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Abstract

Big Data is a source of innovation that has captured the attention of citizens and decision makers in both the public and private sectors. Making use of the technology innovations in big data could contribute to economic growth and sustainable development and to capture the explosive growth of big data. For some time now, the world has stepped up in its focus on evidence based policy making and monitoring of development progress, hence the measurement and analysis of diverse sources of data, combined with advanced analytics, promise to create value for decision makers and society hence for economic growth and development.

There are 17 Sustainable Development Goals (SDGs), 169 SDG targets and 230 SDG indicators, The 17 Sustainable Development Goals and 169 targets demonstrate the scale and ambition of this new universal Agenda of countries to collect and maintain relevant standardized data such that it will support domestic technology development, research and innovation in developing countries.

This paper highlights the new technological innovations in big data and cloud computing which can lead to economic growth and sustainable development. Also, we present a comprehensive survey of the Big Data challenges, Big Data technology challenges, cloud computing and relevant technology landscape like Internet of Things (IoT) towards economic growth and technological innovation.

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1.0   INTRODUCTION

Big data refers to large, diverse, complex, longitudinal, and/or distributed data sets generated from instruments, sensors, Internet transactions, email, video, click streams, and/or all other digital sources available today and in the future (The National Science Foundation, 2012), datasets that could not be perceived, acquired, managed and processed by traditional IT and software/hardware tools within a tolerable time (Chen et al., 2014).

Big Data is a source of innovation that has captured the attention of citizens and decision makers in both the public and private sectors. While some would assert that Big Data currently is riding the crest of its "hype cycle" (Zwilling, 2014), application of Big Data has been effectively applied in numerous diverse settings and it is perceived to be as relevant for sustainable development in various sector of the economy like agriculture, finance, technology, transport, manufacturing.

Big data includes structured data, semi structured and unstructured data. Structured data are those data formatted for use in a database management system. Semi structured and unstructured data include all types of unformatted data including multimedia, web and social media content. Big data are also provided by myriad hardware objects, including sensors and actuators embedded in physical objects, which are termed the Internet of Things (Purcell, 2013). These types of data are sometimes also referred to as 'organic data' since they are not produced for statistical purposes and emerges independent of data collection efforts, which can be referred to as 'designed data' (Groves, 2011). Such emerging data sources can be mined and analyzed to monitor human and societal behavior in near real time and potentially turned into statistics.

Making use of the technology innovations in big data could contribute to economic growth and sustainable development and to capture the explosive growth of big data. For some time now, the world has stepped up in its focus on evidence based policy making and monitoring of development progress, hence the measurement and analysis of diverse sources of data, combined

with advanced analytics, promise to create value for decision makers and society hence for economic growth and sustainable development.

Several technologies are associated with Big Data and these could be evaluated and adopted for achieving Sustainable Development Goals (SDGs). There are 17 SD goals, 169 SDG targets and 230 SDG indicators, The 17 Sustainable Development Goals and 169 targets demonstrate the scale and ambition of this new universal Agenda. They seek to build on the Millennium Development Goals and complete what they did not achieve. They are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental. The goals and targets will stimulate action over the next 15 years in areas of critical importance for humanity and the planet (United Nations, 2015).

This paper highlights the technological innovations in big data and cloud computing which can lead to sustainable development. Also, we present a comprehensive survey of the V's of Big Data and challenges, cloud computing and relevant technology landscape towards innovation, specifically Internet of Things (IoT).

2.0   V's OF BIG DATA

Big data refers to datasets too large to be handled by traditional database systems hence the shift from the static mode to an accelerating data arena sharpened by volume, velocity, variety, veracity and value. The Volume dimension of Big Data is not defined in specific quantitative terms. Rather, Big Data refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze. This definition is intentionally subjective; with no single standard of how big a dataset needs to be to be considered big. And that standard can vary between industries and applications.

According to Manyika et al., 2011, three dimensions often are employed to describe the Big Data phenomenon: Volume, Velocity, and Variety. Each dimension presents both challenges for data management and opportunities to advance business decision making. These three dimensions focus on the nature of data. Marr (2015) present the first V which refers to the volume of data which is growing explosively and extends beyond our capability of handling large data sets; volume is the most common descriptor of Big Data (Hsu, Slagter, and Chung, 2015). For sustainable development, there is need to adopt the new technologies and techniques emerging

due to big data. An example of one firm's use of Big Data is provided by General Electric (GE) — which now collects 50 million pieces of data from 10 million sensors everyday (Hardy, 2014). GE installs sensors on turbines to collect information on the "health" of the blades. Typically, one gas turbine can generate 500 gigabytes of data daily. If use of that data can improve energy efficiency by 1%, GE can help customers save a total of $300 billion (Marr, 2014).

Velocity refers to the fast generation and transmission of data across the Internet as exemplified by data collection from social networks, massive array of sensors from the micro (atomic) to the macro (global) level and data transmission from sensors to supercomputers and decision-makers (Yang, Huang, Li, Liu and Hu, 2017). Sometimes it's not enough just to know what has happened; rather we want to know what is happening and an example is with real-time traffic information. Google Map provides live traffic information by analyzing the speed of phones using the Google Map app on the road (Barth, 2009). Based on the changing traffic status and extensive analysis of factors that affect congestion, Google Map can suggest alternative routes in real-time to ensure a faster and smoother drive.

Variety refers to the diverse data forms and in which model and structural data are archived. We can refer to data as numbers meaningfully arranged in rows and columns. The most novel and intriguing of the Vs of big data is variety. For Big Data, the reality of "what is data" is wildly expanded in diverse form of making data available. Some of the types of data available to be converted into information include: Financial transactions, movement of your eyes as you read this text, "Turns of a screw" in a manufacturing process, Tracking of web pages examined by a customer, Photos of plants, GPS locations, Text, Conversations on cell phones, Fan speed, temperature, and humidity in a factory producing motorcycles, Images of plant growth taken from drones or from satellites, Questions and so on. (Sonka, 2015).

Veracity refers to the diversity of quality, accuracy and trustworthiness of the data. In big data analysis the question of the data that is being stored, and mined meaningful to the problem being analyzed is of great importance. veracity in data analysis is the biggest challenge when compares to things like volume and velocity because it is the biases, noise and abnormality in data hence there is need to clean data and process to keep 'dirty data' from accumulating in your systems.

All four V's are important for reaching the 5th V, that is, Value, which focuses on specific research and decision-support applications that improve our lives, work and prosperity (Mayer-Schönberger and Cukier, 2013). Being able to translate data into sustainable development advantage is the core value of innovations which need to provide value to users and to do that in a way that provides incentives and compensation to the inventors (business entities employing the innovation to provide goods and/or services), policy makers and the entire populace. The processes of value creation and value capture, therefore, are keys to sustainable development.
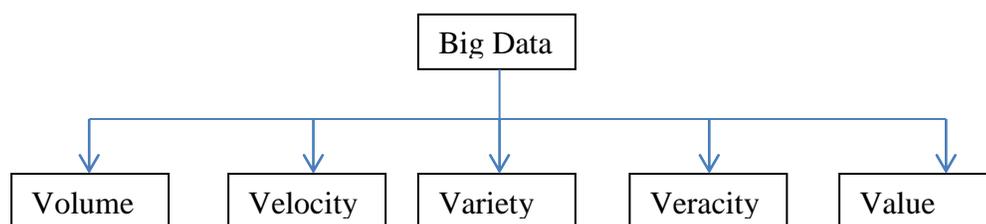
Fig 1: V's of big data

2.1 ECONOMIC GROWTH AND SUSTAINABLE DEVELOPMENT GOALS (SDGs)

There is broad consensus on the targets under the 5th subsection of the 9th Sustainable Development Goals (SDG) which seeks to Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending. To achieve sustainable and resilient infrastructure development and economic growth in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and Small Island developing States as identified in the subsection of the goals, big data has a role to play.

The SDGs emphasize the need to monitor each goal through objective targets and indicators based on common denominators in the ability of countries to collect and maintain relevant standardized data such that it will support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities. All these are achievable by turning the big data into information for policy making.

We should be collecting big data that can be used to model and test an array of different scenarios for sustainably transforming the production and consumption of energy, improving food and water security, and eradicating poverty. Also help to rebalance important biogeochemical cycles (especially the carbon, nitrogen and phosphorus cycles), mitigate climate change, reverse ocean acidification and reduce the loss of biodiversity (ICSU, 2015). Big data will help to illuminate the origins, nature and scale of these challenges, and how they relate to one another.

Technological innovations in Big Data can significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020 as part of the target of SDGs and other targets. Initiatives similar to those of the Intergovernmental Panel on Climate Change and the Global Ocean Observing System could fill the gaps in scientific, technical and socio-economic data.

3.0   BIG DATA: OPPORTUNITIES AND CHALLENGES

The increased mobile penetration and technological innovation which brings about production of data independently of any data collection effort such as surveys – it is often the data that is available as a by-product of user interaction with digital services, such as mobile phone records, social media posts (Twitter, facebook, Instagram, and so on) and online search records (Google search statistics such as that available through Google Trends) (Prydz, 2013).

Wesolowski et al (2012) shows how mobile phone data can be used to trace the spread of malaria in Kenya. By combining mobile phone data to trace people's movements and data on malaria incidence, they were able to trace the spread of malaria outbreaks across the country. In Rwanda, researchers used mobile phone data to investigate how Rwandan's transferred money to earthquake victims and to investigate internal patterns of migration (Blumenstock et al 2012).

According to Letouze (2012), in Indonesia, they show that the way people speak about rice on Twitter can be correlated with actual market price of rice. It is important to note that Big Data capabilities already are being employed within the food and agribusiness sector. Firms at the retail and manufacturing level are aggressively monitoring social media and other data sources to better understand and serve consumers. Bioinformatics has become an essential tool for firms providing genetic resources for crops and livestock. In addition to direct application of the

resulting information, linkages with associated partners at other levels of the sector offer the potential for further economic and social gains.

In recent years, public sector and government also use big data analytics to maintain the general services administration data for huge access. For example, Amazon Web Service (AWS) GovCloudis constructed to move exhaustive workloads to the cloud. Cloud computing and big data have reduced the execution time (both upload and download) and operational costs (Frost.com, 2016; Kim et al., 2014). Nowadays, Social networking and the internet have been playing a vital role in day-to-day life. Over 2 billion people are actively using social media each month as announced by Facebook recently. In the area of education, students on social networks communicate and interact with each other to get the best in their studies.

McAfee and Brynjolfsson (2012) report on an effort to monitor mobile phone traffic to infer how many people were in the parking lots of a key retailer on Black Friday — the start of the holiday shopping season in the United States — as a means to estimate retail sales. Also, given the expansion of mobile and online platforms for giving and receiving microloans means that today a large amount of microfinance data is available digitally and can be analysed in real time, thus qualifying it to be considered big data for sustainable development.

According to UN Global Pulse report (2012), properly analysed, Big Data offers the opportunity for an improved understanding of human behaviour that can support the field of global development in three main ways:

1. Early warning: early detection of anomalies in how populations use digital devices and services can enable faster response in times of crisis;
2. Real-time awareness: Big Data can paint a fine-grained and current representation of reality which can inform the design and targeting of programs and policies;
3. Real-time feedback: the ability to monitor a population in real time makes it possible to understand where policies and programs are failing and make the necessary adjustments.

Data will be used to guide decision-making and underpin evidence-informed policy action. New initiatives such as Global Pulse (www.unglobalpulse.org) could help in mining and mobilizing big data, which are available in real time as a result of the explosive growth in new media and these applications are highly promising. Big data present opportunities for sustainable

development if maintained and well managed; but, as has been emphasized over and over, there is nothing automatic, lest simple, about turning Big Data sources into actionable information in development contexts hence has its own challenges.

Big data challenges ranges from data storage to transmission, management, mining and knowledge discovery. The issue of data – as it is presented in Agenda 2030 (United Nations, 2015) – is identified as playing a fundamental and necessary role in the sustainable development space. The breadth of the 2030 Agenda for Sustainable Development and on-going development of ICTs provide opportunities for a more systematic and ambitious approach to data collection, management and integration.

a. **Data Storage:** Storage challenges are posed by the volume, velocity and variety of Big Data. Storing Big Data on traditional physical storage is problematic as hard disk drives (HDDs) often fail, and traditional data protection mechanisms (e.g. RAID or redundant array of independent disks) are not efficient with PB-scale storage (Robinson 2012). To meet the storage challenge, an increasing number of distributed file systems (DFSs) are adapted with storage of small files, load balancing, copy consistency and de-duplication (Zhang and Xu 2013) in a network-shared files and storage fashion (Yeager 2003)

b. **Data Transmission**

Data transmission proceeds in different stages of data life cycle as follows: (i) data collection from sensors to storage; (ii) data integration from multiple data centers; (iii) data management for transferring the integrated data to processing platforms (e.g. cloud platforms) and (iv) data analysis for moving data from storage to analyzing host (e.g. high performance computing (HPC) clusters). Transferring large volumes of data poses obvious challenges in each of these stages. Therefore, smart preprocessing techniques and data compression algorithms are needed to effectively reduce the data size before transferring the data (Yang, Long, and Jiang 2013).

c. **Data Management**

It is difficult for computers to efficiently manage, analyze and visualize big, unstructured and heterogeneous data. The variety and veracity of Big Data are redefining the data management

paradigm, demanding new technologies (e.g. Hadoop, NoSQL) to clean, store, and organize unstructured data (Kim, Trimi, and Chung 2014).

To address Big Data challenges, a variety of methodologies, techniques and tools are identified to facilitate the transformation of data into value for sustainable development. The next section introduces some of these methodologies and technologies that underpin Big Data handling

4.0   BIG DATA ANALYTICS AND VISUALIZATION

Big Data analytics is an emerging research topic with the availability of massive storage and computing capabilities offered by advanced and scalable computing infrastructures. Having data is not sufficient for sustainable development; the hidden 'beauty' of big data is the analytics. There are many big data analytics engines that take care of the variety of big data for sustainable development. Baumann et al. (2016) introduced the EarthServer, a Big Earth Data Analytics engine, for coverage-type datasets based on high performance array database technology, and interoperable standards for service interaction. The EarthServer provided a comprehensive solution from query languages to mobile access and visualization of Big Earth Data.

4.1   CLOUD ENABLING TECHNOLOGY INNOVATIONS FOR ECONOMIC GROWTH AND DEVELOPMENT

Computing and data have been moved from desktops, personal computers and super computers to large data centers located in geographically dispersed locations around the world (Sidhu and Kinger, 2013). It as a frame work for enabling a suitable on-demand network access to a shared pool of computing resources (such as networks, servers, storage, applications, services etc.) that can be provisioned and de-provisioned quickly with minimal management effort or service provider interaction.

Cloud based technologies with advantages over traditional platforms are rapidly utilized as potential hosts for big data. In general, cloud computing is defined by five attributes Multitenancy (Shared Resources), Massive Scalability, Elasticity, Pay as You go and Self-Provisioning of resources. While cloud computing emerged a bit earlier than Big Data, it is a new computing paradigm for delivering computation as a fifth utility (after water, electricity, gas and telephony) with the features of elasticity, pooled resources, on-demand access, self-service and pay-as-you-go (Mell and Grance 2011).
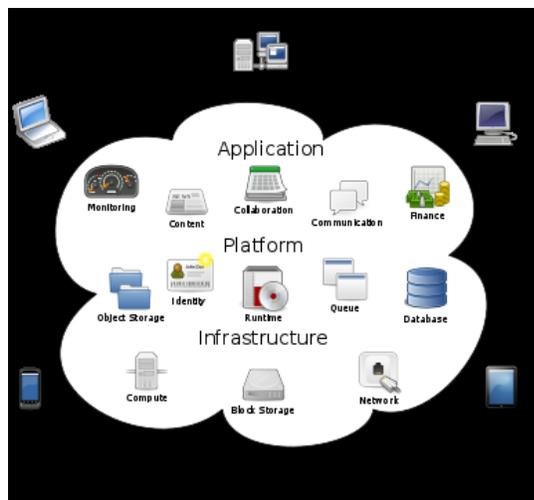
Shahzad (2014) defined cloud computing as "a disruptive technology that has the potential to enhance collaboration, agility, scaling, and availability, and provides the opportunities for cost reduction through optimized and efficient computing". Advocates claim that cloud computing allows companies to avoid up-front infrastructure costs (e.g., purchasing servers). As well, it enables organizations to focus on their core businesses instead of spending time and money on computer infrastructure. Proponents also claim that cloud computing allows enterprises to get their applications up and running faster, with improved manageability and less maintenance, and enables Information Technology (IT) teams to more rapidly adjust resources to meet fluctuating and unpredictable business demand (Wikipedia, 2017).

Fig 2: Cloud computing logical diagram Source: Wikipedia 2017

Cloud data are stored and accessed in a remote server with the help of services provided by cloud service providers. Providing security is a major concern as most of the data being transmitted are majorly done over the internet. Before implementing big data in an organization, security challenges needs to be addressed first.

4.2   INTERNET OF THINGS (IoT)

IoT as "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies". The IoT is used to connote set of related technologies that can be used together to achieve exciting ends, which include the use of sensors, RFID chips, nanotechnologies and identification systems (chips, cards, SIMs), among others. Overall, IoT and various related technical developments (including convergence, cloud services, data analytics and the proliferation of sensors) are resulting in:

1. Greater monitoring and measurement of humans, machines and things; as well as

2. A shift from human-to-human communications to M2M, something-to-everything, and everything to-everything communications.

3. Greater and more rapid awareness of and information about status, function, and environment.

IoT interventions are increasingly common in advanced economies; this can enhance sustainable development if emulated in developing economies. For example, Wearable sensors in watches, bracelets and even clothes can help users monitor their vital signs and improve their health and wellbeing. In homes, offices and factories, sensors can detect when rooms are in and out of use, enabling more efficient heating and lighting and helping improve working conditions. In many more environments, smart meters can coordinate the energy consumption of appliances to smooth out variations in overall energy consumption and achieve more effective use of variable renewable energy sources.

The advancement of IoT and mobility service is expected to bring the public within easy access to valuable results from Big Data and cloud computing. However, advancements are needed to provide the best information or knowledge enabling the public to make decisions including travel plans and health/property insurance (Abbas, A., K. Bilal, L. Zhang, and S. U. Khan, 2015). IoT technologies are also being used to address immediate challenges in humanitarian response, such as the Ebola outbreak in West Africa. The United States Agency for International Development (USAID) has supported and employed IoT solutions via connected wearable technologies. Sensor Technology and Analytics to Monitor, Predict, and Protect Ebola Patients (or STAMP2 for short) has been tested on Ebola patients in the United States and is being scaled up to meet the needs of government agencies such as USAID for its Ebola treatment strategy in Liberia (Biggs, P., Garrity J., LaSalle, C., and Polomska, 2016).

The IoT has the potential to improve health and wellbeing through greater efficiency and improved care in existing healthcare settings, by enabling greater use of remote telehealth provision, and enabling individuals to monitor their own health day-to-day, improve wellbeing and better manage conditions (such as stress, encouraging exercise and healthy eating), diagnose medical conditions more quickly and promote treatment regimes. In terms of preventative care, Apple and Google have added features to their latest smartphone operating systems to integrate

health sensor devices and promote users to monitor their own health data using non-specialist health tracking apps. (Biggs, P., Garrity J., LaSalle, C., and Polomska, 2016).

5.0 CONCLUSION

Technological innovations are unlocking opportunities to collect and analyze data in ways never before imagined. These Big Data 5V features and challenges will be driving the explosive advancements of relevant cloud computing technologies and internet of things in different directions for sustainable development. The availability and use of big data and cloud computing is an established and popular gear to policy making. One can turn such massive unstructured data into structured ones, and then to structured networks and actionable knowledge.

The analysis of data may lead to important insights and innovations that will benefit not only individual consumers, but society at large. While data is typically collected for a single purpose, increasingly it is the many different secondary uses of the data wherein tremendous economic and social value lies. For example, recent studies have shown that large-scale mobile phone data can help city planners and engineers better understand traffic patterns and thus design road networks that will minimize congestion. In many cases, the use of big data, such as for optimizing industrial systems, improving public safety, or understanding the environment, does not involve the use of personally identifiable information. However, when datasets do include personally identifiable information, organizations will need the tools to both protect privacy and enable data analytics.

Less economically developed nations will require investment in infrastructure and capacity for a data-driven process so as to enhance or achieve economic growth and sustainable development goals. The future of the sustainable development agenda will be data-intensive and its ultimate success will depend on international ability to mobilize the data revolution. This requires working across multiple scales (integrating international, national, local, and city-wide agendas). Considerable responsibility will fall upon researchers operating within the context of local, regional and global multi-stakeholders frameworks to provide the evidence base: but this will not be possible unless the data are openly available and the previously mentioned infrastructure and capacity needs are addressed.

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