

# Eco-Innovation and Industry 4.0: A Big Data Usage conceptual model

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**Abstract.** Driven by Cyber Physical Systems, Big Data Analytics, Internet of Things and Automation, Industry 4.0 is expected to revolutionize the world. A new era beckons for enterprises of all sizes, markets, governments, and the world at large as the digital economy fully takes off under Industry 4.0. The United Nations has also expressed its desire to usher in a new era for humanity with the Sustainable Development Goals 2030 (SDG's) replacing the Millennial Development Goals (MDG's). Critical to the achievement of both of the above-mentioned ambitions is the efficient and sustainable use of natural resources. Big Data Analytics, an important arm of Industry 4.0, gives organizations the ability to eco-innovate from a resource perspective. This paper conducts an analysis of previously published research literature and contributes to this emerging research area looking at Big Data Usage from a strategic and organizational perspective. A conceptual framework that can be utilized in future research is developed from the literature. Also discussed is the expected impact of Big Data Usage towards firm performance, particularly as the world becomes more concerned about the environment. Data driven eco-innovation should be in full motion if organizations are to remain relevant in tomorrow's potentially ultra-competitive digital economy.

## 1 Introduction

The rapid development of information and communication technologies (ICT's) has transformed economies and societies, fundamentally changing how human beings live and work. At the heart of the paradigm shift is the emergence of the digital economy (Hojeghan, Esfangareh, & Sciences, 2011). The digital economy has affected organizations, reshaping traditional markets into being more open and networked (Jetzek, Avital, & Bjørn-Andersen, 2014). Talk of the digital economy began as early as the year 2004, as researchers observed two paradigms, the growth of the internet and the digitization of information. These two paradigms would give rise to The New Economy (Carlsson, 2004). This New or Digital Economy, dynamic in nature, would be

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concerned with new products and activities rather than higher productivity alone (Carlsson, 2004). Present day research has buttressed the earlier prediction of the emergence of a Digital Economy (Garifova, 2015). The digitization and transmission of information via digital networks enables new opportunities to emerge for business development - giving rise to the digital economy (Garifova, 2015).

The digital economy continues to gather pace and momentum, with business models and methods of consumption being remodeled. For instance, the digital economy has been instrumental in the emergence of disruptive digital business models such as Airbnb (Martin, 2016). In fact, the disruptive digital business models have been indispensable in the establishment of the sharing economy. The successes of the Silicon Valley enterprises such as Airbnb and Uber for instance, have catalyzed the proliferation of the digital economy (Cockayne, 2016). Through Cyber-Physical Systems (CPSs), Industry 4.0 is expected to merge the digital and physical domains. This in turn will drive the digital economy by further improving the already established digital business models, as well as the creation of new digital business models (Pereira & Romero, 2017).

Networks and data traffic are indispensable for Industry 4.0. Networks and data connecting machines enable data exchange. These aspects also go hand in hand with digitalization (Fernández-Miranda, Marcos, Peralta, & Aguayo, 2017). Increasingly large amounts of Information (data) can now be compressed, transported, unpacked and analyzed at high speed, at any location in the world that has access to network or data centers (Inniss & Rubenstein, 2017). Big Data is the term used to refer to this increasingly large information/data. Big Data contains a plethora of unstructured data when compared to traditional data (M. Chen, Mao, & Liu, 2014). Real-time analysis is needed for unlocking meaning and value from Big Data (Günther, Rezazade Mehrizi, Huysman, & Feldberg, 2017). As a result, Big Data creates potential challenges – particularly regarding the management and organization of the collected data. However, utilizing Big Data presents organizations with an opportunity of value creation and enables firms to gain an in-depth understanding of the Big Data in their hands (M. Chen et al., 2014).

Apart from Cyber-Physical Systems, Big Data Analytics (BDA) is also anticipated to be one of the active drivers of the Industry 4.0 (Zhong, Xu, Klotz, & Newman, 2017). In addition to BDA and CPS, other key information and communication technologies that will buttress Industry 4.0 and the digital economy are cloud computing, and the Internet of Things (IoT). These key technologies are expected to spark new ideas that will drive Industry 4.0 and the Digital Economy (Zhong et al., 2017).

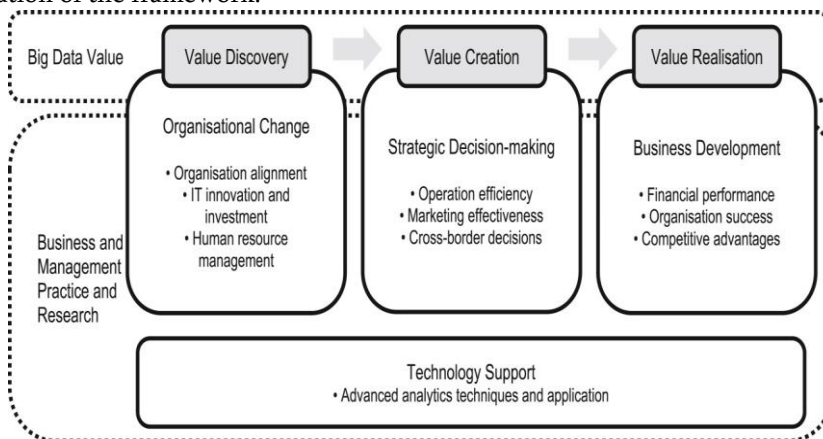
Big data when coupled with new generations of Big Data Analytics avails much opportunities for businesses. New generation Big Data Analytics enable organizations to fully utilize Big Data. As a result, the capability of organizations to utilize Big Data (Big Data Usage), is a growing area of importance and a potential source of a competitive advantage (Gupta & George, 2016). Despite these facts and the hype about big data utilization as a key trend, the phenomenon has yet to be fully investigated from a strategic and organizational perspective (Morabito, 2015). In fact, the dynamic nature of the global environment demands dynamic capabilities as well as a good strategy. These

two aspects are essential to enterprises in their quest to attain and sustain superior performance. Thus, firms need to constantly assess and reconfigure their resources and strategies, so as to be aligned to the ever-changing competitive landscape (Teece, 2014). Furthermore, despite the increase in publications concerning Big Data, studies that showcase the mechanism with which Big Data Usage can potentially buttress decision making and consequently drive positive firm performance are scant (Arunachalam, Kumar, & Kawalek, 2018). In addition, studies that investigated the relationship between Big Data usage and firm performance have produced mixed results (Wamba et al., 2017). For instance, it was found that big data utilization induces positive firm performance (Tan, Zhan, Ji, Ye, & Chang, 2015; Wang, Gunasekaran, Ngai, & Papadopoulos, 2016; Zhong et al., 2015). However, prior investigations argued that big data utilization does not deliver superior firm performance (Finlay, 2014; Irani, 2010). It was conceded that more research in this area would be helpful in addressing this gap (Gunasekaran, Kumar Tiwari, Dubey, & Wamba, 2016; F. Li, 2018).

This paper therefore, contributes to this research area by taking a look at the role and contribution of Big Data Usage from a strategic and organizational perspective. This paper also considers the outcome of utilizing Big Data from a strategic and organizational perspective. These two aspects are critical, given the much anticipated Fourth Industrial Revolution/Industry 4.0 (Tjahjono, Esplugues, Ares, & Pelaez, 2017).

## 2 Research Objectives

Analyzing and interpreting big data (Big Data Usage) can enhance a firm's strategic decision making. Big Data can be a vital cog of the organization's strategic machinery. A firm's performance hinges on its ability to make strategic decisions. Hence, in order to unlock value from Big Data Usage, it is proposed that a framework should factor in strategic and organizational factors (Sheng et al., 2017). The figure 1 below gives an illustration of the framework:



**Fig. 1.** Potential role of strategic and organizational factors in Big Data Usage (Sheng, Amankwah-Amoah, & Wang, 2017).

So therefore, the main objective of this paper is to develop a theoretical framework that can be used to investigate Big Data Usage from a strategic and organizational perspective.

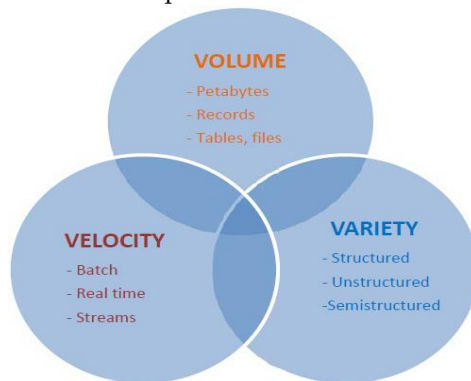
This theoretical framework will help in identifying potential pathways for the formulation of data-driven strategies and the outcome.

### 3 Literature Review

In order to build and sustain a competitive advantage, a firm can utilize several resources such as its capabilities; organizational processes; firm attributes; information; knowledge; as well as all assets. The control of the variables by the organization must enable it to formulate and implement strategies that improve its efficiency and effectiveness. Knowledge and information is one of the key components in organizational information processing abilities and firm decision making (Barney, 1991). Hence, the collection and usage of Big Data enables firms to potentially exploit two resources: knowledge and information. The organization they have accumulated through data collection. Creating the conditions for optimum usage of a firm's resources could possibly help it generate higher returns of time (Wernerfelt, 1984).

#### 3.1. Big Data and Firm Performance

A relationship exists between three aspects relevant to organizations: data, information, and knowledge. Knowledge can be arrived at through information. Information in turn constitutes of data. Hence it is imperative to look at and define data (Schuster, 2017).



**Fig. 2.** The Three V's of Big Data (Fernández-Miranda et al., 2017)

Big Data is explained as being data that is beyond the capacity capabilities of conventional database systems. This comes about as a result of the data being either too large, moving too quickly, or exceeding the limitations of the structure of present dataset architectures (M. Chen et al., 2014). Hence, if organizations are to salvage value from such copious amounts of data, alternative ways of processing the data must be considered (McAfee & Brynjolfsson, 2012). The above challenges - posed by big data - birthed the notion of big data being defined in terms of its characteristics: volume,

variety, and velocity (Zikopoulos & Eaton, 2011). These also popularly referred to as the 3V's in short (M. Chen et al., 2014; Johnson, Friend, & Lee, 2017).

### *3.1.1 Big Data Volume*

Under Big Data, Volume concerns the magnitude of data. The sizes of Big Data are usually denoted in terabytes and petabytes (Gandomi & Haider, 2015). For example, it was approximated that the internet provides about 12 terabytes of Tweets daily (Morabito, 2014). One of the reasons that organizations should be enticed by big data analytics is the benefits enjoyed by having large of information to process (Morabito, 2014). Applying simple mathematics to large amounts of data can be greatly effective. Having more information could be an asset for firms, as it could help them predict business aspects such as demand (Dumbill, 2012). Furthermore, collecting more information enables organizations to have a clearer picture so that they can make firm level strategic decisions (H. Chen, Chiang, & Storey, 2012). For instance, firms could then know whether to explore markets or exploit markets given the information they have. This may be more difficult or less reliable with few information (Dumbill, 2012). In addition, Big Data volume helps firms improve their product sentiment analysis (Morabito, 2014).

However, there was also a sobering discussion - concerning the challenges Big Data Volume bring to organizations. The challenges emanate from the fact that, most organizations possess conventional Information Technology storage structures and Software (Provost & Fawcett, 2013). However, current Volumes of Big Data being generated have overtaken the capacity of conventional databases for organizations. Current Volumes of Big Data are outstripping the processing ability of most organizations' software (Provost & Fawcett, 2013). Despite this, it was argued that argued that Big Data Volume is likely to be more beneficial to firms in their market forecasts, planning and other crucial strategic planning tools (Dumbill, 2012).

### *3.1.2 Big Data Velocity*

Velocity of Big Data is concerned with the generation and arrival speed of data. Velocity also factors in the speed at which the generated data should be processed and acted upon (Gandomi & Haider, 2015). Therefore, Big Data Velocity considers the time sensitive nature of data. Digital devices such as smartphones and sensors have contributed to unprecedented velocity of Big Data. As a result, there is a growing need real time analysis of Big Data (Kitchin, 2014).

Drivers of big data have facilitated the increased rate at which the volumes of data are captured by the organization. The speed at which organizations process and analyze data is important and is related to the dynamics of data volume. This is often where firms can be able to exploit the data streams being created, and sometimes - done in real time - i.e. data is processed and analyzed as it is created or arrives (Kitchin, 2014; Morabito, 2015). For instance, real-time big data analysis of created data streams from

millions of daily telecommunications records could predict peak hours or customer switch (Terzi, Terzi, & Sagioglu, 2017).

Another potential problem of big data has also been observed. As was found in big data volume, the ability to analyze big data in real time is hampered by a lack of IT infrastructure and analytical software. Capturing and analyzing Big Data in real time often required specialized IT infrastructure and software (Marz & Warren, 2015). But, a sizable number of firms still possess previous generations of IT infrastructure and analytical software, making big data velocity troublesome for them (Fan, Han, & Liu, 2014).

However, firms that have committed to invest in IT infrastructure and software, have the ability to do real time analysis (Buhl, Röglinger, Moser, & Heidemann, 2013). For instance, it was found that one organization in the financial services sector was able to analyze and correlate close to five million market messages per second. Once analyzed, they are able to execute algorithmic option trades, all with a latency of 30 microseconds on average (Zikopoulos et al., 2013).

### *3.1.3 Big Data Variety*

Variety is concerned with how the dataset is structured that is, structured, semi-structured, and/or unstructured data (Gandomi & Haider, 2015). As technology has advanced, firms are not able to use the different types of data. Big Data, which is now being driven by different aspects such as IoT, smartphones, the internet or social media can come in different categories (Morabito, 2015; Sagioglu & Sinanc, 2013). The type of the data often is a measure of its richness. The variety aspect of big data attempts to capture the data that are utilized in the decision-making process. Data can range from text, log files, audio, video, Global Positioning System signals, network sensors or images posted on social media (Amini, Gerostathopoulos, & Prehofer, 2017).

Variety of Big Data is not something that is new to organizations. Approximately 95 percent of Big Data is unstructured. Organizations have access to unstructured Big Data from internal and external sources. This Big Data needs to be prepared and neatly organized. Doing so enables it to be ready for integration into application. For instance, the task of making sense out data such as opinion and intent musings on Facebook may create a need for moving data from source data to pressed application data (Dumbill, 2013).

Emerging Big Data Analytics and new data management technologies enable firms to innovatively leverage collected Big Data into their business process so as to achieve better performance. For instance, organizations can utilize large volumes of semi-structured data from their website for better marketing, cross-selling, and further improving their website design (Gandomi & Haider, 2015). Firms are beginning to realize the strategic potential of Big Data utilization. Utilizing the Big Data also has the ability to help organizations generate revenue from new streams and improve their operational efficiency, resulting in the firm building a competitive advantage over rivals (Sivarajah, Kamal, Irani, & Weerakkody, 2017).

### **3.2. Big Data, Eco-Innovation Strategy and Firm Performance**

There is great importance in assessing the strategic configuration of the organization itself. Organizations can ask themselves the question 'Is the configuration getting the best out of/exploiting the organization's resources and competencies?' (Wheelen, Hunger, Hoffman, & Bamford, 2014). In order to harness exploit a resource (Big Data), organizations need to be configured to optimize this resource (Tulder, 2014; Wheelen et al., 2014).

Innovation is the source of value creation (Vargo, Wieland, & Akaka, 2015). Innovations also have the ability to create competitive advantages for organizations (Reyppens, Lievens, & Blazevic, 2016; Tantaló & Priem, 2014). Firms are also afforded another avenue to differentiate themselves from technology driven innovations. For example, technological developments such as Big Data have enabled companies who fully utilize this data to differentiate themselves from competitors (Hemerly, 2013).

Usage of Big Data also offers firms with opportunities of not only innovating, but in eco-innovating (Man & Strandhagen, 2017). Organizations need to think about sustainability, and innovations in terms of their approach to production and consumption (McIntyre, Ivanaj, & Ivanaj, 2013; Rennings, 2000). For example, Big Data collection and usage could enable firms to design eco-products, use fewer raw materials, and recycle more products (Man & Strandhagen, 2017). Firms, which implement a green business strategy - are able to generate a positional competitive advantage. The competitive advantage became stronger where there was high regulatory intensity, high public concern, high market dynamism, and high competitive intensity (Leonidou, Christodoulides, Kyrgidou, & Palihawadana, 2017). The competitive advantage enabled firms to gain heightened financial and market performance. For instance, organizations are seeking Leadership in Energy and Environmental Design (LEED) Certifications for their commercial and institutional buildings so as to positively impact their triple bottom line performance (Newsham, Mancini, & Birt, 2009).

Organizations that pursue sustainability in their business approach have witnessed a notable increase in innovation as well as risk mitigation (Wheelen et al., 2014). Whilst, organizations have a long-term responsibility to shareholders, the environment and society's wellbeing must also be roped in to measure the firm's true performance. Organizations that focused on business sustainability saw their employees register higher levels of community engagement and more creative involvement (Cheng, Ioannou, & Serafeim, 2013). In addition, earnings per share (EPS) of organizations which adopted business models that paid attention to environmental sustainability issues grew close to four times more than organizations that did not (Glavas & Piderit, 2009).

Eco-Innovation however is in need of further research. Organizations struggle in their quest to successfully embed eco-innovations (Xavier, Naveiro, Aoussat, & Reyes, 2017). There is a need to assess performance from a holistic perspective, as financial performance of eco-innovating firms is inconclusive (Hojnik, Ruzzier, & Antončič, 2017). Making distinctions concerning the type of eco-innovation could be helpful.

Knowing the type of eco-innovation which drives the most influence towards performance would be helpful as this research is still in its infancy (Hojnik et al., 2017).

#### 4. Methodology

This paper conducted a literature search of the emerging subject area of Big Data as well as Eco-innovation. The literature search consisted of two parts; a library search on the subject matter and a search of previous research literature publications. The library search entailed usage of online and offline materials. The search of article journals as well as book chapters that discussed the subject matter of Big Data as well as Eco-Innovation was undertaken during the library search. The search keywords featured in this paper were limited to: “Big Data Usage” AND “firm performance”; as well as “sustainable innovation strategy” OR “Eco-innovation strategy” OR “environmental-innovation strategy” AND “firm performance”:

**Table 1.** Literature Search Keywords

Keyword	Authors	Total
Big Data Usage	(Akter, Wamba, Gunasekaran, Dubey, & Childe, 2016; Côte-Real, Oliveira, & Ruivo, 2017) (Amini et al., 2017; Sagioglu & Sinanc, 2013) (Arunachalam et al., 2018; Tan et al., 2015; Wamba et al., 2017; Wang et al., 2016; Zhong et al., 2015) (Fan et al., 2014) (Gandomi & Haider, 2015; Johnson et al., 2017) (Gunasekaran et al., 2016) (H. Chen et al., 2012; Kitchin, 2014; Provost & Fawcett, 2013; Terzi et al., 2017) (Hemerly, 2013) (Janssen, van der Voort, & Wahyudi, 2017) (M. Chen et al., 2014; Günther et al., 2017; Gupta & George, 2016; Zhong et al., 2017) (Secundo, Del Vecchio, Dumay, & Passiante, 2017) (Sheng et al., 2017) (Sivarajah et al., 2017)	26
Eco-innovation Strategy	(Díaz-García, González-Moreno, & Sáez-Martínez, 2015; Mat Dahan, Mohd Yusof, & Taib, 2017) (Fernando & Hor, 2017) (Fernando & Wah, 2017; Lee & Min, 2015) (Ghisetti, Marzucchi, & Montresor, 2015; Ociepa-Kubicka & Pachura, 2017) (Hojnik et al., 2017; Xavier et al., 2017) (Munodawafa & Johl, 2018) (Rennings, 2000) (Shaharudin, Fernando, & Wah, 2016)	11
Sustainable Innovation Strategy	(Shrivastava, 2013) (Shrivastava, Ivanaj, & Ivanaj, 2016)	2
Environmental Innovation Strategy	(Long et al., 2017) (Newsham et al., 2009) (Watson, Wilson, Smart, & Macdonald, 2017)	3
<b>Total</b>		<b>42</b>



These search keywords were utilized because they are useful and essential in the selection of topics to review in the content analysis. Hence, having the above words mentioned in the title, abstract or keywords gave a reason for evaluation of previously published material that featured these keywords. The previously published material used as references in this paper were not taken from a single country, but were taken from global contexts.

The research literature publication search entailed the usage of and reference to online databases.

**Table 2.** Literature Search Sources

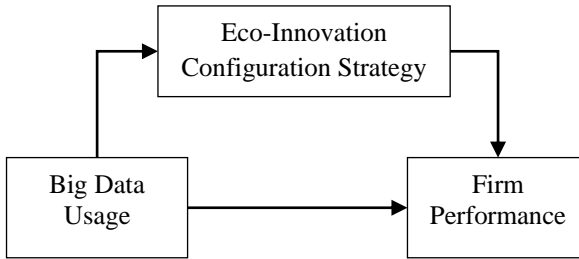
Database	Number
Science Direct	20
Google Scholar	10
Springer	2
Web of Science	2
IEEE Conference Publication	4
SCOPUS	4
<b>Total</b>	<b>42</b>

The online databases utilized during the research literature publication search were Scopus, Web of Science as well as Google Scholar, Science Direct, Springer, and IEEE Conference Publication. These databases are reliable and provide a basis for conducting a robust research literature publication search (Falagas, Pitsouni, Malietzis, & Pappas, 2007). Modern researchers pointed out the effectiveness of these databases (Díaz-García et al., 2015; Mat Dahan et al., 2017; Watson et al., 2017; Xavier et al., 2017).

## 5. Conceptual Framework and Hypothesis

### 5.1 Conceptual Framework

Big Data is actually a plethora of complex data that is collected from different instruments as it moves from acquisition, storage and sharing, analysis and visualization (Davenport, 2014). In this study, Big Data Usage refers to the utilization of the Big Data collected by organizations (Johnson et al., 2017). The usage is based upon the three dimensions of Big Data – that is, Volume, Velocity and Variety, by firms that collect this data as described under the Literature Review section.



**Fig. 3.** Conceptual Framework (Johnson et al., 2017; Tippins & Sohi, 2003; Zhang, Wang, Li, & Cui, 2017)

## 5.2 Hypotheses

### 5.2.1 Big Data Usage and Firm Performance

Research suggests that Big Data is a key resource, in accordance with the resource based view theory (Barney, 1991; Newbert, 2008). Big Data is a key resource, especially in decision making. Big Data also helps to bridge gaps within organizations, by removing silos (Pries & Dunnigan, 2015). Big Data systems enable the placing of information in a central, accessible place. Big Data also bridges the gap between technical variables whilst concurrently being pragmatic in lowering costs. Risk minimization becomes another spin off benefit of Big Data (Pries & Dunnigan, 2015).

Furthermore, usage of Big Data was found to be a significant predictor of firm performance, meaning that when companies utilize the Big Data, they are able to register better firm performance than those who do not. In addition, it was also found that Big Data proved to be an important strategic antecedent (Akter et al., 2016). Big Data usage was also pivotal in value creation (Côte-Real et al., 2017). However, the relationship between Big Data Usage and Firm performance is still debatable (Wamba et al., 2017). For instance, in some instances big data utilization did not deliver superior firm performance (Finlay, 2014; Irani, 2010). More research in this area would be helpful in addressing this gap (Gunasekaran et al., 2016; F. Li, 2018). Therefore, it is expected that:

**H1:** Big Data Usage is positively related to Firm Performance.

### 5.2.2 Big Data Usage and Eco-innovation configuration strategy

Innovation itself as a process is a result of an invention and diffusion i.e. its successful establishment into a market (Seliger, 2001). Eco-Innovation is not exempted from these two factors. Eco-innovation encompasses processes that result in sustainable development. Firms need to understand the concepts and value of environmental issues so that they may leverage their resources and capabilities to usher in sustainable development (Shrivastava et al., 2016). Leveraging the firm's capabilities will allow

them to exploit new opportunities emerging from these challenges (Fernando & Hor, 2017).

Enterprises ought to take advantage of the potential of Big Data (Janssen et al., 2017), particularly because of its potential in assisting eco-innovation and sustainable development (Man & Strandhagen, 2017). As a result of its potential, enterprises are striving to find methods to harness the potential of Big Data as a vital decision making apparatus (Janssen et al., 2017). One of such potential uses is innovation configuration (Zhang et al., 2017). For instance, Big Data from developed technologies is useful in product lifecycle management (Q. Li, Luo, Xie, Feng, & Du, 2015). As information technologies develop, Big Data can now originate from various sources, and facilitates a sensing environment for enterprises (Q. Li et al., 2015). Furthermore, the increase in cloud computing, mobile internet, and Internet of things contribute to Big Data, originating from different sources. This needs organizations to meet the new challenges posed from the variety of the data such as converging, fusing and processing all the data from the various sources (Q. Li et al., 2015). Big Data is also an asset for enterprises as it helps in problem solving, activity coordination, plan development and strategy configuration (Cummins, 2017). Despite these findings, researchers conceded that more research is needed. Studies that showcase the ability of Big Data Usage in driving organizational decision making and consequently drive positive firm performance are scant (Arunachalam et al., 2018). Therefore:

**H2:** Big Data Usage is positively related to Eco-Innovation Configuration Strategy.

### *5.2.3 Eco-innovation configuration strategy and firm performance*

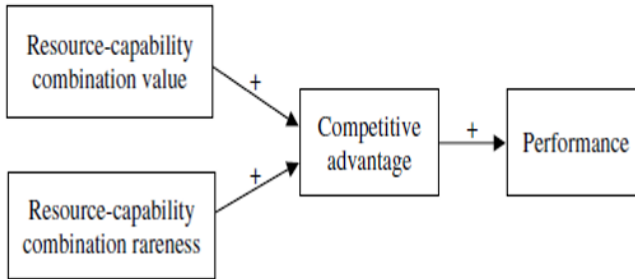
The concept of eco-innovation can be utilized as an apparatus to improve firm performance. The firm's performance improves as a result of eco-innovation practices. Adopting cleaner production processes results in companies producing less wastes and greenhouse gas emissions (Fernando & Wah, 2017). Companies that implement some sort of eco-innovation strategy stand to reap financial returns. These are realized as a result of lower production costs whilst concurrently saving the environment (Fernando & Wah, 2017).

Green research and development, a facilitator to eco-innovation was positively related to financial performance of the firms they examined (Lee & Min, 2015). Hence, firms need to configure their unique resources and capabilities in line with a proactive environmental strategy. Adoption of a proactive environmental strategy would enable firms to configure themselves, helping to get the best out of the resources and capabilities. This would in turn, result in superior performance (Lee & Min, 2015). Environmental innovation is paramount to organizations, as it was found to act as a catalyst to sustainable development (Long et al., 2017). Cleaner production processes also help to reduce environmental pollutions (Long et al., 2017). Therefore:

**H3:** Eco-Innovation Strategy Configuration Strategy is positively related to Firm Performance.

### 5.2.4 Eco-innovation Strategy Configuration

Value as well as rareness contributes positively towards establishing a competitive advantage (Newbert, 2008). This competitive advantage then in turn enhanced the performance of the firm in the positive. Furthermore, future scholars have been encouraged to address the lack of research in this area by continuing to conduct tests of the RBV. This will help scholars have more robust, rigorous evidence to confirm, refine and supplement the RBV's fundamental hypotheses (Newbert, 2008).



**Fig. 4.** Resource Based Drivers of Competitive advantage (Newbert, 2008)

Previous empirical studies have identified various variables as being the drivers of eco-innovation (Ghisetti et al., 2015; Munodawafa & Johl, 2018; Ociepa-Kubicka & Pachura, 2017; Xavier et al., 2017). These drivers of eco-innovation have been shown to have a positive link to firm performance (Fernando & Wah, 2016; Shaharudin et al., 2016). However, further research will also enrich the level of understanding on the importance of resources and capabilities, with regards to organizations' success and survival (Lin & Wu, 2014; Munodawafa & Johl, 2018; Newbert, 2008; Schneider & Spieth, 2013). In addition, despite big data utilization being a hot topic, it has yet to be fully investigated from a strategic and organizational perspective (Morabito, 2015). Therefore, this paper hypothesizes that:

**H4:** Eco-Innovation Strategy Configuration Strategy positively mediates the relationship between Big Data Usage and Firm Performance.

## 6. Conclusion

This paper has undertaken an analysis and review of previously published research literature. The areas that this paper has looked at are the emerging areas of Big Data and Eco-innovation. This paper sought to develop a conceptual framework that can be utilized in future research in the area of Big Data as well as Eco-Innovation, and how these emerging areas are expected to impact the performance of the firm. As Big Data can be considered a resource, utilizing this resource for an expected outcome can result in firms obtaining a competitive advantage through enhanced competency. This sustained competitive advantage can help organizations register better performance compared to their competitors.

In addition, Big Data gives organizations the ability to eco-innovate from a resource perspective i.e. more information and knowledge. Having this resource will allow firms to develop competency (eco-innovate) which in turn impacts its performance via a competitive advantage.

Another spin off of Big Data usage by organizations is in driving innovations (Hemerly, 2013). Having more information and knowledge through Big Data increases the intellectual capital of organizations (Secundo et al., 2017). Firms are also using increased intellectual capital to engage in ground-breaking sustainability innovations, signifying the growing importance of eco-innovating (Amin & Aslam, 2017).

Lastly, leading industry analysts believe that an organization's eco-innovation attempts leads to better performance and may provide firms better access to capital as well as be used to earn employees' trust and loyalty (Carmeli, Brammer, Gomes, & Tarba, 2017; Krisher & Durbin, 2017; OECD, 2017). Therefore, it would be interesting to note what the results from the empirical testing of this developed conceptual framework would be to firms.

## References

- Akter, S., Wamba, S. F., Gunasekaran, A., Dubey, R., & Childe, S. J. (2016). How to improve firm performance using big data analytics capability and business strategy alignment? *International Journal of Production Economics*, *182*, 113-131. doi:<https://doi.org/10.1016/j.ijpe.2016.08.018>
- Amin, S., & Aslam, S. (2017). Intellectual Capital, Innovation and Firm Performance of Pharmaceuticals: A Study of the London Stock Exchange. *Journal of Information & Knowledge Management*, *16*(02), 1750017. doi:10.1142/S0219649217500174
- Amini, S., Gerostathopoulos, I., & Prehofer, C. (2017, 26-28 June 2017). *Big data analytics architecture for real-time traffic control*. Paper presented at the 2017 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS).
- Arunachalam, D., Kumar, N., & Kawalek, J. P. (2018). Understanding big data analytics capabilities in supply chain management: Unravelling the issues, challenges and implications for practice. *Transportation Research Part E: Logistics and Transportation Review*, *114*, 416-436. doi:<https://doi.org/10.1016/j.tre.2017.04.001>
- Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, *17*(1), 99-120. doi:10.1177/014920639101700108
- Buhl, H. U., Röglinger, M., Moser, F., & Heidemann, J. (2013). Big Data. *Business & Information Systems Engineering*, *5*(2), 65-69. doi:10.1007/s12599-013-0249-5
- Carlsson, B. (2004). The Digital Economy: what is new and what is not? , *15*(3), 245-264.

- Carmeli, A., Brammer, S., Gomes, E., & Tarba, S. Y. (2017). An organizational ethic of care and employee involvement in sustainability-related behaviors: A social identity perspective. *Journal of Organizational Behavior*, 38(9), 1380-1395. doi:10.1002/job.2185
- Chen, H., Chiang, R. H. L., & Storey, V. C. (2012). Business Intelligence and Analytics: From Big Data to Big Impact. *MIS Quarterly*, 36(4), 1165-1188.
- Chen, M., Mao, S., & Liu, Y. (2014). Big Data: A Survey. *Mobile Networks and Applications*, 19(2), 171-209. doi:10.1007/s11036-013-0489-0
- Cheng, B., Ioannou, I., & Serafeim, G. (2013). Corporate social responsibility and access to finance. *Strategic Management Journal*, 35(1), 1-23. doi:10.1002/smj.2131
- Cockayne, D. G. (2016). Sharing and neoliberal discourse: The economic function of sharing in the digital on-demand economy. *Geoforum*, 77, 73-82. doi:<https://doi.org/10.1016/j.geoforum.2016.10.005>
- Côrte-Real, N., Oliveira, T., & Ruivo, P. (2017). Assessing business value of Big Data Analytics in European firms. *Journal of Business Research*, 70, 379-390. doi:<https://doi.org/10.1016/j.jbusres.2016.08.011>
- Cummins, F. A. (2017). Chapter 6 - Enterprise Data Management. In F. A. Cummins (Ed.), *Building the Agile Enterprise (Second Edition)* (pp. 183-208). Boston: Morgan Kaufmann.
- Davenport, T. (2014). *Big data at work: dispelling the myths, uncovering the opportunities*: Harvard Business Review Press.
- Díaz-García, C., González-Moreno, Á., & Sáez-Martínez, F. J. (2015). Eco-innovation: insights from a literature review. *Innovation*, 17(1), 6-23. doi:10.1080/14479338.2015.1011060
- Dumbill, E. (2012). *Planning for Big Data*: O'Reilly Media.
- Dumbill, E. (2013). Making sense of big data. In: Mary Ann Liebert, Inc. 140 Huguenot Street, 3rd Floor New Rochelle, NY 10801 USA.
- Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., & Pappas, G. (2007). Comparison of PubMed, Scopus, Web of Science, and Google Scholar: strengths and weaknesses. *The FASEB Journal*, 22(2), 338-342. doi:10.1096/fj.07-9492LSF
- Fan, J., Han, F., & Liu, H. (2014). Challenges of Big Data analysis. *National Science Review*, 1(2), 293-314. doi:10.1093/nsr/nwt032
- Fernández-Miranda, S. S., Marcos, M., Peralta, M. E., & Aguayo, F. (2017). The challenge of integrating Industry 4.0 in the degree of Mechanical Engineering. *Procedia Manufacturing*, 13, 1229-1236. doi:10.1016/j.promfg.2017.09.039
- Fernando, Y., & Hor, W. L. (2017). Impacts of energy management practices on energy efficiency and carbon emissions reduction: A survey of Malaysian manufacturing firms.

*Resources, Conservation and Recycling*, *126*, 62-73.  
doi:<https://doi.org/10.1016/j.resconrec.2017.07.023>

Fernando, Y., & Wah, W. X. (2016). Moving forward a Parsimonious Model of Eco-Innovation: Results from a Content Analysis. In *Handbook of Research on Climate Change Impact on Health and Environmental Sustainability* (pp. 619-631): IGI Global.

Fernando, Y., & Wah, W. X. (2017). The impact of eco-innovation drivers on environmental performance: Empirical results from the green technology sector in Malaysia. *Sustainable Production and Consumption*, *12*, 27-43.  
doi:<https://doi.org/10.1016/j.spc.2017.05.002>

Finlay, S. (2014). *Predictive Analytics, Data Mining and Big Data: Myths, Misconceptions and Methods*: Palgrave Macmillan UK.

Gandomi, A., & Haider, M. (2015). Beyond the hype: Big data concepts, methods, and analytics. *International Journal of Information Management*, *35*(2), 137-144.  
doi:<https://doi.org/10.1016/j.ijinfomgt.2014.10.007>

Garifova, L. F. (2015). Infonomics and the Value of Information in the Digital Economy. *23*, 738-743.

Ghisetti, C., Marzucchi, A., & Montresor, S. (2015). The open eco-innovation mode. An empirical investigation of eleven European countries. *Research Policy*, *44*(5), 1080-1093.  
doi:<https://doi.org/10.1016/j.respol.2014.12.001>

Glavas, A., & Piderit, S. K. (2009). How Does Doing Good Matter? Effects of Corporate Citizenship on Employees. *The Journal of Corporate Citizenship*(36), 51-70.

Gunasekaran, A., Kumar Tiwari, M., Dubey, R., & Fosso Wamba, S. (2016). Big data and predictive analytics applications in supply chain management. *Computers & Industrial Engineering*, *101*, 525-527. doi:<https://doi.org/10.1016/j.cie.2016.10.020>

Günther, W. A., Rezazade Mehrizi, M. H., Huysman, M., & Feldberg, F. (2017). Debating big data: A literature review on realizing value from big data. *The Journal of Strategic Information Systems*, *26*(3), 191-209. doi:<https://doi.org/10.1016/j.jsis.2017.07.003>

Gupta, M., & George, J. F. (2016). Toward the development of a big data analytics capability. *Information & Management*, *53*(8), 1049-1064.  
doi:<https://doi.org/10.1016/j.im.2016.07.004>

Hemerly, J. (2013). Public Policy Considerations for Data-Driven Innovation. *Computer*, *46*(6), 25-31. doi:10.1109/MC.2013.186

Hojeghan, S. B., Esfangareh, A. N. J. P.-S., & Sciences, B. (2011). Digital economy and tourism impacts, influences and challenges. *19*, 308-316.

Hojnik, J., Ruzzier, M., & Antončič, B. (2017). Drivers of eco-innovation: empirical evidence from Slovenia. *International Journal of Entrepreneurship and Innovation Management*, *21*(4-5), 422-440. doi:10.1504/IJEIM.2017.085688

Inniss, D., & Rubenstein, R. (2017). Chapter 6 - The Data Center: A Central Cog in the Digital Economy. In D. Inniss & R. Rubenstein (Eds.), *Silicon Photonics* (pp. 119-132). Oxford: Morgan Kaufmann.

Irani, Z. (2010). Investment evaluation within project management: an information systems perspective. *Journal of the Operational Research Society*, *61*(6), 917-928. doi:10.1057/jors.2010.10

Janssen, M., van der Voort, H., & Wahyudi, A. (2017). Factors influencing big data decision-making quality. *Journal of Business Research*, *70*, 338-345. doi:<https://doi.org/10.1016/j.jbusres.2016.08.007>

Jetzek, T., Avital, M., & Bjørn-Andersen, N. (2014). *Generating sustainable value from open data in a sharing society*. Paper presented at the International Working Conference on Transfer and Diffusion of IT.

Johnson, J. S., Friend, S. B., & Lee, H. S. (2017). Big Data Facilitation, Utilization, and Monetization: Exploring the 3Vs in a New Product Development Process. *Journal of Product Innovation Management*, *34*(5), 640-658. doi:10.1111/jpim.12397

Kitchin, R. (2014). The real-time city? Big data and smart urbanism. *GeoJournal*, *79*(1), 1-14. doi:10.1007/s10708-013-9516-8

Krisher, T., & Durbin, D.-A. (2017). Tesla or GM? Investors bet on promise over profits. *Chicago Tribune*. Retrieved from <http://www.chicagotribune.com/classified/automotive/sc-tesla-general-motors-autocover-0608-20170601-story.html>

Lee, K.-H., & Min, B. (2015). Green R&D for eco-innovation and its impact on carbon emissions and firm performance. *Journal of Cleaner Production*, *108*, 534-542. doi:<https://doi.org/10.1016/j.jclepro.2015.05.114>

Leonidou, L. C., Christodoulides, P., Kyrgidou, L. P., & Palihawadana, D. (2017). Internal Drivers and Performance Consequences of Small Firm Green Business Strategy: The Moderating Role of External Forces. *Journal of Business Ethics*, *140*(3), 585-606. doi:10.1007/s10551-015-2670-9

Li, F. (2018). The digital transformation of business models in the creative industries: A holistic framework and emerging trends. *Technovation*. doi:<https://doi.org/10.1016/j.technovation.2017.12.004>

Li, Q., Luo, H., Xie, P.-X., Feng, X.-Q., & Du, R.-Y. (2015). Product whole life-cycle and omni-channels data convergence oriented enterprise networks integration in a sensing environment. *Computers in Industry*, *70*, 23-45. doi:<https://doi.org/10.1016/j.compind.2015.01.011>

Lin, Y., & Wu, L.-Y. (2014). Exploring the role of dynamic capabilities in firm performance under the resource-based view framework. *Journal of Business Research*, *67*(3), 407-413. doi:<https://doi.org/10.1016/j.jbusres.2012.12.019>



- Long, X., Chen, Y., Du, J., Oh, K., Han, I., & Yan, J. (2017). The effect of environmental innovation behavior on economic and environmental performance of 182 Chinese firms. *Journal of Cleaner Production*, *166*, 1274-1282. doi:<https://doi.org/10.1016/j.jclepro.2017.08.070>
- Man, J. C. d., & Strandhagen, J. O. (2017). An Industry 4.0 Research Agenda for Sustainable Business Models. *Procedia CIRP*, *63*, 721-726. doi:<https://doi.org/10.1016/j.procir.2017.03.315>
- Martin, C. J. (2016). The sharing economy: A pathway to sustainability or a nightmarish form of neoliberal capitalism? *Ecological Economics*, *121*, 149-159. doi:<https://doi.org/10.1016/j.ecolecon.2015.11.027>
- Marz, N., & Warren, J. (2015). *Big Data: Principles and best practices of scalable realtime data systems*: Manning Publications Co.
- Mat Dahan, S., Mohd Yusof, S. r., & Taib, M. Y. (2017). Performance measure of eco-process innovation: insights from a literature review. *MATEC Web Conf.*, *131*.
- McAfee, A., & Brynjolfsson, E. (2012). *Big data: the management revolution*.
- McIntyre, J. R., Ivanaj, S., & Ivanaj, V. (2013). *Strategies for sustainable technologies and innovations*.
- Morabito, V. (2014). *Trends and Challenges in Digital Business Innovation*: Springer International Publishing.
- Morabito, V. (2015). *Big Data and Analytics: Strategic and Organizational Impacts*: Springer International Publishing.
- Munodawafa, R. T., & Johl, S. K. (2018). Eco-Innovation And Firm Performance: Is Leadership The Game Changer? Paper presented at the Asia International Multidisciplinary Conference 2017.  
<https://www.futureacademy.org.uk/files/images/upload/AIMC2017F94.pdf>
- Newbert, S. L. (2008). Value, rareness, competitive advantage, and performance: a conceptual-level empirical investigation of the resource-based view of the firm. *Strategic Management Journal*, *29*(7), 745-768. doi:10.1002/smj.686
- Newsham, G. R., Mancini, S., & Birt, B. J. (2009). Do LEED-certified buildings save energy? Yes, but... *Energy and Buildings*, *41*(8), 897-905. doi:<https://doi.org/10.1016/j.enbuild.2009.03.014>
- Ociepa-Kubicka, A., & Pachura, P. (2017). Eco-innovations in the functioning of companies. *Environmental Research*, *156*, 284-290. doi:<https://doi.org/10.1016/j.envres.2017.02.027>
- OECD. (2017). *Green Finance and Investment Mobilising Bond Markets for a Low-Carbon Transition*: OECD Publishing.

Pereira, A. C., & Romero, F. (2017). A review of the meanings and the implications of the Industry 4.0 concept. *Procedia Manufacturing*, *13*, 1206-1214. doi:10.1016/j.promfg.2017.09.032

Pries, K. H., & Dunnigan, R. (2015). *Big Data Analytics: A practical guide for managers*: Auerbach Publications.

Provost, F., & Fawcett, T. (2013). Data Science and its Relationship to Big Data and Data-Driven Decision Making. *Big Data*, *1*(1), 51-59. doi:10.1089/big.2013.1508

Rennings, K. (2000). Redefining innovation — eco-innovation research and the contribution from ecological economics. *Ecological Economics*, *32*(2), 319-332. doi:[https://doi.org/10.1016/S0921-8009\(99\)00112-3](https://doi.org/10.1016/S0921-8009(99)00112-3)

Reyeps, C., Lievens, A., & Blazevic, V. (2016). Leveraging value in multi-stakeholder innovation networks: A process framework for value co-creation and capture. *Industrial Marketing Management*, *56*, 40-50. doi:<https://doi.org/10.1016/j.indmarman.2016.03.005>

Sagiroglu, S., & Sinanc, D. (2013, 20-24 May 2013). *Big data: A review*. Paper presented at the 2013 International Conference on Collaboration Technologies and Systems (CTS).

Schneider, S., & Spieth, P. J. I. J. o. I. M. (2013). Business model innovation: Towards an integrated future research agenda. *17*(01), 1340001.

Schuster, A. J. (2017). *Understanding Information: From the Big Bang to Big Data*: Springer International Publishing.

Secundo, G., Del Vecchio, P., Dumay, J., & Passiante, G. (2017). Intellectual capital in the age of Big Data: establishing a research agenda. *Journal of Intellectual Capital*, *18*(2), 242-261. doi:10.1108/JIC-10-2016-0097

Seliger, G. (2001). Product Innovation – Industrial Approach. *CIRP Annals*, *50*(2), 425-443. doi:[https://doi.org/10.1016/S0007-8506\(07\)62989-8](https://doi.org/10.1016/S0007-8506(07)62989-8)

Shaharudin, M. S., Fernando, Y., & Wah, W. X. (2016). Does a firm's innovation category matter in practising eco-innovation? Evidence from the lens of Malaysia companies practicing green technology. *Journal of Manufacturing Technology Management*, *27*(2), 208-233. doi:10.1108/JMTM-02-2015-0008

Sheng, J., Amankwah-Amoah, J., & Wang, X. (2017). A multidisciplinary perspective of big data in management research. *International Journal of Production Economics*, *191*, 97-112. doi:<https://doi.org/10.1016/j.ijpe.2017.06.006>

Shrivastava, P. (2013). Sustainable Innovation Responses to Global Climate Change. In: Edward Elgar Publishing.

Shrivastava, P., Ivanaj, S., & Ivanaj, V. (2016). Strategic technological innovation for sustainable development. *International Journal of Technology Management*, *70*(1), 76-107. doi:10.1504/IJTM.2016.074672

- Sivarajah, U., Kamal, M. M., Irani, Z., & Weerakkody, V. (2017). Critical analysis of Big Data challenges and analytical methods. *Journal of Business Research*, 70, 263-286. doi:<https://doi.org/10.1016/j.jbusres.2016.08.001>
- Tan, K. H., Zhan, Y., Ji, G., Ye, F., & Chang, C. (2015). Harvesting big data to enhance supply chain innovation capabilities: An analytic infrastructure based on deduction graph. *International Journal of Production Economics*, 165, 223-233. doi:<https://doi.org/10.1016/j.ijpe.2014.12.034>
- Tantalo, C., & Priem, R. L. (2014). Value creation through stakeholder synergy. *Strategic Management Journal*, 37(2), 314-329. doi:10.1002/smj.2337
- Teece, D. J. (2014). A dynamic capabilities-based entrepreneurial theory of the multinational enterprise. *Journal of International Business Studies*, 45(1), 8-37. doi:10.1057/jibs.2013.54
- Terzi, D. S., Terzi, R., & Sagiroglu, S. (2017, 5-8 Oct. 2017). *Big data analytics for network anomaly detection from netflow data*. Paper presented at the 2017 International Conference on Computer Science and Engineering (UBMK).
- Tippins, M. J., & Sohi, R. S. (2003). IT competency and firm performance: is organizational learning a missing link? *Strategic Management Journal*, 24(8), 745-761. doi:10.1002/smj.337
- Tjahjono, B., Esplugues, C., Ares, E., & Pelaez, G. (2017). What does Industry 4.0 mean to Supply Chain? *Procedia Manufacturing*, 13, 1175-1182. doi:<https://doi.org/10.1016/j.promfg.2017.09.191>
- Tulder, R. v. (2014). *Managing the transition to a sustainable enterprise : lessons from frontrunner companies*.
- Vargo, S. L., Wieland, H., & Akaka, M. A. (2015). Innovation through institutionalization: A service ecosystems perspective. *Industrial Marketing Management*, 44, 63-72. doi:<https://doi.org/10.1016/j.indmarman.2014.10.008>
- Wamba, S. F., Gunasekaran, A., Akter, S., Ren, S. J.-f., Dubey, R., & Childe, S. J. (2017). Big data analytics and firm performance: Effects of dynamic capabilities. *Journal of Business Research*, 70, 356-365. doi:<https://doi.org/10.1016/j.jbusres.2016.08.009>
- Wang, G., Gunasekaran, A., Ngai, E. W. T., & Papadopoulos, T. (2016). Big data analytics in logistics and supply chain management: Certain investigations for research and applications. *International Journal of Production Economics*, 176, 98-110. doi:<https://doi.org/10.1016/j.ijpe.2016.03.014>
- Watson, R., Wilson, H. N., Smart, P., & Macdonald, E. K. (2017). Harnessing Difference: A Capability-Based Framework for Stakeholder Engagement in Environmental Innovation. *Journal of Product Innovation Management*, 35(2), 254-279. doi:10.1111/jpim.12394
- Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management Journal*, 5(2), 171-180. doi:10.1002/smj.4250050207

Wheelen, T. L., Hunger, J. D., Hoffman, A. N., & Bamford, C. E. (2014). *Strategic management and business policy : globalization, innovation, and sustainability*.

Xavier, A. F., Naveiro, R. M., Aoussat, A., & Reyes, T. (2017). Systematic literature review of eco-innovation models: Opportunities and recommendations for future research. *Journal of Cleaner Production*, *149*, 1278-1302. doi:<https://doi.org/10.1016/j.jclepro.2017.02.145>

Zhang, F., Wang, Y., Li, D., & Cui, V. (2017). Configurations of Innovations across Domains: An Organizational Ambidexterity View. *Journal of Product Innovation Management*, *34*(6), 821-841. doi:10.1111/jpim.12362

Zhong, R. Y., Huang, G. Q., Lan, S., Dai, Q. Y., Chen, X., & Zhang, T. (2015). A big data approach for logistics trajectory discovery from RFID-enabled production data. *International Journal of Production Economics*, *165*, 260-272. doi:<https://doi.org/10.1016/j.ijpe.2015.02.014>

Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent Manufacturing in the Context of Industry 4.0: A Review. *Engineering*, *3*(5), 616-630. doi:<https://doi.org/10.1016/J.ENG.2017.05.015>

Zikopoulos, P., Deroos, D., Parasuraman, K., Deutsch, T., Giles, J., & Corrigan, D. (2013). *Harness the power of big data: The IBM big data platform*: McGraw-Hill New York, NY.

Zikopoulos, P., & Eaton, C. (2011). *Understanding big data: Analytics for enterprise class hadoop and streaming data*: McGraw-Hill Osborne Media.