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Big data analytics as an operational excellence approach to enhance sustainable supply chain performance

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ABSTRACT

Operations management is a core organizational function involved in the management of activities to produce and deliver products and services. Appropriate operations decisions rely on assessing and using information; a task made more challenging in the Big Data era. Effective management of data (big data analytics; BDA), along with staff capabilities (the talent capability in the use of big data) support firms to leverage big data analytics and organizational learning in support of sustainable supply chain management outcomes. The current study uses dynamic capability theory as a foundation for evaluating the role of BDA capability as an operational excellence approach in improving sustainable supply chain performance. We surveyed mining executives in the emerging economy of South Africa and received 520 valid responses (47% response rate). We used Partial Least Squares Structural Equation Modelling (PLS-SEM) to analyze the data. The findings show that big data analytics management capabilities have a strong and significant effect on innovative green product development and sustainable supply chain outcomes. Big data analytics talent capabilities have a weaker but still significant effect on employee development and sustainable supply chain outcomes. Innovation and learning performance affect sustainable supply chain performance, and supply chain innovativeness has an important moderating role. A contribution of the study is identifying two pathways that managers can use to improve sustainable supply chain outcomes in the mining industry, based on big data analytics capabilities.

1. Introduction

Operations management as a discipline emphasizes planning and configurations of resources to achieve organizational outcomes, especially in engineering and management sciences. The synchronization between operational activities (internal) and supply chain management (external) activities is indispensable to ensure enduring supply chain performance. Supply chain managers carefully benchmark their operational performance (Lun, 2011; Zhou and Zhou, 2015; Hu et al., 2019; Mangla et al., 2019; Taelman et al., 2019). However, contemporary supply chains are exposed to dynamic business environments with high levels of uncertainties (Ahmadi et al., 2017; Bag, 2017; Bag et al., 2018; Bag et al., 2019). In response to uncertainty, rather than develop resources, firms focus on the development of dynamic capabilities to mitigate risks (e.g., a loss of reputation) and build competitive advantages. The concern with risks is particularly relevant now as the environmental impact from firms' activities can lead to reputational and financial risks for failing to meet sustainability objectives (Wood et al., 2018).

Big data analytics (BDA) tools may support significant business benefits and drive organizational improvements (Gunasekaran et al., 2017). In general, big data is characterized by 5 Vs (viz., volume, veracity, variety, velocity, and value) (Tao et al., 2018). BDA elicits two major viewpoints to achieve the operational excellence of the organizations. First, the collection of big data (BD) from the firm and external environment. This type of data suggests high volume and velocity of processing data that can provide many improvements and benefits when compared with the existing form of traditional data processing

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systems (Frank et al., 2019). Second, the use of BD in business analytics (BA) to inform decisions and manage operations. BA consists of capabilities and the potential to assess the strategic move of organizations to attain successful planning of businesses of the organizations. The strategic improvements available through BA (such as forecasting, statistical, and operational analysis via optimization techniques) significantly contribute to the enhanced operational efficiency (Mathivathanan et al., 2018; Chams and García-Blandón, 2019). The combination of these two aspects results in a comprehensive concept of big data analytics (BDA). BDA not only benefits organizations with an enhanced competitive advantage but also results in correct and timely decisions. Improved competitiveness often rests on the gains in operational efficiency and appropriate decisions made by the organizations (Olugu et al., 2011; Hazen et al., 2014). Corporations widely recognize the importance of the BDA phenomenon as it contributes to the strategic objectives of the organizations. It is nonetheless pertinent to mention the importance of strategic planning towards the operational efficiency of the organizations as this supports and enhances the supply chain sustainability performance (Singh et al., 2019). Supply chain management constitutes a necessary process in the overall efficiency of the organizations. The consideration of BDA and the connection within a range of operational and supply chain practices (such as procurement, inventory, logistical, and planning activities) is gaining popularity (Wang et al., 2016; Gong et al., 2018). The overall business or financial performance can be effectively addressed by applying BDA to supply chain management processes of organizations (Lin et al., 2018).

This research explores BDA to enhance sustainable supply chain performance within the South African mining sector. The context is important as mining resources are considered the backbone of this continent, and the activities have environmental consequences. The workforce also suggests social effects of mining decisions as the industry depends on a large workforce. Due to the ethnic composition of the workforce, black economic empowerment (BEE), which has evolved into the broad-based black economic empowerment (BBBEE) scorecard, has become an increasingly crucial managerial factor for workforce the skill development initiatives. The preservation of the mining industry and its resources becomes even more critical because it is one of the fastest-growing sectors in South Africa. However, the advent of technology is posing severe challenges for this industry. Mining companies are developing dynamic capabilities at two levels in ways that enhance the sustainable outcomes from their operations. Dynamic capabilities and sustainability performance improvements occur at the business process level and during the management of organizational resources (Braganza et al., 2017; Dubey et al., 2013). Business process management aims to optimize the structure, functions, and organizational elements (Samaranayake, 2009). Every mining company can potentially optimize their sales order process cycle, procurement process cycle, manufacturing execution cycle, and logistics process cycle (Yadav and Desai, 2016; Yadav et al., 2017; Yadav and Desai, 2017; Yadav et al., 2018a, b). Business process optimization can save significant funds and reduce lead times resulting in enhanced customer satisfaction levels. It also plays an instrumental role in conserving scarce natural resources to improve sustainable outcomes (Powers, 1989; Wu and Dunn, 1995; Glenn Richey et al., 2005; Ghadimi et al., 2019).

This research is important as it explores how operational activities and workforce capabilities support BDA in enhancing operational and sustainable outcomes. Unstructured data generated from social media, mobile devices, machines, and sensors provide valuable business insights (Wamba et al., 2017). BDA can be used to enable plant automation in this age of fourth industrial revolution (Tseng et al., 2018; Telukdarie et al., 2018). However, existing literature fails to explain how BDA capabilities can influence the innovative green product development and employee development and further impact on innovation and learning performance, which is the foundation of sustainable supply chains in connection to the mining industry in South Africa. Hence, the principal objective is to explore how BDA enhances supply chain management performance when operational excellence is emphasized. To address this objective, this study aims to answer two key research questions:

RQ1. Do BDA capabilities (management and talent) affect sustainable supply chain performance to attain operational excellence?

RQ2. Does supply chain innovativeness moderately affect the sustainability of supply chain performance for operational excellence?

The rest of the article is organized as follows. We present the literature review with a particular focus on sustainable components of supply chains and the development of our hypotheses. We then present the research design, the survey structure and sampling, and statistical analysis and the results. The final sections present the results in context and explain the relevance to past studies before we draw the conclusions and the subsequent managerial implications.

2. Literature review

Operational excellence in an organization is the foundation for success in other functions. With respect to the day-to-day requirements of the customers, as end-users of every product and service, operations management stands responsible for interaction with all other concerned people and departments. Management of operations is also affected by various technological evolvements, including BDA. Similarly, supply chain management performance is not an exception but is the external extension of operational decisions. The operational performance of a supply chain is strongly dependent upon the ability to address optimization problems relating to the planning and use of resources; these problems can be adequately addressed with BDA. Given this background, we examine the role of BDA management, green developments, workforce capabilities, and innovation and learning performance. From these discussions, we formulate our hypotheses for the study.

2.1. BDA management capability and innovative green product development

With high levels of environmental uncertainty, it becomes vital for organizations to adopt and develop processes using big data management capabilities to achieve supply chain sustainability performance (Janssen et al., 2017). Strategic capabilities define the sustainable existence of an organization. Braganza et al. (2017) proposed a business process architecture for implementing big data (BD) projects and argued that BD programs need to go beyond one-off initiatives to become a dynamic capability. Gunasekaran et al. (2017) conducted a study that used the resource-based view to explain how resources (specifically related to information sharing and subsequent connectivity) influenced the capability of BD assimilation. Also, the overall firm-level performance and supply chain performance is determined by innovative green product development, which is further dependent upon the mediation effect of senior management support. Substantial green product development success is realized only if an organization develops operational excellence to achieve competitive edge (Chiou et al., 2011). The innovative green product development is likely to benefit overall managerial capabilities in terms of sustainable growth and achievements.

2.2. BDA talent capability and employee development

The dynamic changes in technology forces organizations to implement strategic consideration of employee talent and capabilities. The involvement of a high volume of data in almost every sphere of contemporary organizations increases the difficulty of employee development (Shah et al., 2017). Tiwari et al. (2018) reviewed six years of research to investigate BDA application in supply chain management over strategic sourcing and procurement through to demand planning

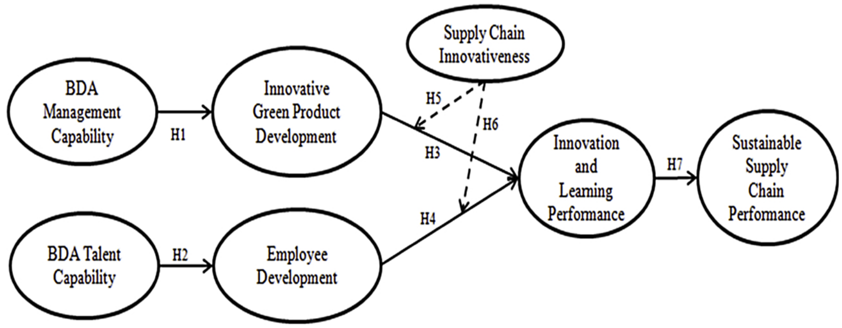

Fig. 1. Conceptual framework.

and logistics activities. Such a breadth of applications has also been identified, with the benefit of BDA, in particular for planning purposes, but often requiring specialized staff skills (Wood et al., 2017). Zhong et al. (2016) reviewed BDA applications over multiple business areas and suggested that the future of BD will focus on smart, cloud-based infrastructure. The processing technologies will accommodate collaborative and simultaneous smart services, and intelligent processors to accomplish various processing modes to fit different processing requirements (Zhong et al., 2016). There are many opportunities for holistic employee development based on BDA capabilities (Dries et al., 2012). Therefore, BDA talent capabilities result in effective employee development, which can, in turn, enhance the working style of companies and generate new employee competencies (Malik and Singh, 2014).

2.3. Supply chain innovativeness

Without innovation, it is not plausible for any organization to achieve a competitive edge, and the success of supply chain processes relies on innovation (Hult et al., 2004). Supply chain innovativeness supports new product and process developments while emphasizing a rapid response to customer requirements (Azadegan and Dooley, 2010). BDA assimilation and routinization supports higher levels of supply chain and organizational performance. Given the current technology stage, and the way it has penetrated our day-to-day activities, moving forward without technological innovativeness is not desirable. Sivarajah et al. (2017) conducted a review of organizational challenges with BDA and identified two primary challenges. First, the process challenges relating to data management processes, particularly those relating to acquiring and storing data and data mining and required cleansing activities. Second, the management challenges such as managing privacy, the security of data, governance of data, how the information sharing occurred and was managed, and ownership of the data. A high level of innovativeness is required to realize benefits from technologies. To generate final products and services without the element of supply chain innovativeness is not feasible (Hult et al., 2004; Wang et al., 2015).

2.4. Innovation and learning performance and sustainable supply chain performance

Sustainable supply chain performance is dependent on innovation and how it is implemented to support performance. Innovation, being the key driver to deal with today's extremities of competition, is not possible without management and talent capabilities. Wamba et al. (2017) used the resource-based view (RBV) of the firm to develop a model for how firms could leverage BDA. Their results provided evidence in support of process-oriented dynamic capabilities enhanced the organizational capability to derive insights and, as a consequence, improve performance. Wang et al. (2016) assessed articles on supply chain BDA applications within supply chain and operations strategies. The complex processes and work from different employees in various firms in a supply chain often need to be combined to develop capabilities (Breidbach et al., 2015), to create the sustainable outcomes that have been identified as crucial in industries, such as the construction industry (Wood et al., 2016). A maturity framework was proposed by Wang et al. (2016) to integrate supply chain analytics over four capability levels. Akter et al. (2016) suggested that talent capability, in addition to the management capability of processes and technological capability, all play a crucial role in successful BDA applications. Together our study aims to explore the importance of employee talents and how these interact with BDA to drive sustainable performance.

3. Conceptual framework and hypothesis development

The preceding section extensively explains the theoretical base for our study. We developed a conceptual framework based on the review of the literature and objectives of the study. The dynamic capability view forms the theoretical basis for our study and model (Fig. 1).

The definition of dynamic capabilities from Augier and Teece (2009, p. 412) is "the ability to sense and then seize new opportunities, and to reconfigure and protect knowledge assets, competencies, and complementary assets with the aim of achieving a sustained competitive advantage." Dynamic capabilities, therefore, enable a firm to take a range of resources that they can further develop or combine in new ways with other resources or those drawn from external sources. Dynamic capabilities are distinct from regular capabilities as they consist of higher-level managerial actions that drive towards higher pay-off outcomes. It requires the focus of managers to devise the right strategy and allocate resources to build strong dynamic capabilities to address customer requirements in dynamic environments (Teece, 2014).

In this research, we conceptualize BDA talent capabilities as dynamic capabilities that play an instrumental role in developing innovative green products and develop employees in the organization. Further, these developments affect innovation and learning performance of an organization, which drives the sustainable supply chain performance.

3.1. Research hypothesis

In today's volatile environment, absorbing external knowledge is the key to innovation. A key advantage in this changing environment is the availability of data from multiple sources for making business decisions. BD can include organizational data, data drawn from a range of sensors or equipment, or external social media data. BDA management capability is developed to cover the management aspects. It can play a role in a range of green product development process phases such as prospect identification, product development, product testing, and launch. New green product development projects are likely to fail without proper management of complex activities using BD.

BDA management capability allows managers to plan and execute green product development activities accurately. BDA creates substantial opportunities for developing green products aligned with global customer requirements. Predictive analytics can be used to forecast green product performance in the field. Accurate forecasting will be beneficial for determining the right marketing and operations strategies and further controlling costs in the supply chain. Organizations utilizing BDA tools can adopt a proactive approach and make the right move in the market before its competitors. New green product failures and uncertainties can be eliminated (Zhan et al., 2018). Therefore, we hypothesize:

H1. BDA management capability is positively related to innovative green product development

Building talent capability involves an investment of time and capital in developing the skills for programming, project management, data and network management, maintenance, and analytics (Akter et al., 2016). Leaders are one of the essential requirements of organizations from generations. With the upcoming changes from more considerable internet investments, technological skills are necessary not only for developing existing employees but also for developing leaders who play an instrumental role in implementing big data architecture in the organization. According to Marshall et al. (2015), leaders focus on innovation using BDA within a structured approach and emphasize collaboration. Therefore, we hypothesize:

H2. BDA talent capability is positively related to employee development

Innovative green product development commences with the idea generation and ends with the market launch of the green product. While developing an innovative green product for the mining market, environmental knowledge is shared among the environmental experts and innovative green product development (IGPD) team. The life cycle assessment of green material is conducted, and the environmental database is made accessible to the team. Based on available information, the environmental manager issues guidelines to the IGPD team and critical component suppliers. The IGPD process implemented systematically improves innovation and learning performance. It allows discussions and analysis of errors and failures related to environmental new green product development projects using BDA applications in this organization, on all levels (Akgün et al., 2014; Silvestre, 2015). Therefore, we hypothesize:

H3. Innovative green product development is positively related to innovation and learning performance

Employee development is characterized by different activities. One of the most important aspects is the continuous learning of technological enhancements. A tech-savvy employee is an acceptable resource in contemporary organizations. Employee development is achieved through various training programs. In progressive organizations, the top management supports the aspirations of employees who want to continue their training. The effective development of employees supports innovation and learning in the organization (Dedahanov et al., 2017; Lundkvist and Gustavsson, 2018). Developmental activities help the employees to optimize resource usage using BDA applications. Employee development improves the level of knowledge and increases the capability and support of employees in green product projects (Imran et al., 2018). Therefore, we hypothesize:

H4. Employee development is positively related to innovation and learning performance

The innovativeness in product development allows organizations to develop a competitive advantage. Innovation is the key to stand apart in this highly progressive culture. The continuous improvement embedded within many operations and supply chain processes results in greater satisfaction of employees as well the higher profits for the organizations. The constant growth and development opportunities allow employees to strengthen their skills (Pujari et al., 2003). Supply chain innovativeness can alter the relationship found between innovative green product development and innovation and organizational learning. Firms exhibiting greater innovativeness can leverage their green product development to drive stronger innovation and learning performance. Therefore, we hypothesize:

H5. Organizations with more (less) supply chain innovativeness have a greater (lower) level of innovative green product development for a given level of innovation and learning performance

The development of employees is required for the enduring development of organizational capabilities. Hence, it is the responsibility of managers to understand the requirements of various employees in person and facilitate them with available developmental activities. Employees will continue to deliver excellent services only when they are supported with timely growth opportunities by their organization. If the employees enjoy such services, then it is likely that they will continue to contribute towards customer's needs (Lechuga Sancho et al., 2018), particularly when change and innovativeness are required to meet customer needs. Supply chain innovativeness, therefore, moderates the relationship between employee development and innovation and learning performance. We hypothesize:

H6. Organizations with more (less) supply chain innovativeness have a greater (lower) level of employee development for a given level of innovation and learning performance

Mining is a labor-intensive industry, where co-operation among employees is expected. Technological enhancements provide both benefits and adversities to the employees. The continuous learning is the only way out to perform to the maximum. Mining businesses are situated in dynamic environments, which necessitate learning from past failures and adopting a creative approach that can contribute to enhanced sustainable supply chain performance (Beske, 2012). There can be proactive management of supply chain network risks. Innovativeness can lower supply chain costs and increase profit margins (Luthra and Mangla, 2018). Therefore, we hypothesize:

H7. Innovation and learning performance is positively related to sustainable supply chain performance

4. Research methods

To address the research questions, we opted to use a statistical survey and structural equation modeling. The approach enables us to test hypothesized relationships and moderation simultaneously. The research team used established processes to develop the survey items following the literature review and discussion with five mining industry executives having more than ten years of work experience. The scales are drawn from established research and were selected to ensure reliability and validity within the research. A 5-point Likert-type scale was used; while any number of points can be used, a 5-point scale has been commonly used (e.g., Davenport et al., 2019; Daxini et al., 2019) and we have continued the use of 5-point scales to ensure consistency with the previously validated scales we draw from. The scales, consisting of 48 measurement items, are listed in Table A1 (Appendix A). BDA management capability consists of six items which were adapted from Akter et al. (2016); BDA talent capability consists of nine items which were also adapted from Akter et al. (2016); Innovative green product development consists of ten items which were adapted from Pujari et al. (2003); Employee development consists of four items which were adapted from Lechuga Sancho et al. (2018); Supply chain innovativeness consists of three items which were adapted from Bititci et al. (2016); Innovation and learning performance consists of eight items which were adapted from Akgün et al. (2014) and Silvestre (2015); and the eight items in sustainable supply chain performance were adapted from Gunasekaran et al. (2017).

4.1. Sampling and data collection

To address the research questions, we sampled from executives in the South African mining industry. The South African context is essential in this study, focusing on BDA, as this emerging economy is experiencing rapid growth and digital transformation is a priority for most CEOs of industrial companies. Of the organizations surveyed, 27% self-evaluated as having a high level of digitization with an expectation that this would rise to 64% over the following five years (PWC South Africa, 2018). The digitization is expected to continue to be broad-based, addressing corporate functions and vertical processes, with most firms expected to supplement their services with digital offerings (PWC South Africa, 2018). Given these technology changes, we felt that the population of mining executives would be well-positioned to answer the survey questions as they have oversight of their supply chain applications and efforts and will be managing their BD applications.

We used a pilot study to assess the survey design. We gained 50 responses (not included in this article to maintain brevity) and used these to assess the convergent and discriminant validity. Based on expert feedback and the pilot survey results, we re-worded several items to improve the clarity and removed several items to reduce redundancy and confusion. We used a list from the association databases of the Mineral Council of South Africa to draw a random sample for the survey. Initially, the link for the online survey was emailed to 1100 professionals working in mining companies. We had received 520 complete and valid responses following two follow-ups with respondents. In Table 1, we summarize the respondents' work experience and work responsibilities. The analysis shows that most responses were from mineral processing companies, and most respondents have more than 20 years' work experience, suggesting an in-depth knowledge sufficient to answer the survey questions.

5. Data analysis

We used the variance-based Partial Least Squares Structural Equation Modelling (PLS-SEM) approach to analyze the data. This is a multivariate data analysis approach that enables the simultaneous examination of multiple relationships among many variables, including latent variables. PLS-SEM is appropriate for exploratory analysis of relationships as it maximizes R^2 for the endogenous constructs, minimizes unexplained variance, supporting superior theoretical model development. Therefore, PLS-SEM would enable us to achieve our objectives better than using covariance-based SEM, a commonly used method in organizational and operations management studies.

The check of assumptions and indices was completed before we proceeded with path modeling. First, we determined that there were no missing values in the data. Second, we checked for zero variance, similarity between columns, and whether there were rank problems. Finally, we standardized all columns (indicators) before we proceeded with the analysis.

To test the discriminant validity, we assessed the correlation (in Table 2), examining differences between the latent variables to the square root of the average variance extracted (shown on the diagonal). The AVE value should exceed any correlation linked to the latent variable; our results are within acceptable limits (Table 2).

The results of latent variable coefficients are presented in Table 3. We then evaluated the composite reliability (using Cronbach's alpha). As the values are above 0.70, we judged them to be within acceptable limits.

We then checked the model fit statistics and quality indices (results in Table 4). We used the following indices to evaluate the overall model fit (Kock, 2017): Average path coefficient (APC), Average R-squared (ARS), Average adjusted R-squared (AARS), Average block VIF (AVIF); Tenenhaus GoF (GoF), Sympson's paradox ratio (SPR), and the R-squared contribution ratio (RSCR). Our model fit indices (Table 4) met recommended thresholds, and we, therefore, proceeded with the analysis.

Our testing of each research hypothesis was conducted based on the p-values in the model (Fig. 2). We considered an alpha value of 0.05 ($p < 5\%$) as the determination point for statistical significance, in line with the prevailing norms.

6. Discussion

The present study is based on the assumption that operational excellence is one of the major requirements for an organization. The sustainable existence of the organizations seems difficult as every activity revolves around the fact of how operational activities are being carried out. The shared work aimed to investigate whether BDA can enhance sustainable supply chain performance of organizations and develops an improved understanding of implementation pathways. The research team developed a model with novel paths involving BDA and talent management to understand how BDA influences sustainable supply chain performance by positively enhancing operational performance. The study draws on DCV theory to develop the proposed conceptual framework. The empirical findings suggest that BDA management capability supports innovative green product development, which in turn improves organization innovation and learning performance. The importance of learning capabilities and performance supports earlier findings where greater learning capabilities support financial performance (Akgün et al., 2014), while our results show that it also supports sustainable supply chain performance. Our results highlight the importance of operational innovation in product development and how it can support organizational learning capabilities. On the other side, BDA talent capability supports employee development and which also has a positive relationship with organization innovation and learning performance. The relationship is strong and broadly relates to the findings relating to talent management outlined in Akter et al. (2016). Supply chain innovativeness is found to strongly moderate the relationship between innovative green product development and innovation and learning performance. Supply chain innovativeness moderates the relationship between employee development and innovation and learning performance. In this way, our results add depth to the connection between talent and personnel management capabilities and competitive performance, by highlighting the importance of broader supply chain innovativeness, extending comparable models

Table 1
The domain of work of respondents and their working experience.
(Source: Authors own compilation).

Domain of Work	Years of Work Experience					
	Less than 5 years	6–10 years	11–20 years	21–30 years	Above 30 years	Total
Mines and Quarries	0	6	28	64	120	218
Mineral processing	1	18	52	76	155	302
Total	1	24	80	140	275	520

Table 2
Correlations between latent variables. The square roots of average variances extracted are shown on the diagonal.
(Source: Authors own compilation).

	BMC	BTC	IGPD	ED	ILP	SSCM	SCI	SCI*IGPD	SCI*ED
BMC	(0.945)	0.990	0.987	0.918	0.512	0.716	0.590	−0.990	−0.986
BTC	0.990	(0.924)	0.997	0.929	0.497	0.713	0.599	−0.999	−0.996
IGPD	0.987	0.997	(0.922)	0.928	0.512	0.712	0.604	−0.996	−0.994
ED	0.918	0.929	0.928	(0.824)	0.402	0.653	0.531	−0.929	−0.924
ILP	0.512	0.497	0.512	0.402	(0.988)	0.465	0.497	−0.501	−0.488
SSCM	0.716	0.713	0.712	0.653	0.465	(0.986)	0.532	−0.712	−0.714
SCI	0.590	0.599	0.604	0.531	0.497	0.532	(0.977)	−0.591	−0.573
SCI*IGPD	−0.990	−0.999	−0.996	−0.929	−0.501	−0.712	−0.591	(0.992)	0.995
SCI*ED	−0.986	−0.996	−0.994	−0.924	−0.488	−0.714	−0.573	0.995	(0.989)

Table 3
Latent variable coefficients.
(Source: Authors own compilation).

	BMC	BTC	IGPD	ED	ILP	SSCM	SCI	SCI*IGPD	SCI*ED
R-squared			0.995	0.863	0.228	0.536			
Adj. R-squared			0.995	0.863	0.222	0.535			
Composite reliability	0.980	1.000	0.982	0.893	0.997	0.996	0.985	0.999	0.998
Cronbachs' alpha	0.975	1.000	0.975	0.834	0.996	0.996	0.976	0.999	0.998
Avg. var. extracted	0.892	1.000	0.850	0.680	0.976	0.972	0.955	0.984	0.977

Table 4
Model fit and quality indices. Suggested interpretation and ideal/acceptable levels are drawn from Kock (2017).
(Source: Authors own compilation).

Index	Value	Interpretation
Average path coefficient (APC)	APC = 0.465, $p < 0.001$	Significant when $p < 0.05$
Average R-squared (ARS)	ARS = 0.655, $p < 0.001$	Significant when $p < 0.05$
Average adjusted R-squared (AARS)	AARS = 0.654, $p < 0.001$	Significant when $p < 0.05$
Average block VIF (AVIF)	VIF (AVIF) = 3.3	acceptable if < = 5, ideally < = 3.3
Tenenhaus GoF (GoF)	GoF = 0.23	small > = 0.1, medium > = 0.25, large > = 0.36
Sympson's paradox ratio (SPR)	SPR = 0.7,	acceptable if > = 0.7, ideally = 1
R-squared contribution ratio (RSCR)	RSCR = 0.9	acceptable if > = 0.9, ideally = 1

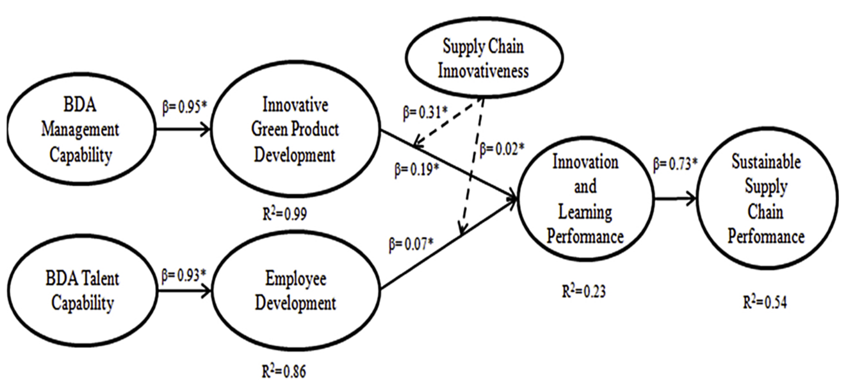

Fig. 2. Tested model (* indicates significance at 5% level).

(Lechuga Sancho et al., 2018). Understanding how supply chain innovativeness moderates the relationships is essential as many firms may otherwise have the necessary elements in place except for supply chain innovativeness and, therefore, fail to secure the full benefit from BDA projects. Finally, innovation and learning performance enhance the overall sustainable supply chain performance, supporting previous findings from other studies (Luthra and Mangla, 2018).

Eventually, the study suggests that the involvement of BDA will enhance and improve the performance of organizations concerning supply chain management operations. Our findings provide support for the approach outlined in Tan et al. (2015) and Braganza et al. (2017) for building advantage, where such earlier studies are often based on small sample case studies. Our data and model provide empirical evidence that an appropriate analytic infrastructure using big data can provide a competitive advantage, at least in the mining sector, that was the context for our research. However, these results also show that big data is a crucial driver of innovation within the firm and suggests that this sustainable innovation in operations can be developed as a competitive advantage. These findings suggest that firms might use BDA and BD in their operations to developing a competitive edge, while also enhancing their supply chain innovativeness.

While the connection between BDA use and either performance of the firm (Wamba et al., 2017) or the supply chain (Gunasekaran et al., 2017) has been demonstrated, our study suggests that not only broad measures of performance can be improved, but specifically the sustainability of the operational performance. That is, we provide evidence that the learning and innovation from effective BDA will support sustainable operations. The importance of learning and innovation in our model provides support for the earlier, case-study based importance of embedding routinized processes to leverage big data (Janssen et al., 2017).

While our findings show the importance of BDA talent management and the connection to employee development, supporting earlier work (Akter et al., 2016; Marshall et al., 2015), we note a significant but weak connection from employee development to innovation and learning performance. The moderation of the relationship (by supply chain innovativeness) is significant but also weak. There may be other factors that have not been included and measured in the current work, such as leadership (Lundkvist and Gustavsson, 2018) or measures of innovation behavior (Dedahanov et al., 2017), that would improve the model.

An important finding relates to the strengths of the pathways that influence overall sustainable outcomes. While both BDA management capability is an influential antecedent to the innovative green product development and BDA and talent capability for employee development, green product development is more closely connected to innovation and learning performance. The result is interesting as it suggests that active employee development, at least in our sample, has not developed the strength of learning (and organizational support based on learning) that we might hypothesize.

6.1. Managerial implications

The findings present several implications for managers aspiring to achieve operational excellence, particularly in the mining industry. Managers can attain operational excellence from the positive association between BDA management capability and innovative green product development. Developing useful BDA management capability is the suggested pathway for firms seeking to develop sustainable supply chain outcomes, and it is particularly strong when there are high organizational levels of supply chain innovativeness. BDA has comprehensively revolutionized the style of working of almost every organization. The entry of BDA has enabled organizations to handle voluminous data in an effective and refined manner. Our findings suggest that effective use of BDA can support sustainable outcomes in operations and supply chain functions of organizations, providing support for the full applications of BDA.

7. Conclusion

In this paper, we provide evidence for the positive association between BDA talent capability and employee development. Our results suggest a connection between the employee development and human capital of the organization and the sustainable supply chain outcomes. Product innovation not only leads to the development of employees but also enhances their performance and the level of innovation. Managers can optimize the performance of their employees by encouraging a learning environment. The higher the emphasis on innovativeness by the managers, the better will be the performance of the employees, mainly through the path of green product design through to sustainable supply chain performance. As supply chain management maintains a sequence of activities, it is possible with the effort of both the personnel- and data-driven approaches. The aspect of training is the key driver here because training can develop skills or can reduce the skill gap among employees. Today, every activity is positioned or examined from the perspective of technology (BDA).

The mining industry operates little differently in comparison to other industries and needs training that focuses on the skill development of employees from a technological perspective. Further, in South Africa, it is necessary to consider black economic empowerment (BEE) and the broad-based black economic empowerment (BBBEE) scorecard during workforce development initiatives. Our results provide support for developing employee capabilities. However, while we have identified a relationship between talent management and overall successful competitiveness, the relationship between product development and competitiveness remains stronger and maybe the area where managers first invest their resources.

7.1. Contributions, future research directions, and limitations

Exploring BDA concerning the mining industry is a unique contribution of this research. The paper shows that training for skill development for existing shortage or non-availability of tech-savvy employees is necessary for the South African mining sector.

Due to the study design, there are several limitations that readers need to assess. The first limitation is the use of cross-sectional data. Second, we have a relatively small sample size, drawn from a single sector (the mining sector) in a single country (South Africa). The sample size and the sampling from a single sector may explain the correlations in the data, and future research, drawing from a wider group of sectors, may overcome this limitation. Third, the research team grounded the theoretical framework using dynamic capability view theory. Future researchers can enhance the scope of research, working with these results as a base to further develop complex models to analyze the effect of big data technological capabilities on green product development. Future studies can also include an investigation of BDA application in managing supply chain risks while considering manufacturing industry.

Additional work should investigate the importance and strength of the employee development and learning performance connection. There may be other relevant factors relating to these variables that have not been investigated in the current study. Furthermore, the particular sample (for the mining industry in a developing nation) may have influenced this outcome, and it is unclear whether these results are generalizable to other settings.

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Appendix A

Annexure (See Table A1)

Table A1
Operationalization of constructs.
(Source: Authors' compilation).

Latent variable	Indicator	Measurement constructs	Adapted from
BDA management capability	BMC1	We continuously examine the innovative green opportunities for the strategic use of BDA	Akter et al. (2016)
	BMC2	We enforce adequate plans for the introduction and utilization of BDA	
	BMC3	We perform BDA planning processes in systematic and formalized ways	
	BMC4	We frequently adjust BDA plans to better adapt to changing environmental conditions	
	BMC5	In our organization, business analysts and design people meet frequently to discuss important issues both formally and informally	
	BMC6	In our organization, information is widely shared between business analysts and line people so that those who make decisions or perform jobs have access to all available know-how	
BDA talent capability	BTC1	Our analytics personnel are very capable in terms of programming skills	Akter et al. (2016)
	BTC2	Our analytics personnel are very capable in terms of managing project lifecycles	
	BTC3	Our analytics personnel are very capable in the areas of data and network management and maintenance	
	BTC4	Our analytics personnel show superior understanding of technological trends	
	BTC5	Our analytics personnel are very knowledgeable about the critical factors for the success of our organization	
	BTC6	Our analytics personnel understand our organization's policies and plans at a very high level	
	BTC7	Our analytics personnel are very knowledgeable about the business environment	
	BTC8	Our analytics personnel work closely with suppliers for providing key inputs useful for developing innovative green products	
	BTC9	Our analytics personnel work closely with customers and maintain productive user/client relationships	
Innovative green product development	IGPD1	Environmental knowledge among environmental specialists and IGPD team was shared	Pujari et al. (2003)
	IGPD2	Enough time was spent on assessing the environmental impact of materials	
	IGPD3	Environmental database was made accessible to the product development team	
	IGPD4	Assessment of life cycle impact of green design material features was done	
	IGPD5	The environmental database was part of the existing management information system	
	IGPD6	Significant amount of time spent on design-for environment issues	
	IGPD7	Environmental information was shared and exchanged with key component suppliers	
	IGPD8	Several revisions of design were made after technical testing of the product	
	IGPD9	The environmental manager issued environmental guidelines to IGPD team	
	IGPD10	The environmental manager reviewed every "stage-gate" of IGPD project	
Employee development	ED1	Supports employees who wish to continue or upgrade their higher education/ training	Lechuga Sancho et al. (2018)
	ED2	Develops/implements regular training programs	
	ED3	Helps the employees to optimize resource usage using applications	
	ED4	Takes into account the employees' interests in developing collaborative relationships with supply chain partners for new applications	
Supply chain innovativeness	SCI1	Foster innovation process	Akgün et al. (2014); Bititci et al. (2016); Bag and Gupta (2017); Bag et al. (2018)
	SCI2	Promote new idea generation	
	SCI3	In this organization, innovative ideas that work are rewarded	
Innovation and learning performance	ILP1	Errors and failures related to environmental projects with BDA applications are always discussed and analysed in this organization, on all levels	Akgün et al. (2014); Silvestre (2015)
	ILP2	Our people take risks and learn from failures	
	ILP3	Our employees pay attention to the "areas" which our competitors have overlooked	
	ILP4	All employees have generalised knowledge regarding this organization's BDA and environmental objectives	
	ILP5	Part of this organization's culture is that employees can express their opinions and make suggestions regarding the BDA procedures and methods in place for carrying out environmental tasks	
	ILP6	Test how the marketplace responds	
	ILP7	Do not do what the customer wants, do something better	
	ILP8	The organization has instruments (manuals, databases, files, organizational routines, etc.) that allow what has been learned in past situations to remain valid, although the employees are no longer the same	
Sustainable supply chain performance	SSCM1	Our organization has visibility of supply chain dynamics in the network	Gunasekaran et al. (2017)
	SSCM2	Risks in the supply network are managed proactively by our organization	
	SSCM3	Our organization has proper control on supply chain costs	
	SSCM4	Wastages in our supply chain network has been reduced significantly	
	SSCM5	Our organization's primary supply chain has the ability to supply final customers with timely complete orders	
	SSCM6	Our organization has the ability to adhere to environmental standards as per customer requirement	
	SSCM7	Our organization has minimized buffer stocks at all levels throughout the supply chain	
	SSCM8	Our organization's supply chain has the ability to respond faster than competitors in volatile business environment	

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