for the creation of new values and the avenue for understanding those values apart from prompting new ways to manage and organize such massive datasets [17]. Big Data technology gives businesses a competitive edge as it helps them make viable decisions using data from multiple sources [36]. According

to McKinsey, with the use of Big Data technology: the US medical industry could achieve a profit of more than USD 300 billion and lessening healthcare costs by 8%; retailers could boost their profit exceeding 60%; governmental operations and transactions can improve their efficiency in developing European economies and save more than EUR 100 billion, and major value addedness can be created for the benefit of businesses and consumers [16]. According to the IDC study, in the next five years, Big Data technology is expected to expand by 12.8% whilst the global revenue for Big Data business analytics (BDA) projects is projected to grow from $130.1 billion to an excess of $203 billion within the time span of 2016-2020. Based on the above, organizations need to take advantage of Big Data investments [37].

Big Data technology helps in identifying prospects and creating values for organizational growth. Organizations are now using Big Data analytics and implementations to gain a competitive edge [23] in the aspects of information technology (IT) infrastructure, management, operations, organizational strategies and so on. Big Data implementation can facilitate business growth and business value creation which in turn result in increased organizational performance [7]. Organizations that fail to leverage on the benefits offered by Big Data are facing risks of being obsolete [30].

With the rapidly expanding digital world, Big Data significantly affects the main organizational elements including strategy, people, structure, rewards, and process [38]. Big Data allows for better decision making leading to its useful real time application [10]. Full benefits can be attained by businesses via enhanced process models aimed at producing Value to Customer (V2C). Big Data is primarily used in analysing markets and segmenting customers such as the collection of social media data streams via YouTube, Twitter, and Facebook as well as e-commerce websites where data of consumer feedbacks, patterns, and online reviews are analysed. Big Data also facilitates customer behaviour identification leading to system designs that fulfil customer needs such as the analysis of unstructured data on web browser clickstreams which identifies consumer patterns leading to service and product recommendations based on that analysis [39].

In sum, Big Data is used to identify customer needs, minimize cost, enhance processes, project risks and detect frauds [36]. It has been projected to be able to generate an annual revenue of $300 billion for the US healthcare industry, and €250 billion for the European public administration [1], [30]. These potentials can be achieved with high levels of advancement, engagement, and groundwork on applications, tools, and resources. Such lengths would nonetheless necessitate even more technology, labour, advancement and operative use of the Big Data capability. Regulations and policies would also need to be formulated to guarantee data security, accuracy, privacy, quality, and control [21], [40]. All these create a new critical issue that must be tackled prior to Big Data implementation.

05. Challenges of Big Data

Big Data whether structured, semi-structured, or unstructured is incessantly being gathered globally from a multitude of sources. Big Data from as small as megabytes (MB) to as massive as petabytes (PB) is difficult to be integrated due to the high speed of data flows [40]. The implementation of Big Data in terms of its collection, technology, organization and resources is mired with complex issues related to security, risks, privacy and ethical concerns [30]. Increasing data volume, variety and velocity lead to various possibilities and uncertainties which render better preparations. The implementation of Big Data hence requires preparing the necessary expertise, human resources, technology, and organizational elements [3].

The success of Big Data implementation depends on several factors. [41] highlighted three interrelated elements that could render the success or failure of Big Data projects i.e. the people, process and technology which are pertinent in managing data. The novelty of this technology requires a comprehensive focus on other crucial elements that might affect

its implementation [42]. A serious venture into Big Data implementation necessitates the preparation of adequate and proper tools, data management systems, governance, technologies, skills, and processes [43]. Similarly, [44] outlined the elements of People, Technology, Organization, Process, and Data Management as crucial for Big Data projects.

5.1 People Challenges

This issue entails finding technology experts on Big Data [45]. The development and application of Big Data will undoubtedly involve financial investments for obtaining new technologies, data experts, IT professionals and competent talents in the subject matter [46]. Big Data is a competitive advantage for businesses particularly in attracting human expertise [1], [30].

Without Big Data experts, the full potential of the technology cannot be harvested [15]. The ineffective and sluggish employment of Big Data is commonly caused by the lack of expertise [8], [28]. Data experts for instance possess the necessary skills and industry know-how to analyse Big Data properly so as to derive optimum outcomes. Specific business knowledge is also an advantage in this matter [43].

Since Big Data is a relatively new field, not many pure experts in this area can be found. Existing ones are known as data scientists [44]. Since the implementation is mainly focused on harvesting business values, Big Data projects need to consist of business experts from the early stages [43].

5.2 Technology Challenges

The growing data volume demands better storage systems, storage mechanisms, new environment, and technologies [16]. The issue of storage is expected and should be tackled at the initial stages of implementation. Conventional database systems are obsolete for handling the matter [43]; instead, advanced techniques, skills, and capabilities for collecting, storing, and analysing the massive volumes of data are needed such as Hadoop and Spark. Efficient processes are crucial to derive optimum values from Big Data implementation [16].

Existing data storage and processing systems are obsolete for managing Big Data [25]. Proper technological infrastructures and large processing capabilities are needed to manage the multitude structured, semi-structured, or unstructured Big Data [18]. The rapid growth in data volume also causes the inability to model and analyse the generated data at similar speeds [3]. Prevailing Big Data technology is still in its infancy [43]. IT-Infrastructure is needed as it can be well adjusted to the features of Big Data. Scalability is also crucial for analytical systems which need to control the varying velocity in capturing and analysing the massive volumes of data [43].

5.3 Organization Challenges

Despite the growing implication of employing Big Data analytics, many organizations worldwide are still unprepared to adopt the technology [44]. Prior to implementing Big Data, organizational stumbling blocks such as developing efficient value discovery processes, gaining top management involvement, emphasizing customer-centrism, and establishing the business side of Big Data implementation must be tackled first to ensure its effective adoption [47].

To gain a solid competitive edge, organizations must establish enhanced data management programs for managing, securing, and expanding the governance of Big Data. Similarly, data veracity needs to be identified and managed. With the kind of data velocity and volume involved, conventional systems are inadequate for monitoring data governance policies [10]. Prior to implementing Big Data, challenges related to governance, legal frameworks, policies and principles,

data management and protection, identity management and privacy must be managed first. This would entail comprehensive elimination of prevailing hindrances [10].

Before we are able to harness the full benefits of Big Data technology, adoption readiness is a crucial prerequisite [23]. Organizations would hence need the appropriate models and tools for supporting their decision making and business operations to attain optimal value from Big Data [25]. When the stumbling blocks have been identified and managed, customer value can be maximized, new revenue streams can be identified and competitive advantage can be ensured [48].

5.4 Process Challenges

The processing of large volumes of data is a problem for many organizations; hence, many are faced by the option of either keeping the mounting data or storing only those with crucial value. Hence, effective processes for identifying the most optimum business values that can be harvested from Big Data is needed [43]. With Big Data, the hindrances are in terms of its volume, velocity, variety, infrastructure, governance/policy, integration, compliance/regulation and visualization [32].

Processing issues begin from the stage of data capturing to its analysis, interpretation and presentation of results [48] which apply to either conventional data, Big Data or both [49]. Five data processing challenges have been identified by [48] namely acquisition and storing, mining and cleansing, integration and aggregation, analysis and modelling, and finally interpretation.

5.5 Data Management Challenges

The challenges with Big Data entail its capturing, management and governance [49]. Capturing and managing numerous types of large data volume in real time is the critical challenge in data management [50]. Data storage contains confidential data related to individual finances, medical records, personal data, and others [49]. According to [48], there are seven issues in data management namely security, privacy, information sharing, data, operational costs, data ownership, and data governance. Meanwhile, [49] outlined data management issues as related to storage, integration, quality, governance, content management, event processing, database administration, and others. Proper and effective Big Data management is vital for harnessing the actual benefits it offers [50].

[51] too emphasizes on the importance of proper Big Data management. Organizations that are new to Big Data will lack the necessary expertise and infrastructure in managing Big Data [50]. Organizations hence must have in place security infrastructures and privacy regulations that are robust enough to facilitate the governance of confidential data [49].

06. Conclusion

Big Data is a solid investment for producing and identifying new values and for uncovering hidden ones. As the digital world expands further, Big Data affects the elements of people, technology, strategy, structure, and process in organizations. The implementation of Big Data must begin with the management of its characteristics and prerequisites. With increasing data volume, changes can occur on the existing technologies, processes, and methods of analysis and management. Having the proper capabilities, technology, infrastructure, processes, data management tools, and human resources can ensure the successful implementation of Big Data. New opportunities can be identified by unlocking the true values of Big Data, managing the issues related to it, and properly preparing for its implementation. In sum, this paper had outlined the definitions, characteristics, implications and challenges of Big Data. It also highlighted the crucial

need for organizations to be properly prepared prior to adopting the technology. Future studies could use this review in further investigations on Big Data towards developing a methodical mapping that organizations can use to properly manage risks and to derive the full benefits of Big Data.

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