Climate Change and big data analytics: challenges and opportunities

Thanos Papadopoulos[1] and M. E. Balta[2]

[1]TIME Research Centre, Kent Business School, University of Kent, Sail and Colour Loft, The Historic Dockyard, Chatham, Kent, ME4 4TE UK

[2]TIME Research Centre, Kent Business School, University of Kent, Canterbury CT2 7FS UK

Abstract

Scholars and practitioners have long acknowledged the impact of climate change on businesses, operations, and supply chains. Nevertheless, there is still scant research on the role of Big Data and Analytics (BDA) in addressing these challenges but also opportunities created by Climate Change for operations and supply chains as they strive to become more sustainable. We address this gap in this opinion paper by identifying and discussing how these challenges and opportunities can be better pursued. We then propose thematic foci that future research on BDA and climate change could follow to facilitate the transition to a sustainable future.

Keywords: Climate Change, Big Data, Big Data Analytics, sustainability, challenges, opportunities

1. Introduction

Over the last years, both scholars and practitioners have underlined the impact of climate change on businesses and the society. The world business council for sustainable development (WBCSD) (2004) has highlighted climate change as a risk for our society, whereas in a recent publication in 2021, they have called for immediate action as big challenges such as climate change, biodiversity loss, and inequality have got worse. These issues, accentuated by the disruption caused by the COVID-19 pandemic have exposed our societal vulnerabilities, and posed a threat to our "long-term stability and prosperity" (WBCSD, 2020: p. 16).

Governments have responded to the challenge of climate change in different ways. In the UK for instance, the government has set measures so as to slash emissions by 78% by 2035 and reach net zero by 2050. The Paris Agreement, signed during the 21st Conference of the Parties included targets for developed countries on limiting global warming and huge investments to fight climate change and support sustainability. These included, for instance, to keep global temperatures below 2.0C and aiming to 1.5C; limit the amount of greenhouse gases by human activity to the same levels that trees, soil and oceans can absorb naturally; and that each country sets its own emission-reduction targets to be reviewed every five years (United Nations, 2015). At the same time, however, the USA, under the Trump administration, no matter if ranked second in the world in gas emissions, refused to sign the agreement, under claims of putting the US economy at risk (British Broadcasting Corporation, 2017). This decision was later taken back under Biden administration, who pledged to return the US to the Paris agreement and to cut carbon emissions by 50-52% below 2005 levels by the year 2030.

Literature on climate change has focused on the challenges and opportunities for organisations (Gasbarro et al., 2017; Seles et al., 2018). Challenges relate to the internal and external stakeholder pressures (e.g. Bottcher and Muller, 2015), the market (Lee et al., 2015) that monitor organisational actions to manage and tackle climate change, as well as regulatory and public pressures (Kolk and Levy, 2001). At the same time though, Seles et al. (2018) refer to the opportunities raised for organisations because of climate change, such as investing in research and development as change mitigation actions, which can lead to both environmental and financial performance. Forward thinking and transiting fast to a low carbon economy can have opportunities for future growth in both large and small and medium organisations.

As organisations and supply chains strive to understand the opportunities and challenges of climate change, they are increasingly based on analytics-driven decisions. To this purpose, they are deploying big data analytics (BDA) (e.g. Grover et al., 2020; Kar and Dwivedi, 2020; Papadopoulos et al., 2017; 2021; Wamba et al., 2015; Wang et al., 2016). So far literature has investigated the role of BDA for supply chain resilience (Brandon-Jones et al., 2014), supply chain and organisational and operational performance (Waller and Fawcett, 2013; Gunasekaran et al., 2017), and social and environmental sustainability (Dubey et al., 2019). A recent paper by Mikalef et al. (2021) investigated how BDA can be leveraged to strengthen or impede capabilities related to value creation.

Despite the popularity of BDA as a research topic, there is still scant research related to the role of BDA in addressing challenges and opportunities created by the impact of Climate Change on operations and supply chains. Such a focus is important as it has the potential to provide insights in the implementation of environmental practices (El-Kassar and Singh, 2018; Seles et al., 2018), going further than being/becoming sustainable. To address this gap, this paper (i) reviews the literature and highlights the importance of BDA for operations and supply chains in their quest to address challenges related to climate change; (ii) identifies future research directions.

The paper is structured as follows: following a brief literature review on BDA, sustainability, and climate change, opportunities, and challenges for the application of BDA within operations and supply chains to address challenges related to climate change are presented. We conclude by discussing the limitations of our work and future research avenues.

2. Big data analytics

Over the last years there has been a plethora of researchers focusing on Big Data Analytics (e.g. Grover et al., 2020; Kar and Dwivedi, 2020; Papadopoulos et al., 2021; Wang et al., 2016; Wamba et al., 2015). Big data refers to unstructured data coming from various sources, inter alia, sensors, social media, photos, videos, GPS, mobile phone apps. Wamba et al. (2015) have defined Big Data in terms of the 3Vs, that is: 'volume', referring to the large amount of data that need to be processed and stored; 'velocity', referring to the speed by which the data is generated or the frequency by which it is delivered; and 'variety', referring to the different sources of data as well as its structured and unstructured nature. In later studies, 'veracity' has also been added, denoting the importance of quality in the data (Addo-Tenkorang and Helo, 2016; Wang et al., 2016); and 'value', referring to the importance of big data for creating value for companies and customers by developing innovative products and services (Guenther et al., 2017; Hazen et al. 2018; Papadopoulos et al., 2017). Value, according to Guenther et al. (2017) may be social and economic: the former refers to the use of big data to improve social wellbeing in areas such as education, healthcare, and public safety and security (e.g. Newell and Marabelli, 2015). The latter term refers to the increase in profit and achievement of competitive advantage resulting from the use of big data. Still, for both types of value to be achieved, organisations need to incorporate big data but also the appropriate insights from business analytics -this led to the development of the term 'big data and business analytics' (BDBA). By analytics it is meant the application of quantitative methods such as statistics, econometrics, simulations, and other techniques that allow organisations to take faster and better-quality decisions.

BDBA has gained prominence in the operations and supply chain literature (Waller and Fawcett, 2013; Wamba et al., 2015; Wang et al., 2016; Mishra et al., 2018; Chehbi-Gamoura et al., 2020; Talwar et al., 2021), humanitarian supply chain management (Gupta et al., 2019; Papadopoulos et al. 2017; Dubey et al. 2018), organisational performance (Gunasekaran et al., 2017), supply chain resilience (Papadopoulos et al., 2017; Dennehy et al., 2021; Ivanov and Dolgui, 2020; Dubey et al, 2021; Belhadi et al., 2021). In a recent paper, Chen et al. (2019) conducted a qualitative study to understand the impact of big data in the post-disruption stage investigating processes and factors for post-disruption management, whereas Dubey et al. (2019) investigated the role of external institutional pressures on the resources of the organization to build big data capabilities, skills and big data culture and subsequently improving cost and operational performance. In another study, Dubey and colleagues (Dubey et al., 2019a) have underlined the associations between data analytics capability, supply chain resilience and competitive advantage under the moderating effect of organisational flexibility. This is because the supply chain disruptions can be dealt with and risks mitigated using data from supply chain partners (Fan et al., 2016). Our brief review of the literature, however, reveals that most of the literature on BDBA is optimistic, stating the numerous benefits of BDBA in dealing with disruptions/risk in operations and supply chain, assisting in timely and informed decision making, and achieving sustainable competitive advantage. In a recent paper, Talwar et al. (2021), in their systematic literature review of 116 articles in operations and supply chain management highlight challenges associated with the implementation of BDBA to achieve, inter alia, agility, coordination, visibility, alertness, customer insights, and sustainability within operations and supply chains. We focus on BDA, sustainability, and climate change in the following section.

3. Big data analytics, sustainability, and climate change impact on operations and supply chains

As organisations and states all over the world are coming to realise the impact of their operations and supply chains on climate change and long-term prosperity, they need to equally address economic, environmental, and social goals so that the needs of today and future are satisfied (Brutland, 1987). With regards to operations and supply chain management, sustainability has been studied, for instance, in terms of Corporate Social Responsibility (Maloni and Brown, 2006; Feng et al., 2017; Yadlapalli et al., 2020) and the impact of CSR orientation on performance (Liu et al., 2021) in different contexts, such as Korea (Cho and Voss, 2011) and India (Nguyen et al., 2021). Reviews of the literature have suggested that a plethora of works has examined the economic, social, and environmental pillars (Seuring et al., 2008; Giannakis and Papadopoulos, 2016; Schaltegger and Burritt, 2014; Kusi-Sarpong et al., 2019; Sarkis, 2021).

Scholars have investigated the importance of BDBA for achieving sustainability; for instance, big data and resilience in supply chains (Papadopoulos et al., 2017), environmental performance (Song et al., 2017); big data and green innovation (El -Kassar and Singh, 2018); BDA and supply chain social risk mitigation (Mani et al., 2017). Researchers have also looked at the pillars of sustainability separately focusing on the role of BDA in environmental (e.g. Braganza et al., 2016; Wolfert et al., 2017), social (Mani et al., 2017; 2021; Khan et al., 2021) and economic (Akter et al., 2016; Wamba et al., 2017; Gunasekaran et al., 2017; Dubey et al., 2019; 2020) pillar of sustainability.

Literature is scant when directly discussing the role of BDA in transforming organisations and supply chains to deal with the repercussions of Climate Change. Most of the literature discusses sustainability, but as operations and supply chains strive to become more sustainable, they would need to acknowledge the wider challenge of climate change to achieve sustainable development. The existing literature on climate change and BDA has investigated the role of big data in selecting low carbon suppliers within the beef supply chain (Singh et al., 2018) and the impact of big data on environmental quality (Ang and Seng, 2016; Zhang et al., 2017; 2018; Yang et al., 2020). Literature has investigated the role of BDA in devising a cleaner production strategy for the sustainable development of manufacturing companies (Zhang et al., 2017), the application of BDA in urban environments including monitoring of air pollution, disaster management, and intelligent transportation (Ang and Seng, 2016) to mention a few applications. Therefore, apart from a few exceptions (e.g. Seles et al., 2018; Zhang et al., 2017; 2018), an explicit discussion of how could big data assist Climate Change is missing from the literature, which, on the impact of climate change in business operations and supply chains, has also been sparse (Alves et al. 2017; Lim-Camacho et al. 2017; Er-Kara et al., 2020). In a recent paper, Ghadge et al. (2020) argue that the impact of climate change on supply chains and operations, in terms of climate-related risks is lacking. Er-Kara et al. (2020) have aimed to address this gap, proposing a threefold methodology due to the lack of studies, beginning with cognitive mapping, then identification of key climate change factors and most influenced supply chain performance dimensions, and proposing a system dynamics model supported by case scenarios to assess the implications of climate change on supply chain performance. Other conceptual developments were based on e.g., a diversification of extreme weather events (heatwave, cold wave, heavy precipitation, storm, and drought) and their impact on financial performance (Bergmann et al., 2016), and resource-related, that is, the impact of resource and raw materials' scarcity and accessibility, regulations, and extra costs (Alves et al., 2017).

The review of the literature denotes a gap in terms of (i) understanding, both conceptually and empirically, the role of BDA in dealing with the challenges and opportunities arising from Climate Change for operations and supply chains; and (ii) how BDA can help promote sustainable development to cope with the wider impacts of Climate Change. In the next section, we outline thematic foci related to challenges and opportunities faced by operations and supply chains due to climate change issues and the role of BDA in dealing with these.

4. Challenges and opportunities faced by operations and supply chains due to climate change issues: the role of BDA

Er-Kara et al. (2020), in their study on climate change risk and supply chain performance, underlined the importance of investigating the implications of climate change from an operations and SC perspective. They have identified challenges faced by business and supply chain operations due to climate change, namely: 'supply problems of raw material resources', 'changes in customer behaviour and demand', 'relocation of production', 'changes in the efficiency and effectiveness of processes', 'changes in product quality', 'decrease in labour performance', 'damage or destruction of facilities', 'infrastructure and physical assets', 'Transportation problems', 'destruction of markets', 'extra costs', 'climate related mortality and morbidity', 'decreased financial performance, 'changes in regulations', 'damage to reputation of the company', and 'changes in energy consumption' (p. 3). In Table 1 we are building on these challenges and their definitions to propose thematic foci for BDA in this context.

Table 1: BDA and challenges faced by operations and supply chains due to Climate Change (based on El-Kara et al., 2020)

Challenges faced by operations and supply chains	**Description of issues**	**Understanding the role of BDA in… (thematic foci)**
Supply problems of raw material resources	Challenges in acquiring resources and raw materials, as well as deterioration in quality and quantity of raw materials with higher prices.	-Reducing the uncertainty in demand for raw materials and supply chain dependability during sourcing process. -Forecasting the demand for raw materials in light of extreme conditions.
Changes in customer behaviour and demand	Challenges related to fluctuation of demand in products and services, as well as changes in market e.g. demand increase for environmentally friendly products.	-Tracking frequently changing trends in customer behaviour and markets - Forecasting and speedy decision making on demand for product and services
Relocation of production	Shifting production to sustainable regions.	-Providing data-driven timely and efficiently decision making in production process.
Changes in the efficiency and effectiveness of processes	The increase in the external temperature may impact negatively on performance and quality of products/services.	-Enabling gathering and analysis of customer preference/market data as well as monitoring the acceptance of innovative products/services. -Enabling high-quality data for timely and efficient informed decision making.
Changes in product quality	Decrease in quality of raw materials resulting in low quality products.	-Forecasting and optimising supplier selection and decreasing the variability in quality of raw materials that result in low quality products

<table>
<tr><td>Decrease in labour performance</td><td>Changes in climate resulting in reduction in productivity of labour (e.g. construction and farming industries).</td><td>-Supporting real-time employee services and optimising employee performance
-Analysing (historical) workforce data from extreme situations and tracking issues affecting productivity and wellbeing.
-Informing decision making with regards to workforce wellbeing and taking measures to motivate staff for achieving higher productivity.</td></tr>
<tr><td>Damage or destruction of facilities</td><td>Extreme weather conditions resulting in destruction of facilities, transportation infrastructure, energy networks, and communication systems.</td><td rowspan="2">-Capturing and analysing data regarding shifts in weather patterns, exposure to hazards, and expected effects of climate change, with a view to providing policies, regulations, and risk mitigation strategies to deal with adverse conditions.</td></tr>
<tr><td>Transportation problems</td><td>Extreme weather conditions resulting in destruction of transportation infrastructure, and delays in the delivery of products.</td></tr>
<tr><td>Destruction of markets</td><td>Human migration and loss of customers due to disasters related to climate change.</td><td>-Analysing human digital traces from mobile devices, online services, and social networking sites, IoT data to answer questions related to migration flows, destination communities.
-Building models to better understand migration and effects on the local and incoming population and devising strategies to deal with unexpected migrations and knock-on effects on wellbeing and planning destinations for growth, skills' influx, healthcare, and participation in governance.</td></tr>
</table>

Extra costs	Higher prices because of difficulties in acquiring resources, regulation costs (taxes, tariffs, environmental regulations), costs of related low-carbon technologies, maintenance costs, cost of innovative solutions and smart technologies to adapt to climate change (e.g. monitoring weather data and predicting extreme events).	-Integrating and analysing data on resources needed for implementation and integration of real-time monitoring technologies and costs related to analytics and storage technologies and efficient detection of change.
Climate related mortality and morbidity	Health problems and deaths of workers and customers, infections, and diseases.	-Analysing data related to the decline and depletion of natural resources and the impact on health problems and deaths of workers to devise strategies, policies, and regulations for the wellbeing of workers and population.
Decreased financial performance	Reduction in profits because of higher operational costs and increase in commodity prices.	-Analysing real-time data on financial performance and operational costs, as well as historical data on extreme situations and performance to early detect changes in performance and devise strategies to counteract such trends.
Changes in regulations	Severer environmental and disaster management regulations and controls.	-Analysing data related to the impact of regulations' change on performance and monitor organisational and product performance based on regulation change.
Damage to reputation of the company	Customer dissatisfaction resulting from lower quality final products and delays in their delivery.	-Analysing data and devising algorithms that enable analysis of social networking data (social listening) to calculate reputation values and subsequently devising

		strategies that monitor how companies interact with the external environment.
Changes in energy consumption	Fluctuations in energy demand for cooling and heating, electricity or alternative energy providers in office and storage.	-Making sense of data to monitor energy consumption, achieve CO2 emission reductions and achieve/integrate with governmental targets for uptake of alternative energy sources. -Energy planning through assessing and mapping building energy performance to estimate space heating and cooling energy levels and future needs in anticipation of extreme changes in climate and weather conditions.

Related to the thematic foci (Table 1) is also the need to investigate the 'dark side' of the use of BDA for climate change. Past research on the adoption of technology has discussed the limitations of technology adoption and barriers to change, as well as commercial uncertainty and technological dynamism (Tarafdar et al., 2015; Gligor et al., 2021). Tarafdar et al. (2015) have argued that it is "quick and easy information access and flexible work patterns vs. addiction, misuse, overuse, overload and stress brought on by IT usage" (p. 270), what D' Arcy et al. (2014) have named 'information overload' and in our case, big data and BDA overload. More research would need to discuss the individual, technological, but also regulatory and governmental characteristics that influence the magnitude and directionality of data and analytics overload. This research could be guided by the framing of Tarafdar et al. (2015), where the unintended consequences of BDA could be studied in terms of the negative outcomes, mitigation mechanisms used, as well as the level of analysis (individual, organisational, societal). Understanding, hence, both the dark and bright side of BDA for Climate Change is crucial to an informed decision making facilitated by BDA and a key to a sustainable future.

5. Conclusions

The paper argued for the challenges and opportunities related to the application of BDA within operations and supply chains to address challenges and opportunities created by Climate Change. By looking at these challenges, we proposed thematic foci that we believe are and will be at the centre of interest by scholars in the foreseeable future. We did not focus on discussing different methodologies and theoretical lenses that could help researchers to understand the particularities of the Climate Change and operations/supply chain context as well as BDA. Hence, we acknowledge this as a limitation of our opinion paper. Nevertheless, by outlining the challenges and opportunities brought by Climate Change for operations and supply chains we believe we are providing useful food-for-thought to those who would like to further expand and explore more these opportunities.

References

Addo-Tenkorang, R., & Helo, P. T. (2016). Big data applications in operations/supply-chain management: A literature review. *Computers & Industrial Engineering*, 101, 528–543.

Akter, S., Wamba, S.F., Gunasekaran, A., Dubey, R., & Childe, S.J. (2016) How to improve firm performance using big data analytics capability and business strategy alignment? *International Journal of Production Economics*, 182,113-131

Alves, M.W., Lopes de Sousa Jabbour, A.B., Kannan, D., & Jabbour, C.J. (2017). Contingency theory, climate change, and low-carbon operations management. *Supply Chain Management: An International Journal*, 22, 223-236.

Ang, L.M., & Seng, K.P. 2016. Big sensor data applications in urban environments. *Big Data Research* 4, 1-12.

Belhadi, A., Kamble, S., Jabbour, C. J. C., Gunasekaran, A., Ndubisi, N. O., & Mani, V. (2021). Manufacturing and Service Supply Chain Resilience to the COVID-19 Outbreak: Lessons Learned from the Automobile and Airline Industries. *Technological Forecasting and Social Change* 163, 12044.

Bergmann, A., Rotzek, J.N., Wetzel, M., & Guenther, E. (2017). Hang the low-hanging fruit even lower - Evidence that energy efficiency matters for corporate financial performance. *Journal of Cleaner Production*, 147, 66-74.

Böttcher C, & Müller M. (2015). Drivers, practices, and outcomes of low-carbon operations: approaches of German automotive suppliers to cutting carbon emissions. *Business Strategy and the Environment* 24, 477–498.

Braganza, A., Brooks, L., Nepelski, D., Ali, M., & Moro, R. (2017). Resource management in big data initiatives: processes and dynamic capabilities. *Journal of Business Research* 70, 328-337.

Brandon-Jones, E., Squire, B., Autry, C. W., & Petersen, K. J. (2014). A contingent resource-based perspective of supply chain resilience and robustness. *Journal of Supply Chain Management*, 50(3), 55-73.

British Broadcasting Corporation, 2017. Climate change: US formally withdraws from Paris agreement. Available at: https://www.bbc.co.uk/news/science-environment-54797743 (Accessed 25th October 2021).

Brundtland, G.H., 1987. Our common future-call for action. *Environmental Conservation*, 14(04), 291-294.

Chehbi-Gamoura, S., Derrouiche, R., Damand, D., & Barth, M. (2020) Insights from big Data Analytics in supply chain management: an all-inclusive literature review using the SCOR model, *Production Planning & Control*, 31(5), 355-382

Chen, H. Y., Das, A., & Ivanov, D. (2019). Building resilience and managing post-disruption supply chain recovery: Lessons from the information and communication technology industry. *International Journal of Information Management*, 49, 330–342.

Cho, E., & Voss, H. (2011). Determinants of international environmental strategies of Korean firms: An explorative case-study approach. *Asian Business & Management*, 10(3), 357–380.

D'Arcy, J., Gupta, A., Tarafdar, M., & Turel, O. (2014) Reflecting on the "Dark Side" of information technology use. *Communications of the Association for Information Systems*, 35(1), 109-118.

Dennehy, D., Oredo, J., Spanaki, K., Despoudi, S. & Fitzgibbon, M. (2021), "Supply chain resilience in mindful humanitarian aid organizations: the role of big data analytics", *International Journal of Operations and Production Management*, 41(9), 1417-1441.

Dubey, R., Gunasekaran, A., Childe, S.J., Wamba, S.F., Roubaud, D., & Foropon, C. (2021). Empirical investigation of data analytics capability and organizational flexibility as complements to supply chain resilience, *International Journal of Production Research*, 59(1), 110-128

Dubey, R., A. Gunasekaran, S. J. Childe, C. Blome, & Papadopoulos., T. (2019). Big Data and Predictive Analytics and Manufacturing Performance: Integrating Institutional Theory, Resource-Based View and Big Data Culture. *British Journal of Management*, 30(2), 341–361.

Dubey, R., Altay, N., & Blome, C. (2019a). Swift trust and commitment: The missing links for humanitarian supply chain coordination? *Annals of Operations Research*, 283(1–2), 159–177.

Dubey, R., Altay, N., Gunasekaran, A., Blome, C., Papadopoulos, T., & Childe, S. J. (2018). Supply chain agility, adaptability and alignment: Empirical evidence from the Indian auto components industry. *International Journal of Operations and Production Management*, 38(1), 129–148

Dubey, R., Gunasekaran, A., Bryde, D., Dwivedi, Y.K., & Papadopoulos, T. (2020) Blockchain technology for enhancing swift-trust, collaboration and resilience within a humanitarian supply chain setting, *International Journal of Production Research*, 58(11), 3381-3398

Er Kara, M., Ghadge, A., & Bititci, U.S. (2020). Modelling the impact of climate change risk on supply chain performance, *International Journal of Production Research*, DOI: 10.1080/00207543.2020.1849844

El-Kassar, A.N., & Singh, S.K., 2018. Green innovation and organizational performance: the influence of big data and the moderating role of management commitment and HR practices. *Technological Forecasting and Social Change* 144, 483-498.

Fan, H., Cheng, T. C. E., Li, G., & Lee, P. K. C. (2016). The Effectiveness of Supply Chain Risk Information Processing Capability: An Information Processing Perspective. *IEEE Transactions on Engineering Management*, 63(4), 414-425.

Feng, Y., Q. Zhu, & Lai, K.-H. (2017). Corporate Social Responsibility for Supply Chain Management: A Literature Review and Bibliometric Analysis. *Journal of Cleaner Production*, 158, 296–307.

Gasbarro, F., Iraldo, F., & Daddi, T. (2017). The drivers of multinational enterprises' climate change strategies: A quantitative study on climate-related risks and opportunities. *Journal of Cleaner Production*, 160, 8-26.

Ghadge, A., Kara, M.E., Moradlou, H., & Goswami, M. (2020). The impact of Industry 4.0 implementation on supply chains. *Journal of Manufacturing Technology Management* 31(4), 669-686

Giannakis, M., & Papadopoulos, T. 2016. "Supply Chain Sustainability: A Risk Management Approach." *International Journal of Production Economics*. 171 (4), 455-470.

Gligor, D.M., Pillai, K.G., & Golgeci, I., 2021. Theorizing the dark side of business-to-business relationships in the era of AI, big data, and blockchain. *Journal of Business Research* 133, 79–88.

Grover, V., Lindberg, A., & Benbasat, I. (2020). The perils and promises of big data research in information systems. *Journal of the Association for Information Systems* 21, 9.

Günther, W. A., Mehrizi, M. H. R., Huysman, M., & Feldberg, F. (2017). Debating big data: A literature review on realizing value from big data. *The Journal of Strategic Information Systems*, 26(3), 191-209

Gunasekaran, A., Papadopoulos, T., Dubey, R., Wamba, S. F., Childe, S. J., Hazen, B., and Akter, S. (2017). Big Data and Predictive Analytics for Supply Chain and Organizational Performance. *Journal of Business Research*, 70, 308–317.

Gupta, S., Altay, N. & Luo, Z. (2019) Big data in humanitarian supply chain management: a review and further research directions. *Annals of Operations Research* 283, 1153–1173.

Hazen, B.T., Skipper, J.B., Boone, C.A., & Hill. R. (2018). Back in business: operations research in support of big data analytics for operations and supply chain management. *Annals of Operations Research* 270, 201-211.

Ivanov, D., & Dolgui, A. (2020) Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak, *International Journal of Production Research*, 58(10), 2904-2915.

Kar, A. K., & Dwivedi, Y. K. (2020). Theory building with big data-driven research–Moving away from the "What" towards the "Why. *International Journal of Information Management*, 54, 102205.

Khan, S.A.R., Zkik, K., Belhadi, A., & Kamble, S. (2021). Evaluating barriers and solutions for social sustainability adoption in multitier supply chains, *International Journal of Production Research*, 59(11), 3378-3397.

Kolk, A., & Levy. D, (2001). Winds of Change: Corporate Strategy, Climate Change, and Oil Multinationals. *European Management Journal* 19, 501-509.

Kusi-Sarpong, S., Gupta, H., & Sarkis, J. (2019) A supply chain sustainability innovation framework and evaluation methodology, *International Journal of Production Research*, 57(7): 1990-2008.

Lee, T.M., Markowitz, E.M., Howe, P.D., Ko, C.-Y., & Leiserowitz, A.A., (2015). Predictors of public climate change awareness and risk perception around the world. *Nature Climate Change* 5, 1014–1020.

Lim-Camacho L, Plagányi ÉE, Crimp S, Hodgkinson JH, Hobday AJ, Howden SM, & Loechel B (2017). Complex resource supply chains display higher resilience to simulated climate shocks. *Global Environmental Change*, 46,126-138.

Liu, Y., Saleem, S., Shabbir, R., Shabbir, M. S., Irshad, A., & Khan, S. (2021). The relationship between corporate social responsibility and financial performance: A moderate role of fintech technology. *Environmental Science and Pollution Research* 28, 20174–20187.

Maloni, M. J., & Brown, M. E. (2006). Corporate Social Responsibility in the Supply Chain: An Application in the Food Industry. *Journal of Business Ethics* 68(1), 35–52.

Mani, V., Jabbour, C.J.C., & Mani, K.T.N. (2017). Supply chain social sustainability in small and medium manufacturing enterprises and firms' performance: Empirical evidence from an emerging Asian economy. *International Journal of Production Economics* 227, 107656.

Mikalef, P., deWetering, R., & Krogstiea, J. (2021). Building dynamic capabilities by leveraging big data analytics: The role of organizational inertia. *Information & Management* 58(6), 103412.

Mishra, D., Gunasekaran, A., Papadopoulos, T., & Childe, S. J. (2016). Big Data and supply chain management: a review and bibliometric analysis. *Annals of Operations Research*, 270, 313–336.

Newell, S., & Marabelli, M. (2015) Strategic opportunities (and challenges) of algorithmic decision-making: A call for action on the long-term societal effects of 'datification'. *The Journal of Strategic Information Systems* 24(1), 3-14.

Nguyen, G.N.T., Mani, V., Kieu, K.M., & Papadopoulos, T. (2021). An empirical investigation of supply chain social sustainability in labour- intensive industries. *Production Planning & Control.*

Papadopoulos, T., Gunasekaran, A., Dubey, R., Altay, N., Childe, S. J., & Wamba, S. F. (2017). The role of Big Data in explaining disaster resilience in supply chains for sustainability. *Journal of Cleaner Production*, 142(2), 1108–1118.

Papadopoulos, T., Singh, S.P., Spanaki, K., Gunasekaran, A., & Dubey, R. (2021). Towards the next generation of manufacturing: implications of big data and digitalization in the context of industry 4.0, *Production Planning & Control*, DOI: 10.1080/09537287.2020.1810767

Sarkis, J. (2020). Supply chain sustainability: Learning from the COVID-19 pandemic. *International Journal of Operations and Production Management* 41, 63-73.

Schaltegger, S., & Burritt, R. (2014). Measuring and managing sustainability performance of supply chains. *Supply Chain Management: An International Journal* 19, 232-241.

Seles, B.M.R.P., de Sousa Jabbour, A.B.L., Jabbour, C.J.C., de Camargo Fiorini, P., Mohd- Yusoff, Y., & Thome, A.M.T. (2018). Business opportunities and challenges as the two sides of the climate change: corporate responses and potential implications for big data management towards a low carbon society. *Journal of Cleaner Production* 189, 763-774.

Seuring, S., & Mueller, M. (2008). From literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production*, 16(15), 1699-1710.

Singh, A., Kumari, S., Malekpoor, H., & Mishra, N. (2018). Big data cloud computing framework for low carbon supplier selection in the beef supply chain. *Journal of Cleaner Production* 202, 139-149.

Song, M., Du, Q., & Zhu, Q. (2017). A theoretical method of environmental performance evaluation in the context of big data. *Production Planning & Control* 28 (11-12): 976-984.

Talwar, S., Kaur, P., Fosso Wamba, S. F., & Dhir, A. (2021) Big Data in operations and supply chain management: a systematic literature review and future research agenda. *International Journal of Production Research*, 59(11), 3509-3534.

Tarafdar, M., Gupta, A., & Turel, O. (2015). Special issue on 'dark side of information technology use: An introduction and a framework for research. *Information Systems Journal*, 25(3), 161–170.

United Nations, 2015. Transforming our world. The 2030 Agenda for sustainable development. Available at: https://sdgs.un.org/2030agenda (Accessed 25th October 2021).

Waller, M. A., & Fawcett, S. E. (2013). Data science, predictive analytics, and big data: a revolution that will transform supply chain design and management. *Journal of Business Logistics* 34, 77-84

Wamba, S., Akter, S., Edwards, A., Chopin, G., & Gnanzou, D. (2015). How 'big data' can make big impact: findings from a systematic review and a longitudinal case study. *International Journal of Production Economics*, 165, 234–246.

Wamba, S., Gunasekaran, A., Akter, S., Ren, S., Dubey, R., & Childe, S. (2017). Big data analytics and firm performance. *Journal of Business Research*, 70, 356–365.

Wang, G., Gunasekaran, A., Ngai, E.W.T., & Papadopoulos, T. (2016). Big Data Business Analytics in Logistics and Supply Chain Management: Certain Investigations for Research and Applications. *International Journal of Production Economics*, 176, 98-110.

WBCSD, 2021. The 2020-2030 Operating Environment Research in support of the Vision 2050 issue brief on macrotrends and disruptions shaping 2020-2030. Available at: https://docs.wbcsd.org/2020/05/WBCSD_V2050_Operating_Landscape_Full.pdf (Accessed 22nd October 2021).

Wolfert S, Ge L, Verdouw C, & Bogaardt M-J (2017) Big data in smart farming-A review. *Agricultural Systems*, 153, 69–80.

Yadlapalli, A., Rahman, S., & Gunasekaran, A. (2020). Corporate social responsibility definitions in supply chain research: An ontological analysis. *Journal of Cleaner Production*, 277, 123265.

Yang, J., Li, X., & Huang, S. (2020). Impacts on environmental quality and required environmental regulation adjustments: A perspective of directed technical change driven by big data. *Journal of Cleaner Production* 275, 124126.

Zhang, Y., Ren, S., Liu, Y., & Si, S. (2017). A big data analytics architecture for cleaner manufacturing and maintenance processes of complex products. *Journal of Cleaner Production* 142, 626–641.

Zhang, Y., Ma, S., Yang, H., Lv, J., & Liu, Y. (2018). A big data driven analytical framework for energy-intensive manufacturing industries. *Journal of Cleaner Production* 197, 57-72.