Big Data Impacts and Challenges: A Review

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***Abstract*— Data is everywhere, organizations, governments, clicks, web server, business partner, and even our body. Big Data comes to life with insights to improve the technology fashion and lifestyle with calling for readiness to change. Big Data has become a significant factor that could be a material asset for both business and government organizations. As such, it is important to understand the definition of Big Data, their key characteristics, and the challenges surrounding the concept and characteristics. The implementation of Big Data brings new critical challenges that need to be addressed before starting the Big Data journey. The main challenges that are commonly faced by organizations are the implementation of Big Data alongside the critical challenges that involve the challenges related to technology, organization, process, data management, and skills. The challenges are difficult and the growth in terms of Big Data is increasing exponentially which calls for further investigation. This paper reviewed the existing literature on Big Data to achieve three objectives: first, to highlight the definitions and characteristics of Big Data and to summarize the most common definitions of existing works; second, to identify the impacts and the opportunities for the Big Data; third, to present and identify the main critical challenges related to Big Data and categorize these challenges as (People, Technology, Organization, Process, and Data management) challenges.**

Keywords—Big Data; Big Data Challenges; Big Data Characteristics; Big Data Analytics; Data Management; Critical Success Factors.

I. INTRODUCTION

Data has grown in terms of the large scale in various fields. According to a report by the McKinsey Global Institute, refers to Big Data as a data-sets with the size that exceed the ability of traditional; database software tools to collect, store, manage and analyze these data [1] [2]. Most of the researcher defined the Big data 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]. Over the past few years, most of the primary technology player, including IBM, EMC, Microsoft, Oracle, Google, Facebook, SAS, and Amazon etc. have begun their Big Data plans. By highlighting IBM as a case, since 2005, IBM has invested 16 billion USD on 30 properties related to Big Data. Many of Big Data key players like SAS Institute, Gartner, IBM, McKinsey consulting corporations indicated to the Big Data as the next edge for innovation, productivity, competition, and quality [3]–[5].

In 2011, McKinsey predicted the Big Data in five domains (the public sector, healthcare, retail, manufacturing, and personal location data) would create about $223 billion [6]. The World Economic Forum highlighted the Big Data as the most remarkable technology of 2012. From an academic perspective, Big Data was also under the light. Most of the research investigated in the Big Data Analytics (BDA) capabilities to cover the dimensions of technology, process, talent, and management that positively affected the organizational performance[7]. Big Data academics have identified various Big Data capabilities and resources as a potential solid base for improving organizational performance. The organization's capability to gain the benefits from various forms of massive data is essential and the readiness for investments in Big Data is now at the center of attention [8], [9].

Recently it is common for organizations to face pressures and challenges to gain and keep their position in the competitive advantage market, identifying ways of cost reduction, improving quality, and reducing time to market [10]. The new era of Big Data transformation requires next-generation technologies, while the traditional capabilities will not achieve their purpose for handling Big Data. Organizations will need to handle it suitably not only for competitive advantage but also for survival in the new digital market[11]. The organization should search for their customers' needs and desires. In other words, the organization should move its data collection and analysis from just a product or service orientation to a future-oriented platform[12]. In addition, organizations should be able to identify the critical data sources, structure, required skills, and architecture, define the underlying process infrastructure that supports Big Data analysis, define a Big Data strategy, and measure the technologies and applications that support the organization's needs regarding preparation for Big Data journey[13].

The directions of existing literature toward the Big Data impacts, issues, and challenges are very limited and need more investigating [3], [14]. This review paper will address the gap and increase the awareness about the Big Data definition, impacts, and challenges. This paper is organized as follows: Section 2 defines Big Data and highlight the most common definitions from previous studies. Section 3 identifies the Big Data characteristics as accepted in existing literature. Section 4 discusses the Big Data impacts and opportunities. Section 5 identifies and discusses some critical challenges faced in Big Data implementation and categories these challenges as (People, Technology, Organization, Process, Data management) challenges. Section 6 serves as the conclusion.

II. DEFINITIONS OF BIG DATA

There are many definitions of Big Data. There is no single unified definitions shared between academia, business,

industry, media, and the various stakeholders. The lack of a systematic definition provide mystery around the Big Data concept [15]. The definition of Big Data is usually an individual, different from industry to another, and depending on the kinds of available software tools and the sizes of datasets are common in a specific industry [1], [16]. There have been considerable discussions from both industry and academia on the definition of Big Data [17]. By connecting the concept of Big Data with current grounded academic studies, the concept of Big Data can be more understandable. A clear view of Big Data concept will improve the awareness about the Big Data phenomenon for both practitioners and academics, leading to faster grown and more effective value creation from Big Data[18].

In 1997, scientists from NASA write a paper with the first definition of Big Data. They referred to the data volume as a provider for an exciting challenge for computer systems increase the demanding to the big volume of main memory, local disk, and as well as remote disk. NASA identified this as a problem of Big Data that need to obtain more resources [19], [20]. In 2001 the META Group analyst Doug Laney (now Gartner) defined data growth challenges and opportunities as being three□dimensional (volume, velocity, and variety) [15], [21]. In 2013, Big Data definition was updated by Gartner who defined the Big Data concept as "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], [19]. SAS define Big Data as "Popular term used to describe the exponential growth, availability, and use of information, both structured and unstructured"[22]. The International Business Machines Corporation (IBM) added another definition for Big Data "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", "Big Data is defined as large set of data that is very unstructured and disorganized", "Big Data is a form of data that exceeds the processing capabilities of traditional database infrastructure or engines" [14], [22], [23].

According to [11], today there is many different definitions and theories on what shape the Big Data. The most often cited definition shown the Big Data exceeds the reach of commonly used hardware environments and software tools to capture, manage, and process it within an acceptable time for its user. The concept of Big Data has improved to describe the new and powerful computational technologies that have been developed to process the huge volume of data. Big data has been defined in different ways but basically it is a new technology that is primarily characterized and derived from Business Intelligence and Business Analytics (BI&BA). It can create business value through its predictive analytics, and decision support capabilities, which provide the ability to deal with data that could not be processed using traditional approaches [24], [25]. According to previous definitions of Big Data, the most common definition of Big Data was coined 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".

III. The Characteristics Of Big Data

In the previous studies, Big Data is characterized as a new generation of technologies and architectures, designed to economically extract value from massive volumes of a wide variety of data, by enabling high-velocity capturing, discovery, and analysis [21]. Because the Big Data phenomenon is still relatively new, it's important for organizations to understand what makes this trend valued and they should recognize the "Vs" that define the key characteristics of Big Data [26] [27]. There are lots of ambiguity and confusion among the V's of Big Data. Some early studies highlighted that there are three, four, five, and seven characteristics of Big Data [28].

The large-scale features of Big Data is reflected in the three characteristics of volume, velocity, and variety. Traditional technology is not able to overcome the massive volume of data, which is generated at an increasing velocity, through online streaming, and from a variety of different sources, such as sensors, transactional systems, web platforms, product/service instrumentation, and social media [28]. These 3V's of Big Data is defined by META Group analyst Doug Laney (now Gartner) to describe the data management in three dimensions represented by a 3 main V's (Volume, Velocity, and Variety)[29]. These three definitions have been repeated by NIST and Gartner in 2012 and expanded by IBM to include the fourth V represented by " Veracity ". Oracle avoids using any Vs in their Big Data definition. Instead, Oracle emphasized that Big Data is the derivation of value from traditional relational database driven business decision making, grown with new sources of unstructured data [15].

Several studies such as [1],[13], [36], [27], [46], [47] have characterized the Big Data by a multi-V model 4Vs (volume, variety, velocity and value). Apart from these, another feature veracity is also identified. Volume refers to a massive amount of data. Velocity refers to the speed or rate with which the data is generated and processed. Variety represents the various sources and data types. Finally, Veracity refers to trust and uncertainty of Big Data and the outcome of the analysis of that data. Another study by [33], [34], highlight the four major characteristics of Big Data, volume, velocity, variety, and value that relates to the insight obtained by an organization from Big Data which not only demand for scalability, but also for better strategies and operational procedures [33], [35]. [36] declared five key characteristics or 5V's which are Volume, Velocity, Variety, Veracity, and Value [36], [37]. [38]–[40] added the "complexity" to their 4Vs (volume, variety, velocity, value) of Big Data. [41] highlighted management, and security as additional characteristics added to the 3Vs of (volume, variety, and value) and represented a critical problem of technical research that requires more investigation by researchers.

These days, another Vs are added to the characteristics of Big Data, which are namely: Validity, Variability/Volatility, Virtual, Visualization/Visibility)[42]. Another study by [2], pointed a seventh Vs for Big Data volume, velocity, variety, value, veracity, variability which is implying heterogeneity and inconstancy of data; and visualization which refers to imply the illustrative character of data. The most widely accepted and common V's are volume, velocity, variety, veracity, and value. However, the other V's also are significant for the Big Data paradigm. The five Vs (volume,

velocity, variety, veracity, and value) differentiating characteristics have formulated the difference between using traditional data and using Big Data [2], [18].

IV. The Big Data Impact And Opportunities

Every click on a website, phone call, blog entry, social media post, a credit-card purchase, or tweets, creates a record that can be stored and has the potential to be analyzed in a manner that will create tangible value for the business[11]. Big Data makes fundamental changes in all industries. The massive data generated in transactions enables marketers to measure and aware of the customers' pattern and needs accurately by applying Big Data technology than was previously possible [25]. Losing the market position in a competitive and fast-grown market has created a sense to combine the Big Data technology into today's organizational decision-making to gain added value for the business [43]. McKinsey & Company observed how Big Data generated fundamental values after a deep research on the U.S. healthcare, the EU public sector administration, the retail, the global personal location data, and global manufacturing. Through investigation on these five main industries that represent the global economy, McKinsey highlighted that Big Data may give an essential role to the economic function, improve the productivity and competitiveness of organizations and public sectors, and create massive benefits for consumers [17], [44].

Recently, industries and many government agencies become concerned in the power of Big Data and stated major plans to speed up the Big Data research and applications [17]. As a new hype in digital transformation world, Big Data has been highly expanding in many industries. Both the public sector and the private sectors, play an important role to invest in Big Data projects to ensure the benefits for organizations and society, improving the services, and increasing the effectiveness and efficiency[19]. Big Data produces new opportunities for discovering new values, helps organizations and governments to gain a deep understanding of the hidden values, and also incites new challenges and issues related to effectively organize and manage such datasets[17]. Big Data is a necessity for businesses to stay ahead in the competition. Big Data is helping the organizations in planning and taking the right decisions based on information gathered from various sources [45]. McKinsey summarized the values that Big Data could create to improve the efficiency, quality, and the potential value of the medical industry in the U.S gained through data may exceed USD 300 billion, therefore reducing the expenditure for the healthcare by over 8%; retailers that fully utilize Big Data may increase their profit by more than 60%; Big Data may also be used to improve the efficiency of governments operations and transactions to develop the economies in Europe and save over EUR 100 billion Big Data will have a huge potential in creating values for businesses and consumers [17], [44]. The Big Data technology market will expand at 12.8% over the next five years, which is also shown by IDC study which highlighted that the Big Data and business analytics (BDA) projects worldwide revenues will grow from $130.1 billion in 2016 to more than $203 billion in 2020. Due to the importance of Big Data in determining organizational well-being, it is very significant for the organizations to assess their current Big Data investments [46].

Big Data can play a big role in organizations to identify useful opportunities and create business value to support organizations' growth. In the complexity of the market environment, many organizations are adopting Big Data state-of-the-art to help them acquire a competitive advantage [25]. Most of the organizations have benefited from Big Data analytics and BD implementation in many ways, such as information technology (IT) infrastructure, managerial, operational, organization benefits, and strategic. BD implementation will also benefit from strategic long-term planning to support business growth and business value creation that leads to organizational performance enhancement [7]. The businesses need to use Big Data for business benefit, thus for those organizations that do not include Big Data as a strategy will be on risk area [37].

Despite the rapid change in the digital world, Big Data has a significant influence on the major elements of the organization (strategy, people, structure, rewards, and process) [47]. Big Data adoption enables organizations to make smarter decisions and perform them when it is most useful to the business and its stakeholders in real time [11]. Big Data helps organizations in earning maximum benefits by improving the business process models for Value to Customer (V2C) objective. To this end, organizations use Big Data mainly for market analysis and customers' segmentation. For example, organizations collect social media data streams like that provided by YouTube, Twitter, and Facebook. In addition, enterprises collect data from e-commerce websites to analyze customers' feedbacks, patterns, and online reviews. On the other hand, Big Data can also assist in discovering the customer behaviors which will enable the design of systems that meet the personal demands of each customer. For example, organization analyses unstructured data on the clickstreams of web browsers to know the customer patterns and recommend services and products according to that [48].

According to [49], organizations use Big Data to understand customer needs better, reduce the cost, make processes more efficient, and predict the risk and check frauds. Big data could generate $300 billion possible annual worth to US health care, and €250 billion to European public administration [1], [37]. The opportunities to achieve the benefits of Big Data require a high levels of development, participation, preparation in terms of the applications, tools, resources and people engagement. However, this investment requires more technology, efforts, better development and effective use of valuable Big Data. Also it need to formulate regulations and policies to ensure data security, accuracy, privacy, high quality, and control of the data [22], [50]. The concept of Big Data with new characteristics and requirements added a new critical challenge need to aware and addressed before starting the Big Data journey.

V. Big Data Challenges

Big Data is being collected every second around the world from various sources and with different forms structured, semi-structured, or unstructured data. Big Data stored in the form of bytes from as small as megabytes (MB) to as big as petabytes (PB), that cannot be easily integrated due to the unbelievable average of various data being flow with a high speed of data [51]. Big data with their characteristics also means new challenges involving complexity, security, uncertainty/risks, privacy and ethical

issue concern in collecting data, technology, organizational, and human resources, all of which might affect the organizational adoption of Big Data [37]. The growing volume, variety and velocity of data present opportunities, risks, and called for more preparations. The main challenges for riding the waves with the Big Data are related to having sufficient people, technology, and organizational preparation which can handle the Big Data characteristics [3].

There are different challenges to success in Big Data projects. According to [52] there are three equally important and interdependent components cause success or failure of an undertaking: people, process and technology". The challenges from perspectives of Technology, Process, and People have to be included in the strategies of information management. The technology is still immature and new to many organizations. Organizations need to pay another attention to other aspects which are importantly involved in Big Data projects [53]. If the organizations are serious about the investment in Big Data projects, they require to prepare for the Big Data challenges with a sufficient and suitable set of tools, data management techniques, governance, technologies, skills, and process [54]. [55]–[57] highlighted the People, Technology, Organization, Process, and Data Management as critical aspects required to ensure the successful implementations of Big Data.

A. People Challenges

The biggest challenge that most organizations will face in attempting to implement Big Data is preparing for Big Data implementation and finding technologists with experience in a Big Data environment [58]. The Big Data development and implementation requires monetary investment for acquiring new technologies, data scientist, trained IT professional and skilful people who have expertise in the Big Data area [59], [60]. Big Data will be the main competition for enterprises, thus introduce new competition attracting employees that have Big Data critical skills and talents [1], [37].

Big Data applications make a pressure for organizations to realize this new technology. A significant restriction on harvest the value from Big Data will be the shortage of skill and the lack of Big Data experts [16]. The slow adoption of Big Data left a gap related to the need for a sufficient preparation and to expertise people that support the decisions related to the adoption process [9], [34], [61]. Data scientists acquire domain expertise or industry knowledge, which is applied later in the analysis of Big Data to harvest the best results and revenue. They also develop a detailed knowledge of specific business practices within their organization [53].

Due to the novelty of the Big Data area, it is very difficult and expensive to find and to hire Big Data experts. These experts are often referred to as data scientists [54] [53].To ensure maximal success in Big Data implementation by focusing on business values, it is necessary for Big Data projects to involve experts from the business side from the beginning of the project [52] [53].

B. Technology Challenges

The increase in volume needs additional data storage system, storage mechanisms, new environment, and technologies that meet the demands of massive data [17]. Due to the large volume of data used in the Big Data projects, storage is going to be an issue needs to be addressed in early planning stages of the project. Furthermore, the traditional database systems won't be able to deal with the massive amount of data [53]. Big Data analytics requires a new technique, skills, and ability to collect, store, and analyze the data using data management tools that use the technology of Big Data like Hadoop, Spark, etc. The increase in volume needs additional data storage system, storage mechanisms, and new environment and technologies that meet the demands of massive data. This new revolution requires efficient processes to move the Big Data into a meaningful value [17].

Another challenge will add through one of the defining characteristics of Big Data is the unsuitability of current data storage and processing techniques to deal with the amount of data that can be generated by using the Big Data technology in business [28], [74]. Big Data application is difficult to perform without sufficient technology infrastructure. Because Big Data comes in all types of formats, structured data in traditional databases, semi-structured, or unstructured like emails and financial transactions, it needs large processing abilities [19], [64]. Also, volume and rapid growth of data increase every day and that precede the ability and capability of modeling and analyzing it at the same speed [3]. In Big Data projects the technology is still immature and still new to many organizations[53]. The availability of IT-Infrastructure, which can easily adapt to the Big Data characteristics, is required. Scalability is the most important characteristic of the analytical systems. The system has to be able to control the changing velocity of capturing and analyzing the large-scale of data [53].

C. Organization Challenges

As the organization's world recognizes the significance of using Big Data analytics, only a few organizations have started realizing the potential of Big Data, though many organizations are still struggling to manage their transactional and operational data and they are not yet ready enough to Big Data adoption [54], [65]. Organization challenges, which including challenges-related to (effective value discovery process; direct involvement of top management; customer-centric focus; strong business need for Big Data implementation) need to be handle to ensure the successful implementation of Big Data [66], [67].

For those organizations who looking to overcome the market competition, it is natural that they will need to improve their data management programs to manage, secure, and expand governance initiatives to address Big Data issues. The veracity of data must be recognized and handled. The ability of organizations to deal with the uncertainty in the quality of this data with the velocity and volume of data involved, traditional data monitoring and manual interventions will not be sufficient for data governance policies[11]. Challenges include issues related to governance, legal frameworks, policies and principles; data management and protection; identity management and privacy need to consider before using the Big Data. However, utilizing the full value of data in the organizations requires removal of many obstacles that still remain in the way [11].

The coming of the Big Data era provides a new opportunity, but to gain value from Big Data promises, organizational readiness is another essential challenge need

to assess [25]. Therefore, there is a need to provide organizations with models and tools to support their ability to gain value from Big Data to support decision making and business operation [28]. Unlock the power of Big Data and address the challenges related to Big Data to maximize customer value, identify new revenue streams and ensure competitive advantage, should be in the priority list for the organization [58].

D. Process Challenges

Many organizations are challenged processing the over growing the large amounts of various data. In order to handle this problem, organizations are likely to get to decide whether to keep all the growing data or store only the valued data. It is important for organizations to establish processes to identify the highest potential business value that can harvest from Big Data [53]. There are various challenges related to the characteristics of Big Data: data volume, data velocity, data variety, data infrastructure, data governance/policy, data integration, data compliance/regulation and data visualization [39].

The challenges related to process issues are a set of challenges meet the organization while processing and analyzing the data that is starting from capture the data to interpreting and presenting the value results[68]. This include collect, store, processing, and delivery the data whether traditional data, Big Data or both. [69]. [68] identified several data processing challenges that are related to Big Data and can be grouped into five steps that is data acquisition and warehousing, data mining and cleansing, data integration and aggregation, data analysis and modeling, and data interpretation.

E. Data Management Challenges

Organization encountered a group of challenges related to the management of Big Data, for example, while capturing, managing and governing the Big Data[69]. The most critical challenge to data management is to capture and manage massive volumes of data in real time and in various types [69], [70]. Data warehouses store huge amounts of sensitive data like financial transactions, insurance claims, medical procedures, personal data, diagnosis codes, etc. [69]. The study by [68] identified and grouped seven areas of challenges for data management such as security, privacy, information sharing, data, and cost/operational expenditures, data ownership, and data governance. Like other data related management challenges, data ownership is basically essential that need to address to can obtain the value of Big Data. Another study by [69] highlighted the data management challenges from another perspective as data warehousing, data integration, data quality, data governance, content management, event processing, database administration, and so on. According to Gartner, it is very significant for organizations to manage Big Data effectively to gain the hidden benefits which are not always visible [70].

The good data management is critical for Big Data analytics[71]. When an organization is new in Big Data, it typically has inadequate staffing or skills relative to managing Big Data, ineligible data management infrastructure[69], [70]. Organizations and businesses need to ensure that they have a solid security infrastructure, standard privacy regulations, that may govern the use of such sensitive information [69].

VI. CONCLUSION

Big Data became one of the most powerful investments for the organization that produces new opportunities for discovering new values and gain a deep understanding of the hidden values. Despite the rapid change in the digital world, Big Data has a significant influence on the major elements of an organization (people, technology, strategy, structure, and process). The concept of Big Data with new characteristics and requirements added a new critical challenge need to aware and addressed before starting the Big Data journey. It is important to realize that as data volume increases, the available technology, process, and methods of analysis and management may change. Organizations also need to ensure that they have the right capabilities, technology, infrastructure, process, data management tools, and human resources asset with Big Data experience and skills. Unlock the power of Big Data and address the challenges related to Big Data to maximize the Big Data value, identify new opportunities, and ensure the sufficient preparation for Big Data, should be in the priorities list for the organization. This paper highlighted the Big Data definitions, characteristics, impact, and (People, Technology, Organization, Process, and Data Management) challenges. Moreover, this paper clarified that the organization needs to be ready for handling the challenges before implementing the Big Data project. Based on this review paper the future work will focus on conducting more investigation related to the challenges of Big Data to provide a systematic mapping for the critical challenges that can be used by the organizations for effective risk management and to extract the maximum value of Big Data.

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