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The future and social impact of Big Data Analytics in Supply Chain Management: Results from a Delphi study

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A B S T R A C T

The continuously growing amount of available data has accelerated the emergence of numerous business intelligence applications that are summarized under the term Big Data Analytics (BDA). BDA is especially relevant to the domain of Supply Chain Management (SCM) as it provides the tools to support decision-making in increasingly global, volatile and dynamic value networks. However, its application challenges traditional institutional arrangements as well as roles that are related to the management of data. The underlying empirical study addresses this challenge with the application of a multi-method approach that is embedded in Organizational Information Processing Theory (OIPT). A Delphi survey was conducted to integrate expert assessments of projections up to the year 2035 and fuzzy c-means clustering was applied to identify future scenarios that span the future of BDA in SCM. The study suggests that BDA will improve demand forecasts, reduce safety stocks and improve the management of supplier performance. However, supply chain (SC) processes will become increasingly automated and traditional tasks of SCM will be partially substituted as a result. Consequently, the transition of the traditional role of SCM within organizations will increase the importance of human intuition, trust and strategic decision-making.

1. Introduction

While the popularity of data-driven decision-making has been prevalent for more than three decades (Chen et al., 2012; Picciano, 2012), the amount of available data has rapidly grown in recent years as a result of the globalization of the world's economy and was further encouraged by the ubiquity of the internet, social media networks and mobile devices (Amankwah-Amoah, 2016; Durahim and Coşkun, 2015; Liu et al., 2016). As a result, the amount of data is currently doubling in volume every two years and is expected to account for 40 trillion GB by 2020 (Gantz and Reinsel, 2012). The availability of continuously growing sources of data is accompanied by significant improvements in data processing capabilities (McAfee et al., 2012), which accelerated the emergence of numerous related and partially overlapping business intelligence applications. Such applications are commonly summarized around and related to the term "Big Data" (Dutta and Bose, 2015; Schoenherr and Speier-Pero, 2015).

Meanwhile, increasing dynamics in the business environment of SCM rang in a new age of volatility and complexity (Christopher and Holweg, 2017). SCs need to be aligned with changing customer preferences to enable the provision of sustainable and individual products and logistics services (Akinc and Meredith, 2015; Dubey et al., 2017; Hu et al., 2016; Nouira et al., 2016), while the ongoing digitalization of operations in production, warehousing and transport logistics intensifies the digital transformation of SCM (Chen et al., 2013; Gautam et al., 2017). In addition, various disruptive technologies and transformative business model innovations such as additive manufacturing (Jiang et al., 2017) or servitization (Vendrell-Herrero et al., 2017) are on the rise with the potential to reshape entire supply ecosystems (Angeleanu, 2015; Ketchen et al., 2014). However, the nature of SC networks is inherently complex (Bode and Wagner, 2015; Serdarasan, 2013) and strategic adjustments require substantial investments that are difficult to change retrospectively (Govindan et al., 2017). SC organizations are therefore exposed to these dynamics with limited options to reduce or to avoid resulting information processing needs (Duncan, 1972; Galbraith, 1977). Thus, effective decision-making in uncertain environments is required to address the dynamics and their impact on future developments in SCM (Galbraith, 2014; Govindan et al., 2017).

In this regard, information processing theory postulates that the quality and performance of decision-making is based on an organization's capability to meet its information processing requirements (IPR) by an adequate level of information processing capacity (IPC) (Galbraith, 1973). Consequently, the effectiveness of decision-making,

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especially in uncertain and equivocal environments, is dependent on the availability of information (Galbraith, 1974; Tushman and Nadler, 1978; Winkler et al., 2015). Thus, the availability of and access to Big Data (BD) provides an opportunity for SCM to support and enable strategic as well as operational decision-making (Gunasekaran et al., 2017a; Waller and Fawcett, 2013). Potential applications of BDA in SCM are manifold and include, inter alia, supplier risk management (Rajesh, 2016; Rajesh and Ravi, 2015; Sanders, 2016), demand forecasting (Chong et al., 2017; Huang et al., 2014; Jun et al., 2014; Sagaert et al., 2016; Yu and Tseng, 2014), logistics planning and scheduling (Zhong et al., 2015), inventory and transportation management (Bertsimas et al., 2016; Huang and Van Mieghem, 2014; Waller and Fawcett, 2013) and reverse logistics (Morgan et al., 2016). While scholars have already widely acknowledged the importance of BDA to increase operational as well as financial performance (Gunasekaran et al., 2017b), there is limited understanding of how emerging BD technologies are going to affect the development of BDA in SCM (Hazen et al., 2016a; Kache and Seuring, 2017).

However, sole availability of information does not guarantee sufficient decision-making, as large amounts of data may also overwhelm managers and hinder the extraction of valuable insights (Williams et al., 2013). Therefore, and in line with OIPT, the capability to manage the usage of available information represents the most critical performance factor of an organization (Galbraith, 1974; Zand et al., 2015). Thus, and in contrast to previous efforts that were focused on the collection, storage and analysis of data, the main challenge is increasingly shifting toward the extraction of valuable insights for decision-making (Addo-Tenkorang and Helo, 2016; Arunachalam et al., 2017; Speranza, 2018; Vidgen et al., 2017; Zhong et al., 2016). For this purpose, however, organizations are required to understand BDA capabilities to translate insights and transparency into value propositions improvements or process optimizations (Arunachalam et al., 2017; Galbraith, 2014; Waller and Fawcett, 2013; Wang et al., 2016).

The application of BDA and the imperative for associated BDA capabilities also challenge traditional institutional arrangements, roles, actors and social structures of SC functions that are related to the processing and management of data (Braganza et al., 2017; Shah et al., 2017; Sivarajah et al., 2016; Waller and Fawcett, 2013; Wang et al., 2016). While the social impact of BDA on the organizational role of SCM becomes more evident, extant literature foremost addresses the economic performance and implications of BDA (Hazen et al., 2016b). Thus, there is also a limited understanding of how BDA will impact social change of SC functions and tasks (Galbraith, 2014; Hazen et al., 2016b). The study contributes to these topics by addressing the following two research questions:

> RQ1. How will Big Data Analytics impact the future development of Supply Chain Management?
> RQ2. How will Big Data Analytics impact the organizational role of supply chain managers and involved dynamics?

In the context of BD related research, Richey et al. (2016) explicitly encourage academics to involve the perception of industry practitioners in order to create valuable insights. In this regard, Brinch et al. (2017) and Hazen et al. (2016a) suggest further research to integrate interdisciplinary perspectives from practitioners and academics with a background in SCM and data science (DS). For this purpose, the consultation of external experts has proven to be a valuable tool to cope with strategic decision-making in dynamic business environments with high uncertainty (Milliken, 1987; Winkler et al., 2015). Hence, a survey that integrates the assessments of subject matter experts in the domain of SCM and DS was conducted. More specifically, a Delphi survey design was chosen since this technique has proven to be a reliable measurement instrument particularly for future-oriented research and examination of complex and uncertain situations, such as technological change (Rowe and Wright, 1999; Winkler et al., 2015).

The Delphi survey included 16 projections that describe short and concise future situations addressing different aspects and levels of the research questions. Particular attention was paid to their rigorous development, similarly to the formulation of hypotheses. A long-term horizon was examined in order to stimulate out-of-the-box, unconventional and creative thinking. In line with previous Delphi studies in the field of SCM, the time horizon of the survey projects into the year 2035 (Darkow et al., 2015; Foerster et al., 2014; Schuckmann et al., 2012). Based on the survey results, fuzzy c-means algorithm was applied to structure the discussion of the panel's assessments by clustering the projections according to each projection's expected probability, impact (if occurred) and desirability.

Thus, this paper contributes to extant literature with an investigation and assessment of the future development of BDA in SCM. The study draws on OIPT to address the limited focus of current research in understanding BDA capabilities in the context of the organizational change to place special emphasis on the dynamics of the organizational role of SC managers. Accordingly, the underlying theoretical framework investigates the role of BDA applications, capabilities and organizational change in achieving the "fit" between information processing needs and capacities in an increasingly dynamic business environment of SCM. For this purpose, this research extends studies by incorporating interdisciplinary subject matter experts in SCM and DS from academia, industry as well as politics/business associations.

2. Literature review and conceptual background

2.1. The role of big data in Supply Chain Management

The application of business analytics to extract valuable insights from information flows to support decision-making has always been an integral and vital ingredient of effective and successful management of SCs (Brinch et al., 2017). However, the amount of information and data generated and available for organizations has been continuously increasing due to the adoption and diffusion of various disruptive digital information technologies (Addo-Tenkorang and Helo, 2016; Arunachalam et al., 2017; Kache and Seuring, 2017; Wang et al., 2016). Accelerators of data volume growth include, inter alia, the internet of things (IoT) (Almada-Lobo, 2016; Arunachalam et al., 2017), sensor technology enabled tracking (Fosso Wamba et al., 2015), cloud computing (Lindner et al., 2010; Soliman, 2014; Tiwari and Jain, 2013), social media feeds (Ramanathan et al., 2017; Sanders, 2016) and computerized mobile devices (Addo-Tenkorang and Helo, 2016; Kache and Seuring, 2017).

Together with increasing size, data is also becoming more variable due to new sources of data. Consequently, more advanced procedures are required to integrate unstructured and heterogeneous formats (Zhong et al., 2016), including textual structures from social media (Chae, 2015; Chan et al., 2016; Cui et al., 2017), visual data from satellite images (Bryant et al., 2008) or sensor data for location, temperature, humidity or shock control (Ilie-Zudor et al., 2015; Li and Wang, 2017). Technological advances exacerbate this challenge by significantly accelerating the speed at which the data is generated and subsequently processed through organizations (Gandomi and Haider, 2015; Waller and Fawcett, 2013). Scholars widely agree on this triple "V" baseline that characterizes the properties of BD, including (1) volume, (2) velocity and (3) variety (Addo-Tenkorang and Helo, 2016; Fosso Wamba et al., 2015; Hofmann, 2017; McAfee and Brynjolfsson, 2012; Richey et al., 2016; Sanders, 2016; Waller and Fawcett, 2013; Wang et al., 2016; Yu et al., 2017; Zhong et al., 2016). However, optional extensions of this baseline encompass the associated dimensions of (4) veracity, which highlights aspects of reliability, trustworthiness and quality of data, and (5) value (Cheng et al., 2016; Fosso Wamba et al., 2015; Gupta and George, 2016; Richey et al., 2016; Yu et al., 2017).

The "value" property implies that increasing volume of highly