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Big data-enabled large-scale group decision making for circular economy: An emerging market context

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ABSTRACT

This study is focused on presenting a unique landscape for big data-enabled circular economy that involves stakeholders as important decision makers. This research is designed based on five case studies from emerging markets with a focus on circular models to propose a framework for large scale decision making. In these cases, different linear economy problems are addressed that further utilizes the integration of big data and large-scale group decision making by stakeholders to achieve circularity. The findings of our study indicate a four-step design (enabling technologies, business significance, deriving value, and circular goals) to implement the 10R's of the circular economy through emerging technologies such as big data and related mobile applications along with cloud-based platforms. The study highlights how cases from emerging markets can be useful for other firms and ecosystems, ranging from e-commerce to manufacturing, that employ large number of decision makers with the aim of creating a circular economy. At the end, the study presents theoretical and practical implications along with the scope for future research.

1. Introduction

Economic activities that require the extraction and consumption of natural resources have a significant environmental impact (Jabbour et al., 2020; Goyal et al., 2018). Concerns about the impact of carbon emissions on the environment on the company, country and world levels are sometimes criticized (Shuai et al., 2019; Peters and Geden, 2017). Resource management and careful utilization have been a much discussed research topic for decades (Desing et al., 2020; Jakhar et al., 2019; Jabbour et al., 2019b). In the recent past, building on the third industrial revolution, Industry 4.0 has appeared. It is characterized by a digital, physical and biological world supported by emerging technologies such as 3D printing, artificial intelligence, the internet of things, and robotics (Philbeck and Davis, 2018; de Sousa Jabbour et al., 2018b; Despeisse et al., 2017). All these technologies are capable of harnessing big data capabilities to help reuse, recycle and reduce the use of resources, thus supporting the objectives of the circular economy (Dragicevic et al., 2020; Nascimento et al., 2019; Müller et al., 2018; de Sousa Jabbour et al., 2018a). In today's world, an incredible amount of data is generated by various connected objects. Big data generated by different platforms can help diverse ecosystems ranging from transportation to smart cities to manage waste, energy, and pollution on a real-time basis (Dubey et al., 2019; Raut et al., 2019; Rathore et al., 2018). In addition, big data can help platforms make well-informed and multi-constrained decisions due to the involvement of a large number of decision makers (Saggi and Jain, 2018). The role of large-scale group decision making (LSGDM) has drawn a great deal of attention due to its status and background and the fact that it views the problem from the perspective of each decision maker differently (Liu et al., 2019; Tang and Liao, 2019). Therefore, as compared to the traditional decision-making approach with few people involved, LSGDM can offer more refined and optimized solutions to circular economy issues by utilizing big data (Power, 2014).

The circular economy is a system that supports the minimization of pollution, waste, and utilization of resources as compared to the linear model of take, make and dispose (Jabbour et al., 2020; Gupta et al., 2019; Tang and Liao, 2019). The concept of circularity has been in existence for years, but has only been researched, emphasized and adopted

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by countries in the last few years (Murray et al., 2017). For example, in 2008, China established a law promoting the circular economy through a commission. This commission is responsible for monitoring remanufactured products traded for old and used products by citizens and firms and offers a discount of around 10% (Guo et al., 2017). Recently, a policy portfolio was established to ensure the accountability of manufacturers with regard to the ecofriendly design, collection, recycling, and disposal of their products (Vijayvargy et al., 2017). Along similar lines, Japan is also focusing on recycling metals up to 98% (Zhang and Xu, 2016). In fact, Japan was the first to implement a take-back law that includes retailers and manufacturers of washing machines, refrigerators, televisions, and air conditioners (Atasu and Van Wassenhove, 2012). In Europe, Germany recycles 65% of their materials and 30% are used for conversion to energy. Only the remaining 5% goes to landfills. In support of this, Germany has the most patents for sustainable and green processes, products and services in the world (Gurita et al., 2018). Apart from economies, companies are also adopting circular practices using big data.

Many emerging economies also have the potential to implement the circular economy (Kinobe et al., 2015). Many of the world's top bodies, like the World Economic Forum (WEF) and the United Nations Environment Program (UNEP) support and promote the circular economy through their activities (Foster, 2020; Reike et al., 2018; De Jesus and Mendonça, 2018). Today, most businesses and ecosystems have been exposed to the digital revolution, and this is opening further possibilities for large-scale data generation through connected devices and the multidirectional flow of data (Rathore et al., 2018). Due to the involvement of big data and the number of decision makers, it is difficult to optimize preferences and alternatives. LSGDM becomes difficult in terms of not only group size, but also knowledge distribution, behavior of decision makers, and process complexity in decision making. The complexity of the group is also defined by varying information (Liu et al., 2019; Tang and Liao, 2019). Therefore, when employing a large number of decision makers to select alternatives in order to achieve a circular economy, challenges arise in terms of reducing group dimensions, assigning weights and aggregating decisional information (Tang and Liao, 2019). In the literature, LSGDM has been found in decision making processes in e-commerce, IT service management, disaster emergency response, and social networks (Wu and Xu, 2018; Gou et al., 2018; Palomares et al., 2013). Presently, research in LSGDM has focused on dimension reduction through clustering methods and algorithms, consensus reaching and approaches adopted to rank optimal alternatives (Tang and Liao, 2019). LSGDM requires further improvement based on these methods and approaches, since the clustering approach and its results may not be repeatable and could lead to a lack of consistency (Ding et al., 2018; Zhu et al., 2016). It may be difficult to reach a consensus in the circular economy since more resources and time are invested in decision making (Kalbar et al., 2012). As a large number of participants are present in the process, participants may provide redundant information and delay the decision making process (Koksalmis and Kabak, 2019). Therefore, to improve the decision-making process in LSGDM, big data and technologies to improve decision-making effectiveness need to be facilitated (Tang and Liao, 2019; Wang et al., 2016). Various participants and parties are involved in the move towards circularity, and big data can be applied to address the concerns of traditional LSGDM (Jabbour et al., 2020; Gupta et al., 2019; Zhao et al., 2017). For instance, a company from the Netherlands, "Dutch aWEARness", produces business-to-business corporate and work-wear garments. Dutch aWEARness uses a circular information system to trace the use of garments by large numbers of users. Once they are done being used, the garments are collected and spun into new materials without compromising quality (Fischer and Pascucci, 2017; Pal, 2017). Another company from China (GEM Co. Ltd.) is involved in recycling a large number of items from the electronics, battery and wastewater industries (Pagliaro and Meneguzzo, 2019; Hao et al., 2017). The adoption of circularity can therefore be advanced by applying big data to gather information from different sources and stakeholders. Therefore, by utilizing the capabilities of big data, LSGDM can meet the challenges of the circular economy such as how to meet consumer expectations without compromising convenience, how to integrate government regulations in this circularity, how to support waste management infrastructure, and how to advance recycling technology. With this in mind, our study intends to explore the following:

R1: *What are the critical parameters in achieving the objectives of the circular economy with the involvement of a large group of stakeholders?*

R2: *How can big data facilitate LSGDM to find sustainable and innovative solutions in different sectors in the move towards a circular economy?*

To address the research questions above, we adopted a case study research approach, since very few firms and ecosystems in the world are utilizing big data in LSGDM for the circular economy at this point in time. Furthermore, we considered case studies from emerging economies (African countries, Brazil, China, India and Uruguay), as these economies require fast growth, emit a large amount of waste and challenge a system of limited resources due to their high population density. Circular economy operations are therefore critical for emerging economies compared to developed ones when applying big data analytics. Our case-based research approach presents integrative findings to demonstrate opportunities for the circular economy using LSGDM (Pagell and Wu, 2009). This approach can help practitioners as well as researchers further their work and enhance the effectiveness of stakeholders as decision makers in the move towards circularity using big data.

The remainder of the paper is presented in seven sections. Section 2 presents underlying aspects followed by a literature review in Section 3. Section 4 presents the research design followed by case studies in Section 5. Section 6 provides the analysis and development of the framework followed by discussion in Section 7. Section 8 concludes our study.

2. Background and theoretical context

2.1. Big data analytics (BDA)

Big data has received significant attention in the last decade in the business world due to its enormous potential to solve commercial problems and open new avenues (Raut et al., 2019; Wang et al., 2016). Big data is not only about volume; it is also about the ability to handle variety, veracity, velocity, value, variability, and visualization of data flowing from multiple directions (Gupta et al., 2019; Sivarajah et al., 2017). Due to the deep penetration of web-based technologies, connected devices and the internet, it creates a path for fast growth of BDA handling large amount of information and impacting business decisions along with other sustainable objectives (Rialti et al., 2019; Nobre and Tavares, 2017). Big data is capable of supporting firms operating in a dynamic environment, first to deploy appropriate methodology to device insights, and second to analyze correlations and patterns that are not bound to any theory (Zhang et al., 2019; Yadegaridehkordi et al., 2018; Saggi and Jain, 2018; Papadopoulos et al., 2017; Power, 2014). In today's world, stakeholders and channel partners play a key role in business decisions, however, due to the involvement of large stakeholders, reaching a consensus through traditional decision making is very challenging (Kunz et al., 2018). Therefore, big data can facilitate the analysis of opinions from different lenses to reach a consensus in minimal time.

2.2. Circular economy (CE)

Traditional commercial models rely heavily on linear economy concepts that result in the disposal of products in the natural environment (Goyal et al., 2018; Urbinati et al., 2017). For decades, the easy availability of disposable products has led us towards linear consumption behavior as consumers (Murray et al., 2017). It is high time we turn to a more sustainable approach that can improve both the environment and business and encourage the general public to change production and consumption methods. Rather than open systems, businesses need to design closed loop systems with the 10R's philosophy (reduce, reuse, refuse, rethink, remanufacture, repair, refurbish, repurpose, recycle, and recover) (Bag et al., 2021). Businesses need to redesign products and services to be more intensively used and develop an awareness among stakeholders to refuse redundant products (Jabbour et al., 2020; Gupta et al., 2019). Firms and stakeholders need to emphasize the minimal use of natural resources when producing a particular product. Reuse of products can be encouraged for discarded products that still have working functionalities, along with the enhancement of repair capabilities to utilize defective products or their parts to the greatest possible extent (Goyal et al., 2018). Apart from this, businesses need to consider remanufacturing, refurbishing, and repurposing their products for the same use or for a different function (Gurita et al., 2018). Recycling is most critical and is practiced according to circular principles to retain the same or lower quality of the material or product. Furthermore, materials and energy can be recovered with incineration activities in the consumption process to close the loop (Bag et al., 2021; Kirchherr et al., 2017).

2.3. Stakeholder theory

CE supports regeneration, sustainability and restoration-related business activities and it cannot be implemented in isolation unless the bottom-up approach is adopted (Jakhar et al., 2019; Dubey et al., 2017). This requires the involvement of stakeholders as critical decision makers and cooperative members to create a paradigm shift towards circular goals in day-to-day activities (Jabbour et al., 2020). Stakeholders are *"individuals or a group who can affect or be affected by the activities and achievements of an organization"* (Freeman, 1984). Stakeholder theory posits the importance of relationships among organizations and their stakeholders (Freeman et al., 2010). Stakeholders and their behaviors towards circular economy practices are also investigated based on the principles of stakeholder theory. Corporate objectives and social capital development represent the normative character of stakeholder theory and support the application of big data as well as the adoption of the circular economy (Gupta et al., 2019). Stakeholder theory is sometime criticized for treating all stakeholders equally, but involving stakeholders in the circular economy does not mean that they must all be considered equal regardless of certain circumstances (Phillips et al., 2003). On the contrary, the top management of a company must decide which stakeholders should contribute inputs and influence in terms of circular economy principles in their business, since the success of a business largely depends on the input of stakeholders, and upper management is dedicated to their well-being (Freeman et al., 2020; Hörisch et al., 2014). In addition, stakeholder theory was developed in the management stream and has now been translated into environmental management fields like circular economy. It has developed the right of power and landscape for utilizing big data among a large number of decision makers (Colvin et al., 2020). As compared to other theories, stakeholder theory is appropriate for studies in circular economy, since it is not an organizational, individual or group responsibility. It involves large number of stakeholders and almost everyone on the planet. The stakeholders are key decision makers in many circular economy activities. These decision makers can range from clients, governments, donors, financial institutions, top management, suppliers, and distributors to play a critical role in positioning an organization to achieve sustainability goals effectively (Gupta et al., 2019). On one hand, the involvement of stakeholders as decision makers opens the door to inclusivity and creates greater awareness, but on the other hand, it offers challenges that may impact critical issues in circular goals (Kunz et al., 2018). For example, reaching a consensus is a complex task when a large number of stakeholders are involved in decision making (Tang and Liao, 2019). It only takes a few stakeholders to start a discussion that may result in extra costs for the decision making process (Liu et al., 2019). Therefore, a structured process according to appropriate weighted alternatives needs to be considered to improve decision quality with the help of technologies (such as big data and mobile applications) that can help integrate and correlate opinions on a real-time basis.

3. Big data enabled decision-making for circular economy

As compared to the linear economy (take-make-dispose), the circular economy focuses on closing the raw material cycle and minimizing their use (Gupta et al., 2019). Raw materials are collected, transformed, and used until they are discarded as waste in the linear economy and value is created through the production and selling of as many items as possible (Guo et al., 2017; Zhang and Xu, 2016). On the other hand, the circular economy follows the reduce, reuse, recycle (3R) model (Bag et al., 2021; Kirchherr et al., 2017). Resource usage is minimized (reduce), re-usage of products and components is maximized (reuse), and materials are reused (recycle) with high standards (De Jesus and Mendonça, 2018). Overall, the circular economy changes the philosophy of an organization with regard to value creation and how it is preserved along with sustainable business models (Reike et al., 2018). For instance, instead of producing music CDs, businesses are creating subscription-based licenses to preserve value. The objective of maintaining sustainability in the circular economy is different compared to the linear economy (de Sousa Jabbour et al., 2018a). In the linear economy, the objective of sustainability is to reduce the ecological impact with the same output, whereas in the circular economy the focus in on the environment as well as economic and social aspects (Shuai et al., 2019; Dubey et al., 2019). The focus therefore shifts from eco-efficiency changes to eco-effectiveness when the circular economy is adopted.

Apart from focusing on core circular economic principles, firms today are influenced by multiple sources of information characterized by volume, variety, veracity, velocity, value, variability, and visualization of data (Raut et al., 2019). Firms are therefore utilizing big data originating from a large set of stakeholders (decision makers) to harness internet, social media and cloud computing capabilities and preserve value (Liu et al., 2019; Saggi and Jain, 2018). Big data helps integrate multiple aspects of the circular economy through physical, cyber and stakeholder interactions (Gupta et al., 2019; Sivarajah et al., 2017; Power, 2014). Jabbour et al. (2019a) presented a circular economy model using a ReSOLVE framework developed by the Ellen MacArthur Foundation (2015), where they mapped the 4 Vs (variety, velocity, volume, and veracity) of big data to ReSOLVE components and demonstrated that CE strategies can be implemented effectively if stakeholders are fully aware of and engaged with the firm's philosophy. The ReSOLVE model consists of six elements: regenerate, share, optimize, loop, virtualize and exchange. "Regenerate" entails the shift in focus towards renewable materials and energy to allow the ecosystem to regenerate and the return of recovered natural resources to the biosphere. This helps in reclaiming, retaining, and restoring the health of natural systems (recover). "Share" highlights the concept of maximizing use via sharing among multiple users and opting for a design that supports maintenance and repair. For example, sharing cars, furniture, and appliances. It emphasizes reuse and secondhand products to minimize use of fresh materials (repair, reduce, and reuse). "Optimize" emphasizes the productivity and efficiency of products and removes waste from the supply chain. Here, firms should use automation, big data analytics and remote sensing to steer circular economy more effectively (reduce, rethink, refurbish and remanufacture). "Loop" involves keeping a closed circuit and working on inner loops such as remanufacturing/-refurbishing and recycling in the end of life of a product (refurbish, remanufacture, and recycle). Firm supply chains should be capable of recycling and digesting material anaerobically as well as extracting biochemicals from organic waste. "Virtualize" means converting products to service-based systems and automating them. For example, books can be converted into e-books, and CDs can be converted into online content (refuse). "Exchange" encourages the ultimate replacement of old material with advanced renewable materials compatible with technologies such as 3D printing (repair and reuse) (Jabbour et al., 2019b; The Ellen MacArthur Foundation, 2015). We mapped 10R's against each element of ReSOLVE, indicating a close relationship among two classifications. Fig. 1 presents the ReSOLVE and big data-enabled model of the circular economy. We mapped both research questions to ReSOLVE and big data analytics for LSGDM towards circular economy. RQ1 falls under the ReSOLVE framework, where RQ2 is more appropriate to the seven V's of big data analytics.

When decision making changes from a simple group of limited members to large scale group decision making (LSGDM), challenges may arise in terms of knowledge distribution, cost, and behavioral changes. Due to the multiple stakeholders in LSGDM, it is essential that the dimensions of the decision makers be reduced through clustering analysis, which can help further reduce complexity and cost (Liu et al., 2019; Zhu et al., 2016). The clustering approach can facilitate pattern identification or opinions (Tang and Liao, 2019; Wu et al., 2018). Furthermore, in addition to clustering analysis, the assignment of weights to sub-groups is complex in LSGDM, since the opinions of decision makers can vary greatly. Therefore, the classical approaches of weighted or arithmetic averages may not be suitable in LSGDM (Koksalmis and Kabak, 2019). Due to diverse backgrounds and aptitudes, the complex behavior of large stakeholders can make it challenging to reach a consensus for effective decision making. Furthermore, due to differences in expertise, status, and education, it may lead to intra-group conflicts in decision making (Palomares et al., 2013). In LSGDM it becomes extremely critical and costly for a moderator, who is responsible for effectively implementing the consensus reaching process, providing suitable alternatives, and ensuring an adequate feedback system, to finalize the decision (Ding et al., 2018; Gou et al., 2018). In LSGDM as compared to group decision making, knowledge distribution is a challenge (Wu and Xu, 2018). In addition, in classical decision making, there are few decision makers and they are considered to be independent, whereas in LSGDM, stakeholders may be associated on the basis of their social status or trust built over a period of time (Tang and Liao, 2019). Table 1 presents on overview of the literature on big data and the circular economy. The studies presented in Table 1 indicate big data and stakeholder involvement in the circular economy in insolation. The studies show an absence of mechanisms for big data to act as an enabler to achieve the objectives of circular economy. Our study attempts to remediate this absence by involving stakeholders as decision makers to work towards a circular economy.

4. Research design

The classical approach by Eisenhardt (1989) highlighted the use of case study-supported research on organizational science and supply chain management (Pagell and Wu, 2009). The objective of achieving circularity in the economy includes multiple stakeholders as decision makers and therefore poses a challenge with regard to reaching a consensus through a structured consensus reaching process (CRP) (Wu and Xu, 2018; Gou et al., 2018). Therefore, techniques that are capable of handling large numbers of opinions in terms of volume, variety, velocity, veracity and value creation must be used (Liu et al., 2019). Big

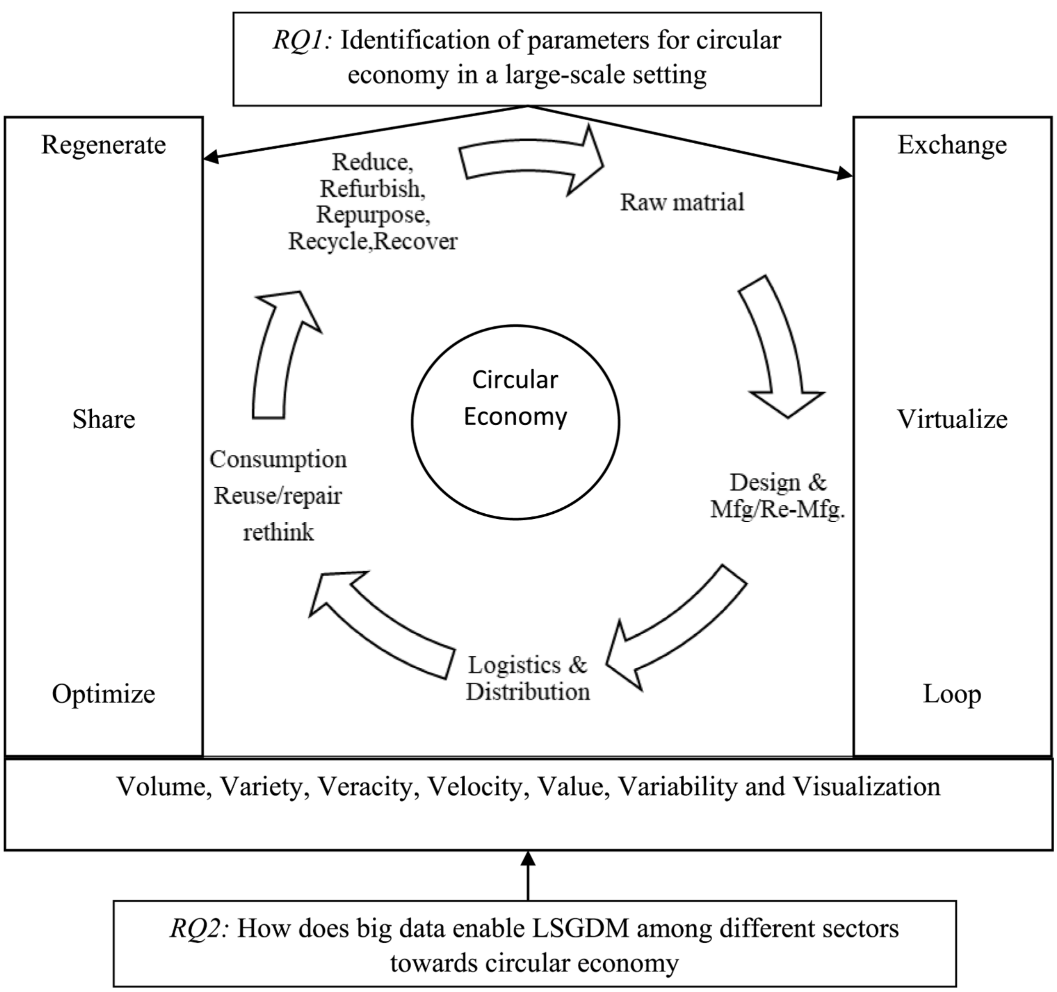

Fig. 1. Big data and ReSOLVE model enabled circular economy (Inspired by Jabbour et al., 2019a and The Ellen MacArthur Foundation, 2015).

Table 1
Big data and the circular economy with the involvement of large stakeholders.

Author/Year	Objective	Level of analysis	Analysis tool	Approach adopted	Setting of the study	Major findings
Jabbour et al. (2020)	Investigate the connections between stakeholders, circular business models and firms	Firms	Multivariate statistical analysis using the PLS-PM method	Survey	ISO 9001 and ISO 14,001 certified companies in Brazil	Regulatory stakeholders are not relevant in an emerging economy like Brazil's. Company owners and shareholders are critical stakeholders in driving the principles of the circular economy. In addition, internal barriers are more difficult to overcome compared to external ones. Circular economy principles may drive the firm towards sustainable operations.
Gupta et al. (2019)	Examine decision making among supply chain networks to facilitate the circular economy through big data	Firm	Thematic categorization	Qualitative	Semi-structured interviews from key managers	Stakeholder coordination is critical in a supply network that further acts as a basis to achieve the ecological, economic, and social benefits of the circular economy.
Tang & Liao (2019)	How to manage the decision-making process in large groups as compared to traditional group decision making	Literature	Systematic Analysis	Literature Review	Identification of gaps in terms of representation format and applications	The potential scope of large-scale group decision making can involve emergency situations like pandemics and disasters. Other areas include logistics and supply chain management, investment management, engineering management, and destinations for travel and tourism.
Liu et al. (2019)	Develop a mechanism for trust-based relationship conflict detection in large-scale decision making	Stakeholders	Non-linear optimization	Social network analysis	Minimizing the degree of conflict in large groups	The non-linear model follows a three-stage process to eliminate conflict in trust-based relationships (trust propagating process, conflict detection and elimination process, selection process based on weight).
Jabbour et al. (2019a)	Role of big data in the circular economy	Literature	Thematic categorization	Qualitative	ReSOLVE model	A framework that integrates CE data, stakeholders and volume, variety, velocity and veracity of data flow.
Jabbour et al. (2019b)	Investigating CE business models from the human perspective	Literature	Thematic categorization	Qualitative	Resource-based view with green human resources and ReSOLVE model	Stakeholders and RBV present the human side of organizations and businesses. The study presents the motivations for adopting CE objectives.
Nascimento et al. (2019)	Investigating the scope of Industry 4.0 in the CE	Firm	Classification	Qualitative coding	Focus group interviews	Business sustainability can be improved by reinserting waste in the supply chain and utilizing technologies like additive manufacturing.
Kunz et al. (2018)	Analyze the challenges in implementing extended product warranties.	Firm	Categorization	Qualitative	Semi-structured interviews	A strong legal framework can help industries and society to achieve the objectives of the circular economy together.
de Sousa Jabbour et al. (2018)	Advance the state-of-the-art to the point of convergence between Industry 4.0 and the CE	Literature	Classification	Literature Review	CE strategies and support from Industry 4.0	Smart technologies under Industry 4.0 need to be harnessed to target CE principles.
Nobre & Tavares (2017)	Scientific analysis of IoT for the CE	Literature	R statistical tool	Bibliometric analysis	Content and social network analysis	China and the USA are interesting leading economies and present significant research opportunities. Countries like Brazil and Russia are still lacking in this area.
Urbinati et al. (2017)	Examining the taxonomy of business models in the circular economy	Literature	Critical analysis	Literature Review	Models based on the degree of circularity adopted	Promote circular economy principles by offering the customer value propositions, creating a network for interactions, and internalizing certain aspects of stakeholder processes.

data analytics-type techniques are suitable for handling this problem to achieve sustainable solutions (Tang and Liao, 2019; Sivarajah et al., 2017). We considered and observed different organizations that are working towards the CE in their day-to-day operations by involving large stakeholders. Consolidating and integrating LSGDM big data analytics is best suited to this and can be further applied to generate, test and expand the theory. Different propositions have been identified that lead to the development of a framework that can be considered as a starting point for theory generation (Fig. 2). In this study, we adopted a case-based approach to develop propositions and a framework (Pagell and Wu, 2009). We considered in-case analysis and cross-case analysis to generate insights.

The main objective of the study is to recognize and identify different approaches and areas considered by organizations in emerging markets when working towards circular economy principles by involving large stakeholders as decision makers. The in-case and cross-case analysis helped us drive insights on LSGDM for the purpose of achieving the objectives of the circular economy. We adopted the inductive reasoning approach to further deepen our insights and to finalize the propositions and framework. A structured process was used to map circular economy principles. Furthermore, we checked to see whether any common practices were followed across the case studies to understand their importance. In case research, the validity of data is often a challenge, so different sources are consulted to ensure consistency between the research outcome and reality. To ensure reliability and validity, we adopted a triangulation approach by consulting the reports of other

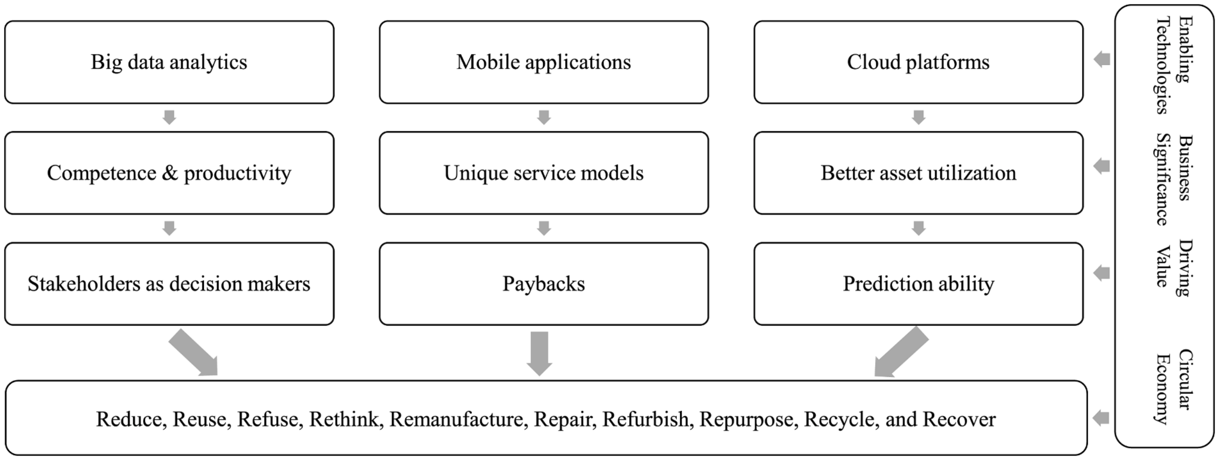

Fig. 2. Proposed framework driven by big data analytics to achieve the circular economy including stakeholders as decision makers.

companies, existing research and three researchers currently working on circular economy objectives (Voss et al., 2002). We consulted the recently published reports from the Ellen MacArthur Foundation and companies like Dutch aWEARness and GEM Co. Ltd from China and found the outcome of their circular operations to be on similar lines.

5. Case studies from emerging markets

The concept of circularity focuses on the design of economic activities, from consuming limited resources to designing waste so that it can facilitate the economic, environmental and social aspects of future human life (Jabbour et al., 2020; Shuai et al., 2019; Gupta et al., 2019). In this section, we focus on unique case studies of the circular economy from emerging markets that involve large stakeholders as decision makers and we examine how big data can play a critical role in effective decision making. Emerging economies face challenges on various fronts, ranging from available resources, changing government policies and unpredictable consumer behavior (Patwa et al., 2020). There are a number of opportunities for emerging economies to employ the circular economy through big data analytics in LSGDM, since they have considerable potential for waste management, resource depletion and environmental management issues (Garlapati 2016). Therefore, we considered case studies from emerging economies in this study to examine new business models that employ big data for large-scale decision making.

5.1. LATU (the technological laboratory of uruguay)

LATU is a non-governmental organization (NGO) that support manufacturers in their waste identification and management. The firm has been striving continuously towards innovation and advancing technological expertise in a culture of science and entrepreneurship. In 2010, the company launched the Verde Program focusing on reducing, reusing, and recycling the materials generated in their operations as well as other businesses located in the LATU technological park or nearby. Under this program they also signed a cooperation agreement with the Juan Cacharpa Sorters Cooperative (JCSC) to implement it effectively. The JCSC operates in nearby areas and collects solid recyclable waste on a weekly basis, which is then sorted via the LATU's existing sorting mechanism. The company focuses on the 3 Rs. The LATU reduced paper usage by 29% by issuing certificates in electronic format and promoting reuse of water, paper, and packaging. Furthermore, the Verde Program helps other companies sort and recycle their solid waste. In short, LATU optimizes its operations to minimize consumption in terms of energy, paper, water, solvents, and reagents and to manage different types of waste. The objective of circularity involves large stakeholders in the form of clients, colleagues, society, and suppliers where a large amount of data is generated and analyzed.

5.2. Closing the loop (CTL)

The CTL Company is registered in Amsterdam, but operates in countries like Cameroon, Ghana, Rwanda, Uganda, and Zambia, which are emerging economies that have high circular economy potential. The firm collects dead mobile phones (e-waste) from African countries and turns it into metals. The firm focuses on urban mining instead of virgin mining and has great economic, social and environmental potential. This approach to mining metals offers multiple benefits to support the circular economy vision. First, these metals are the cleanest metals, with the lowest CO_2 emissions, and they are conflict free. Second, the extraction of gold from waste results in a 90% reduction in carbon emissions compared to traditional mining activities. CTL emphasizes the fact that if stocks above the ground are available, then there is no reason to mine underground. Since 2012, CTL has responsibly collected and recycled dead mobile phones from emerging markets and recovered 2 million dead phones to date from countries that do not have a formal infrastructure for disposing of electronic waste. CTL, through its innovative approach, develops local economic systems of responsible waste collection and connects them to processing plants. CTL collects mobile phone waste through different platforms that include churches, communities, mobile repairers, and scrap dealers. According to CTL's estimates, they have approximately 2000 people in their supply chain that can benefit from this waste collection activity while also helping the environment, which is one of the main objectives of the circular economy. The views and opinions of these supply chain stakeholders can be further informed with the help of big data analytics to improve circular economy activities. An old phone scrapped in Uganda goes through recycling and is bought to Europe. In this way, this approach helps match supply with demand without exploiting limited natural resources.

5.3. Shenzhen electric mobility policy

Shenzhen is a modern metropolis in China. It was estimated that fuel vehicles contributed around 20% of the air pollution in the city. The city and national administration were therefore concerned about CO2 emissions as well as air and noise pollution levels. A 100% electric mobility system was thus recommended that can create opportunities for additional revenue on one hand and save the environment on the other hand. With the emergence of new service models, it allows businesses to rent e-busses and batteries. This creates further opportunities for manufacturers. After setting this objective, in 2017 the Chinese city of Shenzhen became the first in the world to achieve 100% electric vehicle operation.

The electrification of vehicles involves multiple stakeholder (suppliers, manufacturers and dealers) and it supports the objective of the circular economy in facilitating the transition towards renewable and low-carbon energy usage. In the future, the system may further support the circular economy by improving battery technologies that support the reuse, recycling, speedy charging and applicability of common batteries to a wide range of vehicles. This will also include a large number of stakeholders, where big data analytics can help with the design of batteries for mobility solutions through LSGDM.

5.4. eStoks

This Brazilian company operates in the electrical and electronic sector to support the objective of the circular economy. This firm can be cited as a particularly good example of turning challenges into business opportunities. According to estimates, around 5% of products are returned by customers due to minor flaws and categorized as pre-customer waste, contributing to around USD 2.5 billion (7.7 billion Brazilian Real) in unrealized revenue for various firms. Furthermore, it contributes to the increasing volume of electronic waste in Brazil. eStoks therefore developed the idea of intervening before the product become waste. The Brazilian manufacturing landscape is concentrated around the south of the country, whereas demand largely comes from the northeast. Therefore, whenever there is a product defect or damage due to packaging or transportation, it becomes difficult to drive value for the customer and return it to OEM for recovery and repair. Considering this scenario, eStoks developed repair centers in the region and collected returned products that could be replaced after evaluating their status and quality. By following this model, the firm refurbishes around 55% of products and 25% are repaired and resold. The remaining 20% are too damaged and end up being used for internal repair operations at eStocks. They utilize big data and LSGDM to sort the products for recycling, resale and repair or to keep them on the shelf to support the objectives of the circular economy.

5.5. Gravity labs

This company originated during an MIT media lab experiment to capture soot from a burning candle and mix the available residue with vodka and vegetable oil. Learning from this experiment, the company founders developed a device that could capture air pollution and convert it into a secure and safe water based ink. At first, the company collaborated with Heineken for sustainability. The technology “KAALINK” helps capture 95% of air pollution and can be further treated as a purified carbon pigment and converted into ink. This is achieved through an AIR-INK process, which can be used in markers or for printing purposes in packaging materials. So far, the company has three clients on the Fortune 500 list. The company has produced 20,500 liters of AIR-INK and offset 700 tons of carbon. Furthermore, the company recently helped develop a credit card with a carbon limit in collaboration with Mastercard & Doconomy.

This way, the company can help firms decarbonize their supply chains to reduce their carbon footprint by up to 150% and minimize operational costs, thus leading towards the circular economy, where a large number of stakeholders are present.

6. Analysis and framework development

Further exploration of the underlying principles of the circular economy for companies leads us to develop our understanding of the use of big data analytics and the involvement of stakeholders that result in sustainable alternatives for the ecosystem (Jabbour et al., 2020; Nobre and Tavares, 2017). This paradigm shift of applying big data analytics to achieve circular economy objectives through the involvement of stakeholders is presented in this section.

6.1. Reducing the burden on the environment

With the beginning of Industry 4.0, more and more connected devices have been and continue to be developed (Nascimento et al., 2019). This will enable the role of big data and large stakeholders as decision makers in their movements towards the circular economy (de Sousa Jabbour et al., 2018a). The application of big data with other emerging technologies is helpful for emerging economies to enhance visibility and control and to track the location, usage, state, and value of products at each stage of their lifecycle (Bag et al., 2021; de Sousa Jabbour et al., 2018b). The application of big data can address the problems of LSGDM for supply chains by closing loops in operations, remanufacturing and refurbishing along with offering products as service models (Gurita et al., 2018). For instance, the eStoks firm from Brazil has addressed the pre-consumer waste issue by deploying repair centers and collection mechanisms where they combine cloud and big data capabilities to sort and diagnose products and further classify defects in electrical and electronic items. They then offer them to consumers after repair, recycling, and re-sale or keep them on shelf for their own purposes. They have platforms ranging from B2C, B2B, and Parts to re-sell the developed products. This creates a win-win scenario for the firm, stakeholders, and ecosystem for the following reasons: (i) the refurbishment process helps create six times more value compared to recycling; (ii) this process makes high quality products available to lower income groups; (iii) this process facilitates the reduction of logistics costs by up to 60–65%. Furthermore, the company can expand its business into other second-hand markets to contribute towards the circular economy and utilize big data effectively in LSGDM involving multiple stakeholders. These findings lead us to our first proposition:

Proposition 1. *Firms can be better encouraged to adopt CE principles if they see the appropriate business sense that helps them derive productivity from their operations. Firms can see other business opportunities in terms of diversifying their business models from product-based to service-based and use resources more effectively to develop their capabilities.*

Businesses around the world have failed in capturing the business value of waste and its impact on the environment. Therefore, firms need to rethink and redesign their strategies to match the objectives of the circular economy to create new business models for diverse stakeholders. The waste generated from households is less harmful than the industrial waste produced by factories (Kalbar et al., 2012). Like households, factories are not incentivized enough to follow and focus on circular economy principles such as the 10R’s (Zhang and Xu, 2016). In most emerging economies, the regulatory framework does not focus on industrial waste as compared to household waste. Therefore, there is a gap and a need for third parties to step in and reduce the burden on the environment. The LATU (the Technological Laboratory of Uruguay) is one of the pioneer companies in tackling this issue and making their contribution to the circular economy. The company demonstrates its abilities in technology, transfer, innovation, and promotion of science. Apart from handling and designing waste disposal solutions, the firm has established a permanent connection with stakeholders, which is one of the challenges in LSGDM that can be effectively handled with big data analytics. Furthermore, by implementing LATU’s Verde Program, firms are able to successfully separate solid waste that can be further recycled such as paper, polyethylene terephthalate (PET), and tin amounting to around 800 kg/month. There is also no cost involved for businesses for transporting the waste due to cooperative third party firm involvement. The cost aspect as a challenge to LSGDM has therefore been addressed in this scenario. LATU operations and contributions towards the circular economy offer social, environmental and governance benefits to society, supply chain stakeholders, cooperatives, and LATU in general. These operations also provide a reduction in CO2 emissions due to the rationalization of vehicle use and the optimization of different routes. Decreasing waste disposal can also positively impact soil pollution. These insights lead us to our second proposition.

Proposition 2. *Big data and related mobile applications can be helpful in classifying waste and the most suitable type of operation to be performed with the involvement of supply chain partners upstream and downstream as critical decision makers.*

It is important to map each principle of the circular economy for each business process and for firm operations in general. We mapped the ReSOLVE framework to the different circular economy principles as follows: regenerate (recover), share (repair, reduce, and reuse), optimize (reduce, rethink, refurbish, and remanufacture), loop (refurbish, remanufacture, and recycle), virtualize (refuse), and exchange (repair and use). We found 10R's mapped in the ReSOLVE framework. We therefore mapped the firms considered in the study with regard to the 10R's. Table 2 presents the firm characteristics for the circular economy.

6.2. Potential for big data in the achievement of circular economy

Today, due to high connectivity and internet penetration, there is a data explosion that can be harnessed as an accelerator towards the circular economy. A smart city like Shenzhen that uses digital technologies for smart mobility systems can utilize big data analytics to better analyze the flow of resources, waste, and pollution. For a smart city, electric mobility is one aspect that is in line with circular economy principles, but the smart distribution of energy in other forms like electricity is also a main concern (Kinobe et al., 2015). To address this, cities are utilizing smart grids, where with the help of big data analytics, they can manage distribution efficiency and promote effective energy solutions with minimal waste (Iqbal et al., 2020; Rathore et al., 2018). Smart grids can obtain the real time requirements of consumers at different locations and balance the supply-demand equation to further optimize operations and upstream energy distribution (Dragicevic et al., 2020). The same concept can be applied to the efficient management of resources such as batteries for electric vehicles in Shenzhen city, where it can be decided whether the batteries need to be owned, rented or charged at traditional gas stations. Furthermore, the application of the 10R's (Bag et al., 2021) in the lifecycle management of batteries can be further supported with big data analytics. These aspects of the case study lead us to the third proposition:

Proposition 3. *The structured utilization of smart technologies (big data-enabled cloud platforms) can define the future of cities in terms of infrastructure including transportation, electricity distribution and real time supply-demand matching of other entities.*

Over the last two decades, smartphones have become tech toys. Many people buy them frequently, as is evident from rising sales. This frequent purchasing behavior among other things leads to smart phone disposal problems. Once disposed of, they result in landfills full of toxic chemical, polluting the environment. According to reports, electronic waste accounts for 70% of toxic waste in landfills. It has therefore become essential to find a circular solution for smartphone disposal. It is as important as paper, aluminum, plastic, and glass recycling. Therefore, firms like CTL can play a critical role in developing a blueprint and service model for e-waste management in emerging economies, where formal infrastructure is lacking. The company is focused on utilizing emerging technologies such as the internet of things and big data analytics to enhance the visibility and demand for the urban market of dead mobile phones to extract metals. This approach involves a large number of stakeholders ranging from repair shops to community centers and contributes to sustainability by preventing waste from being dumped in the environment. With the help of these urban-mined metals, firms can design business models to supply metals for other businesses. It is difficult to calculate the size of the market due to the nature of offset collection mechanisms and operations in emerging economies. Big data analytics can therefore play an important role in convincing companies like Samsung, Apple, and other manufacturers to contribute to this noble cause of achieving a circular economy. Firms like CTL contribute to the social and environmental view of the circular economy due to the following: (i) they offer a value proposition by paying consumers, scrap collectors, and repair workshop owners; (ii) they increase awareness among society and lead to environmental improvement; (iii) they enable material neutrality requirements from buyers. These findings lead us to our fourth proposition:

Proposition 4. *Firms are willing to maintain transparency while achieving goals of circular economy with the involvement of stakeholders. This involvement of a large number of stakeholders as decision makers can help companies derive a unique value proposition and control business activities while employing smart technologies.*

Based on the above analysis, we propose a framework that can act as a facilitator to enhance the achievement of the circular economy in the different aspects presented in Fig. 2.

7. Discussion

Based on the in-case, cross-case analysis along with propositions and the proposed framework (Fig. 2), we consider that our study offer some unique and interesting contributions to the debate involving big data analytics as a dynamic capability to enable circular economy objectives while involving large stakeholders as decision makers. This study can be viewed as an integration effort from three fields, i.e. operations research, environmental management, and information systems. In the past, researchers like Gupta et al. (2019) and Jabbour et al. (2020) tried to link information systems and environmental management literature. However, these studies harnessed different business models and the relationship between big data and the circular economy instead of including stakeholders as decision makers. Firms operating in the field of circular operations can work with other relevant stakeholders to have a wider reach and optimize decision making. For instance, LATU (focuses on reduce, re-use, and recycle) has signed an agreement with JCSC to implement circular economy operations effectively. Based on what has been learned from CTL (focus on reuse, rethink, recycle, and recover) operating in African countries, circular economy activities should be designed to have maximum impact on the environment, society and the

Table 2
Firm characteristics concerning the circular economy.

Company	Country	Company business	Application of circular economy principles (10R's)									
			Reduce	*Re-*use	Refuse	*Re-*think	*Re-*manufacture	*Re-*pair	*Re-*furbish	*Re-*purpose	*Re-*cycle	*Re-*cover
LATU	Uruguay	Industrial Waste Management	√	√							√	
CTL	African Countries	Recycling of Dead Mobile Phones		√		√					√	√
Shenzhen Electric Mobility Policy	China	Electric Mobility	√		√					√		
eStoks	Brazil	Pre-Customer Waste				√	√		√	√	√		
Gravity Labs	India	Environmental Carbon to Ink	√	√		√				√	√	√

economy as a whole. CTL provides economic benefits to around 2000 people directly and indirectly not including environmental aspects and involves large stakeholders in the form of communities, mobile repair centers, and scrap dealers. This is possible with the help of state-of-the-art mobile applications to trace the scrap available at each scrap dealer and mobile repair center. The objectives of low energy usage and new business models can be observed in the Shenzhen electric mobility policy (focus on reduce, refuse, and repurpose) implemented in China for a 100% electric mobility system. Another key business model of circularity can be seen in eStoks (focus on rethink, remanufacture, repair, refurbish, and repurpose), where they manage pre-customer waste and help e-commerce companies save on logistics costs while contributing to lowering CO_2 emissions by impacting product returns for small defects. Therefore, collaboration with e-commerce on big data analytics can further help companies like eStoks serve customers better. The adoption of circular economy principles is also demonstrated by companies that develop alternative products from environmentally harmful pollution. For instance, Gravity labs (focus on reduce, reuse, refuse, recycle, repurpose and recover) capture and convert CO_2 from air pollution into carbon pigments and ink. In summary, three main pillars, namely enabling technologies, business significance and an orientation to derive value for large scale stakeholders, can play a critical role in revolutionizing the circular economy. Moreover, the existing studies fail to highlight their theoretical contribution driven by case studies. Our study also presents some unique implications for researchers and current managers.

7.1. Implications for theory

We present our study contribution in three different directions. First, the study demonstrates the role of big data as an enabler and dynamic capability to offer sustainable solutions for organizations and supply chains struggling to meet circular economy standards either in a regulatory framework or otherwise (Liu et al., 2018). The propositions derived from the five case studies in emerging economies from the circular economy perspective show the importance of the circular economy for businesses to survive in the long run.

Second, the study also establishes how stakeholder involvement in circular economy principles makes a great deal of sense in terms of value and opportunity for new service-based business models rather than product-based business models (Jabbour et al., 2020, 2019a; Urbinati et al., 2017). Our study attempted to address the key research gaps: *what are the critical parameters in achieving the objectives of the circular economy with the involvement of a large group of stakeholders? How can big data facilitate LSGDM for sustainable and innovative solutions in different sectors in order to achieve a circular economy?* Our study tries to answer the most unyielding questions from environmental and information systems (Shuai et al., 2019; Dubey et al., 2019; Papadopoulos et al., 2013). Our study sets forth a three-step approach driven by big data and mobile applications to track and help businesses promote the circular economy. At minimum, firms, individuals, governments, and circular economy stakeholders should be connected through mobile and cloud applications, and companies should develop big data analytic capabilities to develop an enabling environment. This technological environment will help track and trace the product life cycle at different stages and can set up an end-of-life collection mechanism to further reprocess, recycle, repurpose, or refurbish used products. This requires the involvement of multiple stakeholders from multiple companies (suppliers, providers, retailers, waste collection firms, recycling companies and actual users). The big data-enabled technological environment helps sense business significance in terms of increased productivity by reducing waste in processes and encouraging the emergence of unique service models such as Gravity Labs and eStoks, where they optimize and share (from ReSOLVE) a network of e-commerce-delivered products to prevent extra costs to e-commerce players from product returns for small errors. Circular business significance promotes value for both a large number of stakeholders and the ecosystem. The stakeholders involved in decision making are expected to make considerable efforts to make the program successful and the integration of larger views is facilitated with big data. Moreover, stakeholders are expected to be more active in circular economy activities when they experience coherent paybacks in terms of a clean environment and a sense of satisfaction.

We are in agreement with existing studies about how big data can facilitate and enable the circular economy (Gupta et al., 2019; Nobre and Tavares, 2017), and the fact that the involvement of large numbers of stakeholders plays a critical role in decision making in a business process. However, the literature fails to indicate the process by which big data is seen to drive value by implementing critical principles of the circular economy (Liu et al., 2019; Palomares et al., 2013). Our study provides a step-by-step mechanism that brings visibility and transparency to the development of a circular model and utilizes stakeholders as decision makers. Our study also poses challenges to simple statements about how big data enables the circular economy with a detailed process map. Businesses are interested in their profit first, and then the value proposition they can offer society at large.

Third, the findings of our study revealed that the 10R's (Reduce, reuse, refuse, re-think, re-manufacture, repair, re-furbish, repurpose, recycle and recover) are generally preferred by firms when designing their circular models and engaging stakeholders to contribute to them (Bag et al., 2021; Kirchherr et al., 2017). We know that awareness among consumers and stakeholders is critical to making the circular economy happen and designing business models that can track real-time conditions of products to enable the smooth flow of information and other logistical requirements.

7.2. Implications for practice

Since the present study involves a case-study approach, it offers unique insights for practicing managers in large or start-up firms working within circular model frameworks (Pagell and Wu, 2009). Before investing resources, capabilities or capital into circularity, firms need to consider (i) the degree of business *sense* and its connection to environmental management (ISO14001:2015); (ii) the *opportunity* of converting a product-based system to a service-based system; (iii) the potential for a *value* proposition; (iv) how *technology* can best be used to gain a competitive advantage. Therefore, the growth of connected devices and internet penetration leads to the potential of big data and cloud applications to design new circular models (Rathore et al., 2018). Decision making involving a large number of stakeholders is also easier with mobile applications and big data analytics compared to traditional decision making (Jabbour et al., 2020). This can also be viewed as an instrument to build organizational capabilities in order to apply the 10R's effectively and recognize the possible classification of a particular type of waste based on its characteristics. Big data can be very helpful as a diagnostic tool for waste and other possible scenarios to comply with circular goals. Therefore, managers need to be very careful when deciding on and designing circular models when it comes to using big data to help the organization do business with a value proposition while maintaining a competitive edge. Furthermore, managers can conceptualize circular business models using our framework to gain productivity and efficiency. Organizations and top executives can explore circular business models from emerging economies and how efficiently they can be pursued in other locations. Managers can identify the different dimensions of the ReSOLVE framework and the proposed one to explore different technological environments in different economic settings. It may be difficult to help a large number of stakeholders familiarize themselves with a new technological set-up or application. Either integration with existing applications or a very user-friendly approach therefore needs to be adopted first in order to involve a large number of stakeholders. The new circular models emerging from business significance need to balance different elements, such as their uniqueness, cost, and sustainability. Company executives need to be sure of their circular business models in terms of payback not only for themselves, but also for partners and stakeholders at large in the form of economic, social, and environmental aspects. Once these aspects have been taken care of, the 10R's will be rapidly achieved.

7.3. Implications for policy

There are expected economic, social and environmental benefits when transitioning to the circular economy, but there are also certain challenges for policy makers. Policy makers need to consider how big data and other disruptive technologies can be adopted to advance the circular economy. Big data can inform the opinions of large-scale decision makers and facilitate the development of appropriate organizational structures to adopt different circular models. Policy makers also need to encourage different circular models to address pressing needs such as the rising level of CO_2 and improving recycling infrastructure. Another area of concern for policy makers is increasing energy usage and consumption patterns that need to be addressed with certain procedures. It is important for policy makers to map the possible directions of the circular economy in the form of the 10R's in different sectors to derive maximum value with the help of big data analytics and large stakeholders as decision makers. Participants can be shown the ability to predict the future impact of current practices to encourage the adoption of circular principles on a larger scale. Policy makers can also align the circular economy with sustainable development goals to address different areas on the planet. The growth plans of emerging economies can be linked to circular business models and resource consumption. Industrial policies can be promoted so that businesses actively participate in the application of big data analytics for the circular economy. The government can derive insights from sector-wide analyses to identify barriers and challenges and indicate a suitable course of action. Cross-departmental collaboration between government and industry can also help develop a robust plan for the circular economy. This cooperation can also be aligned with a country's long-term agenda to build manpower skills. Circular economy processes and procedures can be designed to suit local conditions such as (i) present level of circularity, (ii) present technological and institutional set-up, and (iii) present level of resources. Additionally, skills among different sectors can be developed to create annual net value from the circular economy and make it viable in the coming years.

7.4. Limitations and scope for future research

Our study has the following limitations, which can lead to future research opportunities. First the external validity of the proposed framework needs to be tested empirically with a sufficient sample size. Second, we have not considered any competitors across the five case studies that may have developed greater insights about their circular models. Also, we have not considered the translation of circular practices within a firm to their partners, suppliers or industry. Further research could focus on examining other practices that enable circular models. Third, we have examined the circular economy from the standpoint of big data and related technologies such as mobile applications and cloud-based platforms. Future studies can include technologies such as blockchain that may help develop increased trust among stakeholders. Fourth, we have not examined the nature and behavior of top management that influence the circular objective of a business, and this could be considered in future studies. Our study helps recognize different efforts that can be made to achieve a circular economy by involving large-scale stakeholders and employing big data analytics to improve decision making. Our study presents some interesting themes on the circular economy where future research involving big data analytics can be conducted, such as "pre-customer waste", "CO_2 extraction from air pollution", and "urban mining". Future studies can also be conducted on partnerships and contract mechanisms that e-commerce companies could use to connect with local repair and workshop centers to address smaller product defects that would otherwise result in customer returns.

8. Conclusions

Our study investigates the achievement of the circular economy framework with the help of BDA that includes stakeholders as important business partners. We have considered five case studies from emerging economies that indicate the potential and scope these firms have in different areas ranging from industrial waste to electronic waste management along with reducing pollution by decarbonizing supply chains. Our study proposes how big data can facilitate business sense for both large and stat-up firms and help design the value proposition for society at large. Our study offers a link to the arguable debate around BDA enabling circular goals effectively. Overall, the findings of our study indicate that big data analytics act as a capability that impacts critical components of circularity through dynamic settings such as business significance and value proposition. The technical aspects of LSGDM are not well studied. In summary, the findings of our study support the achievement and mapping of the 10R's to remain competitive and meaningful in the circular business environment. To this end, this study provides a framework for developing the strategies that range from harnessing emerging technologies to developing circular business models.

CRediT authorship contribution statement

Sachin Modgil: Formal analysis, Validation, Writing - original draft. **Shivam Gupta:** Conceptualization, Methodology, Resources, Project administration. **Uthayasankar Sivarajah:** Supervision, Writing - review & editing. **Bharat Bhushan:** Data curation, Investigation, Visualization.

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