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Technical Note

Big data analytics in supply chain management between 2010 and 2016: Insights to industries

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ABSTRACT

This paper investigates big data analytics research and application in supply chain management between 2010 and 2016 and provides insights to industries. In recent years, the amount of data produced from end-to-end supply chain management practices has increased exponentially. Moreover, in current competitive environment supply chain professionals are struggling in handling the huge data. They are surveying new techniques to investigate how data are produced, captured, organized and analyzed to give valuable insights to industries. Big Data analytics is one of the best techniques which can help them in overcoming their problem. Realizing the promising benefits of big data analytics in the supply chain has motivated us to write a review on the importance/impact of big data analytics and its application in supply chain management. First, we discuss big data analytics individually, and then we discuss the role of big data analytics in supply chain management (supply chain analytics). Current research and application are also explored. Finally, we outline the insights to industries. Observations and insights from this paper could provide the guideline for academia and practitioners in implementing big data analytics in different aspects of supply chain management.

1. Introduction

Big data is defined as the huge or complex sets of data, which has a range of Exabyte and more. It exceeds the space of technical ability of storage system, processing, managing, interpreting and visualizing of a traditional system (Kaisler, Armour, Espinosa, & Money, 2013). Currently, data is increasing exponentially and is predicted to reach zettabyte per year in a few years. The concept of big data was first introduced by Cox and Ellsworth in October 1997, in an ACM digital library article (GilPress, 2012). Since then, it has attracted great attention from both academia and practitioners.

Academia and practitioners agree that this flood of data creates new opportunities, therefore many organization tried to develop and enhance its big data analytics capability to uncover and gain a better understanding from their big data hidden values. The study of big data is continuously evolved and expanded, and the main attributes of big data are now expanded into "5V" concept consist of volume, velocity, variety, verification/veracity, and value (Addo-Tenkorang & Helo, 2016; White, 2012). Kambatla, Kollias, Kumar, and Grama (2014) discussed the trends in big data analytics which include hardware and software. Collecting data from broadly distributed sources into the storage system that accommodate large datasets and running a diverse set of computation is challenging. Zhong, Newman, Huang, and Lan (2016b) provided the discussion on the current big data technologies including storage, data processing, and data visualization technology.

The term big data analytics can be defined as the application of advanced analytic techniques including data mining, statistical analysis, predictive analytics, etc. on big datasets as new business intelligence practice (Russom, 2011). It refers to the processes of examining and analyzing huge amounts of data with variable types to draw conclusion by uncovering hidden patterns and correlations, trends, and other business valuable information and knowledge, in order to increase business benefits, increase operational efficiency, and explore new market and opportunities (LaValle, Lesser, Shockley, Hopkins, & Kruschwitz, 2013; Loshin, 2013; Rouse, 2012). Fig. 1 illustrates the big data analytics model in the context of big data and data science. Big data analytics permits users to capture, store, and analyze huge amount of data, from internal as well as external of the organization, from multiple sources such as corporate database, sensor-captured data such as RFID, mobile-phone records and locations, and internet in order to understand the meaningful insights (Zakir, Seymour, & Berg, 2015).

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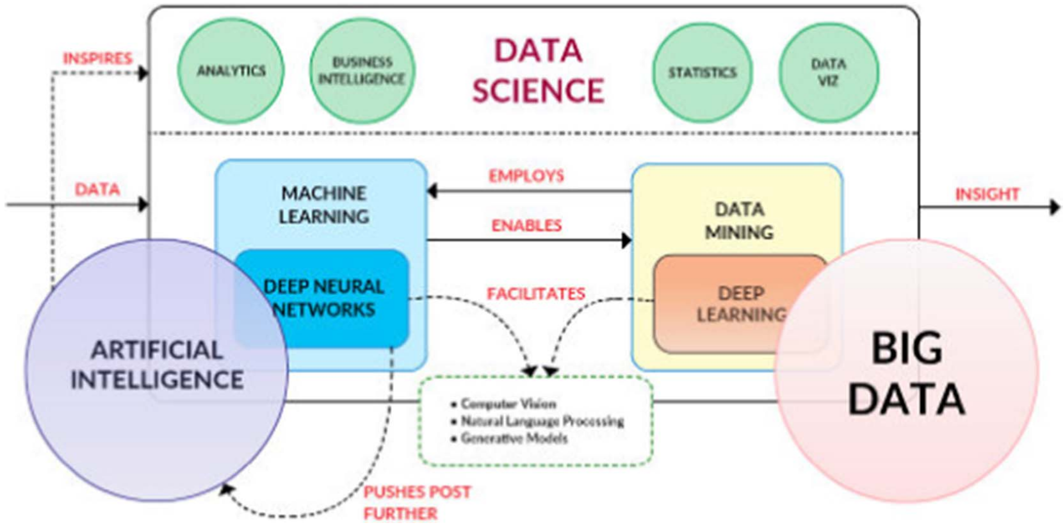

Fig. 1. Big Data analytics model in the context of data science (Mayo, 2017).

Akter, Wamba, Gunasekaran, Dubey, and Childe (2016) suggested that big data analytics has a big impact to enhance firm performance. By improving big data analytics capability, a firm could create new products and services, provide better customer service, increase sales and revenue, and expand into the new market. Zhong et al. (2016b) provided the discussion on the big data applications in various sectors such as financial services sector, healthcare, logistics, and manufacturing. However, present research reveals that there is a limited agreement regarding the performance of big data that support supply chain management. Consequently, this article tries to explore the application of big data and its analysis in supply chain management. This article is structured in the form of a literature review, which discusses the main issues of big data and its research as well as application in the field of supply chain management.

A comprehensive literature review is performed for this research. About 100 or more peer-reviewed journal articles/conference proceedings, as well as industrial white papers, are reviewed. Harzing Publish or Perish software was employed to investigate and critically analyze the trends and perspectives of big data research and applications in supply chain management between 2010 and 2016. This paper addressing big data issues, trends and views in supply chain management in order to extend big data value-adding perspective, thus proposing that big data being explored exhaustively to enable organization, especially industrial managers, business managers and other strategic decision maker, with a value-adding stream of information to have a competitive edge over their competitors.

The remaining sections of this article examine, discuss and elaborate on the following: first, review of big data analytics in supply chain management (supply chain analytics); second, publication and update of big data analytics in supply chain, and the viewpoint of future big data application in SCM; third comprises the managerial implications of big data application in SCM, and lastly the paper ends with the conclusion and recommendations of the research.

2. Supply chain analytics

Analytics in supply chain management is not a new thing (Souza, 2014). For a long time, supply chain management has use statistics and operation research for optimizing the objectives of matching supply and demand. Business analytics using information system support has a strong relationship to supply chain performance (Trkman, McCormack, de Oliveira, & Ladeira, 2010). However, the development of big data indeed brings out new opportunities. The term supply chain analytics can be used to define the advanced big data analytics in supply chain management (Wang, Gunasekaran, Ngai, & Papadopoulos, 2016a). This analytics can be categorized into descriptive, predictive and prescriptive analytics (Souza, 2014; Wang et al., 2016a):

- Descriptive analytics deal with the question of what has happened, what is happening, and why. It attempts to identify opportunities and problem using online analytical processing (OLAP) system and visualization tools supported by real-time information and reporting technology (e.g. GPS, RFID, transaction bar-code). Descriptive statistics are useful to illustrate total stock in inventory, average money spent per customer and year to year changes in sales. Common examples of descriptive analytics are reports that provide historical insights regarding the company's production, financials, operations, sales, finance, inventory, and customers.
- Predictive analytics deal with the question of what will be happening or likely to happen, by exploring data pattern using statistics, simulation, and programming. It attempts to accurately predict the future and discover the reason. It is important to remember that no statistical algorithm can "predict" the future with 100% certainty. Predictive analytics can be used throughout the organization, from forecasting customer behavior and purchasing patterns to identifying trends in sales activities. They also help forecast demand for inputs from the supply chains, operations, and inventory records. Predictive Analytics can be used to predict the future or fill in the information that you do not have.
- Prescriptive analytics deal with the question of what should be happening and how to influence it, by driving alternative decision based on descriptive and predictive analytics, using mathematical optimization, simulation or multi-criteria decision-making techniques. Prescriptive analytics is relatively complex to administer, and most companies have yet to use in their daily course of business. When implemented correctly, they can have a large impact on how businesses make decisions. Some of the larger companies are successful in using prescriptive analytics to optimize production; scheduling and inventory in the supply chain.

Some of the crucial scenarios that prescriptive analytics allows organization/companies to answer include:

- What kind of an offer should we make to each customer?
- What should be the shipment strategy for each retail location?
- Which product should I launch and when?

Statistical analysis, simulation, and optimization are popular techniques in supply chain analytics (Wang et al., 2016a). These techniques are the basis for supply chain decision making besides of other techniques such as meta-heuristic method (Fan, Heilig, & Voß, 2015).

2.1. Statistical analysis

Statistical analysis basically, consists of two types of analysis: descriptive and inferential. Descriptive statistics uses the data to describe or summarize the feature of sample or population, through either numerical calculations or graphs or tables. Inferential statistics uses the data to deduce properties and make predictions about a population based on a sample of data. By doing so, we can use quantitative and qualitative methods. Statistical analysis is necessary when we deal with the supply chain uncertainty, such as in inventory, distribution and risk analysis. Statistical multivariate techniques are useful for supply chain network monitoring to minimize the risk of an undesired situation and for efficient material flow management (Mele, Musulin, & Puigjaner, 2005).

Considering the volume, velocity, variety, and veracity of big data in supply chain analytics, we should have robust and easy to adapt statistical methods (Fan, Han, & Liu, 2014). Traditional statistical methods become invalid because the massive data lead to heterogeneity, noise accumulation, etc. Therefore, seeking effective statistical procedures has received major attention. For example, Cohen, Dolan, Dunlap, Hellerstein, and Welton (2009) proposed data-parallel statistical algorithms to do a sophisticated statistical analysis of big data. This algorithm tries to model and compare the densities as well as distributions of big data using specific methods like Conjugate Gradient, Mann-Whitney U Testing, and Ordinary Least Squares.

2.2. Simulation

Modeling and simulation have an important role in big data during the development of big data application. Modeling and simulation help developer to run the "what-if" analysis under different system configuration and complexity (Ranjan, 2014). One of the big data development challenges is to balance its cost and performance by optimizing the hardware and software configuration. Optimizing the configuration by conducting an empirical study does not cost efficient; it is time-consuming and difficult to control. Therefore, the simulation-based approach offers an important alternative.

Inside the analytic process, simulation empowers the diagnostic, predictive as well as prescriptive analytics for a decision maker. Shao, Shin, and Jain (2014) proposed a simulation for data analytics in a smart manufacturing system. In the case, valuable decisions are made after the manufacturers collect and analyze the huge data from the shop floor and surrounding environment. For example, as a predictive tool, simulation can help the manufacturers to predict the need for machines and additional equipment based on customer order forecast and learning from other historical data such as cycle time, throughput, and delivery performance. A similar model can be used for prescriptive analytics; in addition, we simulate a range of potential changes in input parameter to find the best combination.

Supply chain analytics provides new methods for the simulation problem with a large amount of data. The focus of supply chain analytics is to concentrate on the interrelationship between supply chain operations and system integration (Wang et al., 2016a). LLamasoft (2016) outlined some examples of where supply chain simulation can be used: predict service, test inventory policy, analyze production capacity, determine asset utilization, and validate optimization result.

2.3. Optimization

The Optimization technique is a powerful tool for supply chain data analytics (Balaraj, 2013). It is able to draw the insight from a complex system with multiple factors and constraints such as capacity, route, demand coverage and huge data volume. In addition, an optimization technique is able to uncover new data and analyze multiple objectives such as cost reduction and demand fulfillment. Finally, one can achieve the business objective through supply chain visibility optimization, scenario management, multi-user collaboration, and performance tracker. Optimization techniques in supply chain analytics can help to leverage supply chain planning accuracy, although creating large-scale optimization challenges due to high dimensional data (Wang et al., 2016a). Slavakis, Giannakis, and Mateos (2014) re-examined several statistical learning and signal processing tools for analytic optimization such as compressive sampling, dictionary learning, subspace clustering, and principal component analysis.

Based on SCOR supply chain model, Souza (2014) explored the opportunities for applying big data analytics in supply chain management Wang et al. (2016a) reviewed the critical role of big data analytics in supply chain management on a strategic, tactical and operational level. Strategic supply chain analytics are important for sourcing, network design, and product design. Tactical and operational supply chain analytics are important for demand planning, procurement, production, inventory, and logistics.

3. Big data in supply chain management publications between 2010 and 2016

For our purpose, the Harzing Publish or Perish software program was employed to retrieve academic publication data from 2010 to 2016 that contain all of the keywords "Big Data" and "Supply Chain" in their titles. This database software program uses Google Scholar and Microsoft Academic Search to obtain and analyze the citation (Harzing, 2007). This software tool is designed to enable individual researchers in presenting a noteworthy case for research impact to its best benefit.

Table 1 presents the Publish or Perish search results for "Big Data" and "Supply Chain" with minimum 1 citation in order to maintain the quality. We present the result in Table 1 following the descending year of publication and then the descending number of citation. It is found that the publication on big data analytics in supply chain management start on 2012 and significantly improved in quantity in last three years. The most cited paper is already in excess of 214 citations from Waller and Fawcett (2013b): "Data science, predictive analytics, and big data: a revolution that will transform supply chain design and management".

Our exploration identifies many other publications on big data analytics in supply chain management which are not listed in Table 1 because the title does not match the prerequisite keyword. Therefore we rerun the Publish or Perish software by combining the "Big Data" keyword with several of supply chain management related keywords, such as "sourcing", "network design", "product design, product development", "demand planning, demand forecasting", "procurement, purchasing", "production", "scheduling", "inventory" and "logistics" (Wang et al., 2016a). The results are shown in Table 2. Based on the data in Tables 1 and 2, the growth of publication on big data analytics in supply chain management is documented in Fig. 2.

Since the advancement of big data in the late 1990s, big data analytics is still in its infancy (Wang et al., 2016a). Many research and study tried to analyze, build perspective and advance the opportunities for big data research and application in supply chain management. Some have explored its application on the supply chain as a whole and revealed the benefits as well as the challenges. Others tried to match and optimized the technology and methods that support the application. In the following part, we outline some necessary classification themes used to review the current literature and/or studies. Table 3 provides the summary.

3.1. Supply chain analytics review on definition, benefit, and opportunities

Academia and industrial practitioners have explored the opportunities for big data analytics in supply chain management from a

Table 1
Harzing Publish or Perish publication list of 'Big Data' and 'Supply Chain' keywords with at least 1 citation.

Year	Cites	Authors	Title
2016	38	G Wang, A Gunasekaran, EWT Ngai, T Papadopoulos	"Big data analytics in logistics and supply chain management: Certain investigations for research and applications"
2016	6	BT Hazen, JB Skipper, CA Boone, RR Hill	"Back in business: operations research in support of big data analytics for operations and supply chain management"
2016*	8	R Zhao, Y Liu, N Zhang, T Huang	"An optimization model for green supply chain management by using a big data analytic approach"
2016	6	S Prasad, R Zakaria, N Altay	"Big data in humanitarian supply chain networks: A resource dependence perspective"
2016	5	BT Hazen, JB Skipper, JD Ezell, CA Boone	"Big data and predictive analytics for supply chain sustainability: A theory-driven research agenda"
2016	4	NR Sanders	"How to use big data to drive your supply chain"
2016	4	RY Zhong, ST Newman, GQ Huang, S Lan	"Big data for supply chain management in the service and manufacturing sectors: Challenges, opportunities, and future perspectives"
2016*	3	KJ Wu, CJ Liao, ML Tseng, MK Lim, J Hu	"Toward sustainability: using big data to explore the decisive attributes of supply chain risks and uncertainties"
2016	3	D Mishra, A Gunasekaran, T Papadopoulos	"Big data and supply chain management: a review and bibliometric analysis"
2016*	3	A Gunasekaran, T Papadopoulos, R Dubey, SF Wamba, SJ Childe, B Hazen, S Akter	"Big data and predictive analytics for supply chain and organizational performance"
2016	2	M Giannakis, M Louis	"A multi-agent based system with big data processing for enhanced supply chain agility"
2016	1	RG Richey Jr, TR Morgan, K Lindsay-Hall, FG Adams	"A global exploration of big data in the supply chain"
2016	1	S Biswas, J Sen	"A proposed framework of next generation supply chain management using big data analytics"
2016	1	V Navickas, V Gruzauskas	"Big data concept in the food supply chain: small markets case"
2016	1	P Liu, S Yi	"Investment decision-making and coordination of supply chain: A new research in the big data era"
2015	43	KH Tan, YZ Zhan, G Ji, F Ye, C Chang	"Harvesting big data to enhance supply chain innovation capabilities: An analytic infrastructure based on deduction graph"
2015	36	T Schoenherr, C Speier-Pero	"Data science, predictive analytics, and big data in supply chain management: Current state and future potential"
2015	7	SF Wamba, S Akter	"Big data analytics for supply chain management: A literature review and research agenda"
2015	7	HW Ittmann	"The impact of big data and business analytics on supply chain management"
2015	5	L Wang, CA Alexander	"Big data driven supply chain management and business administration"
2015*	5	E Hofmann	"Big data and supply chain decisions: the impact of volume, variety and velocity properties on the bullwhip effect"
2015	3	L Columbus	"Ten ways big data is revolutionizing supply chain management"
2015	3	Y Fan, L Heilig, S Voβ	"Supply chain risk management in the era of big data"
2015	2	L Ma, F Nie, Q Lu	"An analysis of supply chain restructuring based on big data and mobile internet—A case study of warehouse-type supermarkets"
2015	2	L Hepler	"Big data vs. disease: Mars, IBM bet on food supply chain genomics"
2015	2	DQ Chen, DS Preston, M Swink	"How the use of big data analytics affects value creation in supply chain management"
2015	1	NKG Isasi, EM Frazzon, M Uriona	"Big data and business analytics in the supply chain: A review of the literature"
2015	1	F Kache	"Dealing with digital information richness in supply chain management: A review and a big data analytics approach"
2014	128	BT Hazen, CA Boone, JD Ezell	"Data quality for data science, predictive analytics, and big data in supply chain management: An introduction to the problem and suggestions for research and application"
2014	30	NR Sanders	"Big data driven supply chain management: A framework for implementing analytics and turning information into intelligence"
2014	8	IV Rozados, B Tjahjono	"Big data analytics in supply chain management: Trends and related research"
2014	5	AL Milliken	"Transforming big data into supply chain analytics"
2014	5	GL Schlegel	"Utilizing big data and predictive analytics to manage supply chain risk"
2014	5	J Leveling, M Edelbrock, B Otto	"Big data analytics for supply chain management"
2014	4	AM Chircu, E Sultanow, FC Chircu	"Cloud computing for big data entrepreneurship in the supply chain: Using SAP HANA for pharmaceutical track-and-trace analytics"
2014	2	A Scott	"How supply chain managers dig big data"
2014	2	J Kenny	"Big data can have big impact on supply chain management: The use of data analytics is underused in supply chain management to minimize risk exposure"
2014	2	S Vasan	"Impact of big data and analytics in supply chain execution"
2014	1	L Jian, S Hao	"Study the competitive intelligence system of closed-loop supply chain big data era"
2014	1	M Pearson, FH Gjendem, P Kaltenbach, O Schatteman, G Hanifan	"Big data analytics in supply chain: Hype or here to Stay?"
2013	214	MA Waller, SE Fawcett	"Data science, predictive analytics, and big data: a revolution that will transform supply chain design and management"
2013	45	MA Waller, SE Fawcett	"Click here for a data scientist: Big data, predictive analytics, and theory development in the era of a maker movement supply chain"
2013	19	T Lu, X Guo, B Xu, L Zhao, Y Peng,	"Next big thing in big data: The security of the ICT supply chain"
2013	10	D Zage, K Glass, R Colbaugh	"Improving supply chain security using big data"
2013	6	Y Jin, S Ji	"Partner choice of supply chain based on 3D printing and big data"
2013	2	CH Chao	"The framework of information processing network for supply chain innovation in big data era"
2013	2	P Burnson	"3PLs investing heavily in big data capabilities to ensure seamless supply chain integration"
2012	3	L Cecere	"Five supply chain opportunities in big data and predictive analytics"

Harzing Publish or Perish Software analytical tool was run on 7th April 2017 at 09:30 am.
* Hofmann, Zhao et al., Wu et al., and Gunasekaran et al. are officially published in 2017 but available online since 2015 and 2016.

different perspective. Waller and Fawcett (2013b) provided an example on the connection between big data and supply chain management. There are many research opportunities regarding the application of big data in supply chain management relating to forecasting, inventory management, transportation management and human resources. Souza (2014) described supply chain analytics for decision making on the five SCOR model domains: plan, source, make, delivery and return. Wang et al. (2016a) reviewed the potential application of supply chain

Table 2
Harzing Publish or Perish publication list of 'Big Data' and 'Supply Chain Management' related keywords with at least 1 citation.

Year	Cites	Authors	Title
2016	25	RY Zhong, S Lan, C Xu, Q Dai, GQ Huang	"Visualization of RFID-enabled shop floor logistics Big Data in Cloud Manufacturing"
2016	6	MB Arias, S Bae	"Electric vehicle charging demand forecasting model based on big data technologies"
2016	6	K Katchasuwanmanee, R Bateman, K Cheng	"Development of the energy-smart production management system (e-ProMan): A big data driven approach, analysis and optimization"
2016	3	J Jin, Y Liu, P Ji, H Liu	"Understanding big consumer opinion data for market-driven product design"
2016	2	G Wang, A Gunasekaran, EWT Ngai	"Distribution network design with big data: model and analysis"
2016	2	S Kim, DH Shin	"Forecasting short-term air passenger demand using big data from search engine queries"
2016	1	S Bag	"Selection of big data analyst in purchasing and supply management: fuzzy VIKOR approach"
2016	1	BD Brouer, CV Karsten, D Pisinger	"Big data optimization in maritime logistics"
2016	1	W B Raap	"The design of a common data model for generic synchro- modal cargo-tracking in logistics using web scraping and big & open data"
2015	61	RY Zhong, GQ Huang, S Lan, QY Dai, X Chen, T Zhang	"A big data approach for logistics trajectory discovery from RFID-enabled production data"
2015	9	H Hassani, ES Silva	"Forecasting with big data: A review"
2015	5	AB Ayed, MB Halima, AM Alimi	"Big data analytics for logistics and transportation"
2015	4	R Mehmood, G Graham	"Big data logistics: a health-care transport capacity sharing model"
2015	3	B Mikavica, A Kostić-Ljubisavljević, VR Dogatovic	"Big data: challenges and opportunities in logistics systems"
2015	2	H Afshari, Q Peng	"Using big data to minimize uncertainty effects in adaptable product design"
2015	2	V Stich, F Jordan, M Birkmeier, K Oflazgil, J Reschke, A Diews	"Big data technology for resilient failure management in production systems"
2015*	2	RY Zhong, C Xu, C Chen, GQ Huang	"Big data analytics for physical internet-based logistics data from RFID-enabled intelligent shop floors"
2015	2	I Neaga, S Liu, L Xu, H Chen, Y Hao	"Cloud enabled big data business platform for logistics services: a research and development agenda"
2015	1	T Peristeris, D Redzepovic	"Big data-driven innovation: The role of big data in new product development"
2015	1	S Meister, W Deiters	"Information logistics solutions to cope with big data challenges in AAL and Telemedicine"
2015	1	T Wu, Y Lu, DB Peng	"Regional logistics and freight transportation optimization model research based on big data perspective"
2015	1	CJN Sousa, IHF Santos, VT Almeida, AR Almeida, GM Silva, AE Ciarlini, A Prado, RDA Senra, Gottin, A Bhaya, T Calmon, L Ferreira	"Applying big data analytics to logistics processes of oil and gas exploration and production through a hybrid modeling and simulation approach"
2014	7	S Robak, B Franczyk, M Robak	"Research problems associated with big data utilization in logistics and supply chains design and management"
2014	5	V Frehe, T Kleinschmidt, F Teuteberg	"Big data in logistics: Identifying potentials through literature, case study and expert interview analyses"
2014	5	RY Zhong, GQ Huang, SL Lan	"Shop floor logistics management using RFID-enabled big data under physical internet"
2014	4	T Engel, O Sadovskyi, M Boehm, R Heininger	"A conceptual approach for optimizing distribution logistics using big data"
2014	3	M Johanson, S Belenki, J Jalminger, M Fant, M Gjertz	"Big automotive data: Leveraging large volumes of data for knowledge-driven product development"
2014	2	AP Sivan, J Johns, J Venugopal	"Big data intelligence in logistics based on Hadoop and Map Reduce"
2014	2	Y Shang, D Dunson, JSJ Song	"Exploiting big data in logistics risk assessment via Bayesian non-parametric"
2013	13	A Balar, N Malviya, S Prasad, A Gangurde	"Forecasting consumer behavior with innovative value proposition for organizations using big data analytics"
2013	10	MR Brule	"Big data in exploration and production: Real-time adaptive analytics and data-flow architecture"
2013	10	M Jeseke, M Grüner, F Wieβ	"Big data in logistics: A DHL perspective on how to move beyond the hype"
2013	9	CW Chase Jr.	"Using big data to enhance demand-driven forecasting and planning"
2013	3	FF Wei	"ECL Hadoop: "Big data" processing based on Hadoop strategy in effective e-commerce logistics"
2012	9	S Swaminathan	"The effects of big data on the logistics industry"

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* Wu et al. is officially publish ed in 2017 but available online since 2015.

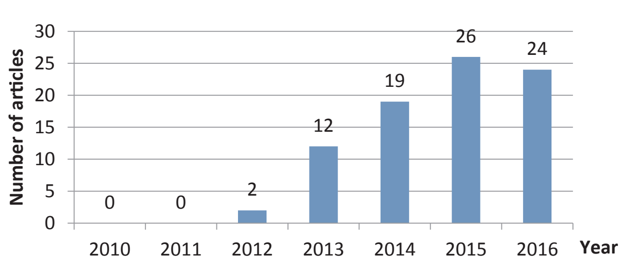

Fig. 2. Publication on big data analytics in supply chain management.

analytics including the analytic techniques and relate them to maturity, sustainability, and holistic business analytics. Addo-Tenkorang and Helo (2016) reviewed big data applications and develop taxonomy based on 5Vs of big data related to supply chain management. Zhong et al. (2016b) discussed big data technologies and models, current application in several service and manufacturing sectors and its global movement. Hofmann (2017) studied the big data volume, variety and velocity properties to reduce the bullwhip effect of the supply chain. Gunasekaran et al. (2017) also confirmed that big data analytics improved supply chain efficiencies, quicker response to changes, enhance relationship and planning capabilities.

Table 3
Classification themes of literature on big data analytics in supply chain management with at least 1 citation.

No.	Classification	Sub-classification	References
1	Review on definition, benefits and opportunities for future research and application on big data analytics in SCM	–	Cecere (2012), Waller and Fawcett (2013a, 2013b), Kenny (2014), Leveling, Edelbrock, and Otto (2014), Milliken (2014), Pearson, Gjendem, Kaltenbach, Schatteman, and Hanifan (2014), Rozados and Tjahjono (2014), Sanders (2014), Vasan (2014), Chen, Preston, and Swink (2015), Columbus (2015), Isasi, Frazzon, and Uriona (2015), Ittmann (2015), Kache (2015), Biswas and Sen (2016), Hazen, Skipper, Boone, and Hill (2016a), Mishra, Gunasekaran, Papadopoulos, and Childe (2016), Richey, Morgan, Lindsey-Hall, and Adams (2016), Sanders (2016), Schoenherr and Speier-Pero (2015), Wamba and Akter (2015), Wang and Alexander (2015a), Wang et al. (2016a), Zhong et al. (2016b), Gunasekaran et al. (2017), Hofmann (2017)
2	Application and exploration of big data analytics in SCM	Strategic sourcing	Jin and Ji (2013)
		SC network design	Prasad et al. (2016), Wang et al. (2016b)
		Product design & development	Johanson et al. (2014), Afshari and Peng (2015), Peristeris and Redzepovic (2015), Jin et al. (2016)
		Demand planning	Balar et al. (2013), Chase (2013), Hassani and Silva (2015), Arias and Bae (2016), Kim and Shin (2016)
		Procurement	Schlegel (2014), Fan et al. (2015), Bag (2016)
		Production	Brule (2013), Zhong et al. (2014, 2015, 2017), Stich et al. (2015), Katchasuwanmanee et al. (2016), Zhong, Lan, Xu, Dai, and Huang (2016a)
		Inventory	–
		Logistics & Distribution	Swaminathan (2012), Burnson (2013), Jeseke, Grüner, and Weiß (2013), Engel, Sadovskyi, Boehm, and Heininger (2014), Frehe, Kleinschmidt, and Teuteberg (2014), Robak, Franczyk, and Robak (2014), Scott (2014), Ayed et al. (2015), Mikavica, Kostić-Ljubisavljević, and Dogatovic (2015), Mehmood and Graham (2015), Sousa et al. (2015), Wu, Lu, and Peng (2015), Brouer et al. (2016)
		Sustainable, Agile SC & Performance	Hepler (2015), Giannakis and Louis (2016), Hazen et al. (2016b), Navickas and Gruzauskas (2016), Wu et al. (2017), Zhao et al. (2017)
3	Technology and methods for big data analytics in SCM	–	Chao (2013), Lu et al. (2013), Wei (2013), Zage et al. (2013), Chircu et al. (2014), Hazen, Boone, Ezell, and Jones-Farmer (2014), Jian and Hao (2014), Shang, Dunson, and Song (2014), Sivan, Johns, and Venugopal (2014), Ma, Nie, and Lu (2015), Meister and Deiters (2015), Neaga et al. (2015), Tan et al. (2015), Raap (2016), Liu and Yi (2016)

3.2. Supply chain analytics application

Here, we highlight some literature on the application of big data analytics in supply chain management areas.

3.2.1. Strategic sourcing

Strategic sourcing is one of the company's strategic long-term partnership which focuses on collaboration and supplier relationship management. The decision not only considers cost, quality, and delivery but also incorporates some strategic dimensions and capabilities of the supplier (Talluri & Narasimhan, 2004). According to Panchmatia (2015), big data analytics supported supplier management decision by providing accurate information on organizational spending pattern. For example, big data can provide accurate information on the return on investment (ROI) of any investment, as well as in-depth analysis of potential supplier. Jin and Ji (2013) applied analytic hierarchy process (AHP) and fuzzy synthetic evaluation in choosing supply chain partner considering big data processing capacity as one of the evaluated factors. The objective is to select supply partner that can adapt to the future challenges from big data.

3.2.2. Supply chain network design

Supply chain network design is another strategic decision that determines the supply chain physical configuration. Wang, Gunasekaran, and Ngai (2016b) developed a mixed integer nonlinear model that utilized big data in selecting the location of distribution centers using randomly generated big datasets for customer demand, warehouse operation, and transportation. They assumed that the behavioral dataset has been analyzed using marketing intelligence tools. They concluded that big data could provide additional information (e.g., service level and penalty cost data), therefore creating opportunities for designing complex distribution network. Recently, Prasad, Zakaria, and Altay (2016) studied the application of big data analytics to design intervention such as disaster relief, healthcare, and education in specific humanitarian supply chain network. As humanitarian data possess the various big data attributes (volume, variety, veracity, velocity, and value), big data analytics can produce superior humanitarian outcomes through a resilience humanitarian supply chain.

3.2.3. Product design and development

The alignment of product design with the supply chain resulted in competitive advantage and supply chain resilience (Khan, Christopher, & Creazza, 2012). Therefore, supply chain constraints must be integrated into the product design phase, and product specificities must be considered in designing the supply chain structure (Labbi, Ouzizi, & Douimi, 2015). Big data analytics in product design and development have received much attention recently. According to Afshari and Peng (2015), big data analytics can improve product adaptability and give more confidence to the designer. Customer purchase record and online behavior are the examples of big customer data that can help designers to understand customer requirements (Jin, Liu, Ji, & Liu, 2016). They used customer opinion data polarities to identify product features and predict trends. In the automotive industry, the importance of big data is derived from the vehicle that shows huge performance data and customer needs (Johanson, Belenki, Jalminger, Fant, & Gjertz, 2014).

3.2.4. Demand planning

Many supply chain executives are keen to improve demand forecasting and production planning with big data (Chase, 2013). Big data analytics make it possible to sense demand signal, determine optimal prices and trace consumer loyalty data. This will help to detect new market trends, determine root causes of failures, issues, and defects. However, hardware and software advancement, as well as the algorithm architecture are the main challenges (Hassani & Silva, 2015). Balar, Malviya, Prasad, and Gangurde (2013) argued that big data analytics could support the creation of business service innovation through customer behavior forecast. Arias and Bae (2016) incorporated historical real-world traffic data and weather data in their forecasting model to estimate electric vehicle charging demand. The model can identify where and when the charging demand is high, therefore allowing utility operators to plan the operation and generation profiles. Kim and Shin (2016) developed a forecasting model using big data from search engine queries to estimate short-term air passenger demand. The result has helped the airport authority to set appropriate operation plans with an average forecast error of 5.3%.

3.2.5. Procurement

As a tactical and operational decision, procurement consists of a series of auction mechanism and contracting (Souza, 2014). According to Wang et al. (2016a), supply chain analytics could be applied in procurement to manage supply risks and suppliers performance. Fan et al. (2015) proposed a framework to detect supply chain risk as early as possible using internal and external big data. For example, public news and social media may inform disasters and exchange rate movement that will influence supply chain. The framework enables real-time supply chain risk management monitoring, emergency planning, and decision support. Schlegel (2014) also proposed big data predictive analytics for managing supply chain risk. Big data predictive analytics can help supply chain manager to identify, assess, mitigate, and manage supply chain risk.

3.2.6. Production

Some studies have been done on big data analytics application in the production area. For example, Zhong, Huang, and Lan (2014) applied RFID-enable big data to support shop floor logistics planning and scheduling. He (Zhong et al., 2015) then implemented the Physical Internet concept by using the Internet of Things (IoT), wireless technology, and big data analytics to create an RFID-enabled intelligent shop floor environment. Stich et al. (2015) included the anticipation for production. Katchasuwanmanee, Bateman, and Cheng (2016) also utilized internal and external big data to build a smart system to improve production efficiency and reduce carbon emission.

3.2.7. Inventory

In Publish or Perish Software, only two publications on big data analytics in inventory management were found. Cohen (2015) showed that in inventory management, it was possible to advance the benefits of big data by connecting the internal production system with the external partners (suppliers and consumers). Sharma and Garg (2016) discussed the relationship between automated inventory control system and the generation of big data. Big data analytics can gather the interrelationship among data and optimize the inventory ordering decisions (Wang et al., 2016a).

3.2.8. Logistics and distribution

The researches done on the application of big data analytics in logistics, distribution, and transportation are more prevalent. To be competitive, the application of big data analytics in logistics and transportation companies is critical (Ayed, Halima, & Alimi, 2015). Predictive and prescriptive big data analytics also addressed many maritime companies planning problems (Brouer, Karsten, & Pisinger, 2016). Mehmood and Graham (2015) illustrated how to efficiently improve city health-care service through a transportation capacity sharing using big data. Burnson (2013) reported that most of the major third-party logistics providers (3PLs) were investing heavily in big data capabilities to ensure seamless supply chain integration. It is a fact that big data can support the end-to-end visibility in the supply chain and create agiler logistics/supply chain strategies.

3.2.9. Supply chain agility and sustainability

Some studies have been done to examine big data analytics that supports the advanced supply chain agility (Giannakis & Louis, 2016) and supply chain sustainability (Hazen, Skipper, Ezell, & Boone, 2016b; Hepler, 2015; Wu et al., 2017; Zhao, Liu, Zhang, & Huang, 2017). For example, Zhao et al. (2017) integrated data acquisition and data quality control of big data science in a multi-objective mathematical model for green supply chain management. Wu et al. (2017) combined social media data with the firm's financial and operational data. Moreover, the application of expert judgment has helped LED industry to develop sustainability and strengthen their capabilities to mitigate risks and uncertainties.

Supply chain analytics has been widely implemented in many aspects the supply chains, though the publications on the application of supply chain analytics in inventory management and strategic sourcing are still limited. This is a challenge for people working in this area to take the advantage of the explosion of available data for better sourcing and inventory planning. Big chain analytics can align the sourcing strategies to the organization's strategy and optimize the sourcing decision (Wang et al., 2016a). Big data analytics also improve inventory decision through a better understanding of uncertain customer demand (Bertsimas, Kallus, & Hussain, 2016).

3.3. Supply chain analytics technology and implementation

Developing advanced method and technology to support big data analytics application in supply chain management is critical. Chao (2013) discussed the framework of information processing network to apply big data analytics in supply chain management. Lu et al. (2013) discussed the security of the information and communication technology. Zage, Glass, and Colbaugh (2013) discussed the technical aspect of supply chain security related to supply chain risk management. Chircu, Sultanow, and Chircu (2014) and Neaga, Liu, Xu, Chen, and Hao (2015) discussed the cloud computing technology for big data analytics in the supply chain. Tan, Zhan, Ji, Ye, and Chang (2015) proposed an approach to assist firms to capture their innovation potential with big data analytics. Recently, Liu and Yi (2016) studied the problem of decision-making in big data information investment.

3.4. Future application of BDA in supply chain

Big data provides supply chain networks with greater data accuracy, clarity, and insights, leading to a greater e-contextual intelligence shared across the supply chains. It can be a powerful tool for driving supply chains ahead. Currently, big data solutions have helped large retail supply chains to monitor consumer behaviors by establishing a more accurate prediction of customer preferences. Supply chains decision makers need to continuously seek ways to effectively manage big data sources to gain more values. The effective use of big data sources lead to an abundance of supply chain process improvement:

- Building responsive or agile supply chains through a better understanding of the market trends and customer preferences. Big data analytics can facilitate the real-time monitoring of supply chain that enhances the speed and flexibility of supply chain decision. The triangulation of a range of social media, news, event, and weather data (SNEW), and direct data inputs from multiple static and dynamic data points provide the capability to predict and proactively plan supply chain activities.
- Building reliable supply chains through the application of Internet of Things (IoT) and machine learning in each supply chain activities. For instance, IoT can provide real-time telemetry data to reveal the details of production processes. Machine learning algorithms that are trained to analyze the data, can accurately predict imminent machine failures. Avoiding delivery delays by analyzing GPS data in addition to traffic and weather data to dynamically plan and optimize delivery routes.
- Supporting the sustainability initiatives in supply chain management. Big data analytics undoubtedly will enhance financial

measures, social and environmental performance measures. For instance, IoT can provide real-time traffic data for better delivery planning that affect the cost of fuel consumption as well as carbon emission.
- Enabling global supply chains to adopt a proactive rather than a reactive response to supply chain risks (e.g. supply failures due to fabricated or natural hazards, operational and contextual disruptions). In a more complex global supply chain, big data analytics can help supply chain managers to be more aware of the external future events.

Big data analytics can also be applied across the end-to-end supply chain. For instance, the points of sales (POS) data on retailers provide real-time demand data with price information. It gives the signal for replenishment such as in the vendor managed inventory system. RFID data provide automated replenishment signal, automated receiving and storing information, and automated checkout data which inform the real-time inventory status. Supplier data provide important data for supplier risk management and for better coordination with supplier processes. Manufacturing sensor data provide real-time monitoring of manufacturing equipment and identify an inevitable problem. During the delivery process, GPS data provide real-time inventory location data and help in reducing inventory fulfillment and lead times (Rowe & Pournader, 2017).

Despite the potential use of big data, many supply chains are unable to harness the power of available data to generate useful insights for their businesses. The underlying reasons are due to the lack of capabilities to analyses large sums of data and/or the use of erroneous data which result in significant cost saving (Rowe & Pournader, 2017). Therefore the efforts to strengthen the supply chain analytics capabilities become an important focus for all supply chains.

4. Application of BDA in different types of supply chain

Currently, BDA practices have been extensively reported. One of the main goals is to make full usage of the data to improve productivity, by providing "the right information, for the right user, at the right time" (Brandl, 2007). The BDA has applications in different companies including finance, healthcare, and manufacturing (see Fig. 3).

4.1. Finance

Financial institutions are constantly seeking new ways to maintain a competitive advantage and increase efficiency. In order to stay afloat in the industry, these institutions are incorporating big data into their business strategy. In the past few years, there have been great innovation

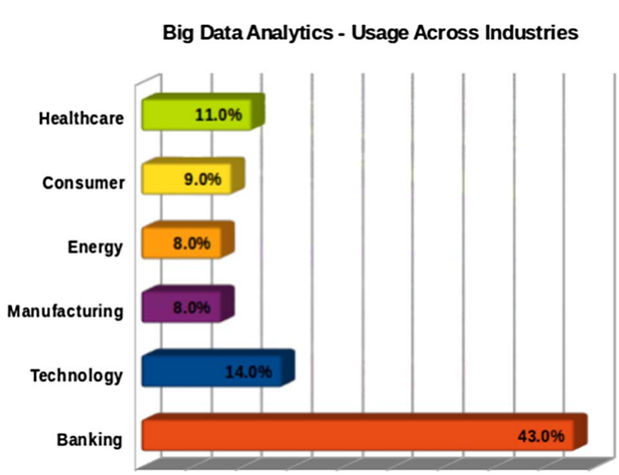

Fig. 3. Application of big data analytics in the different supply chain.
Source: Peer Research-Big Data Analytics Survey.

and investment in Big Data and analytics. With the help of Big Data, banks and financial service organizations can now use this information to continually track client behavior in real time, and provide the exact service and resource as needed. This real-time evaluation will, in turn, boost overall performance and profitability. To gain a competitive advantage for global financial service organization after the 2008 global financial crisis, BDA has become necessary (Sarrocco, Morabito, & Meter, 2016). Due to the huge transactions and activities, the application of big data is now common in most of the financial organizations such as insurance companies, asset management, capital market and banks. Bean (2016) reported that 70% global financial service organization thought BDA was important and 63% has applied big data in in their organizations. It was projected that the spending on the big data technology in a global financial industry from 2015 to 2019 will grow around 26%, reaching an estimated value of USD 7 billion (Technavio, 2015). BDA help financial service industry to achieve better performance by improving customer intelligence such as customer centricity, customer risk analysis, and customer retention. BDA also support financial service industry operation and transaction such as generating new product and services, algorithmic trading and analytics, and organizational intelligence such as employee collaboration. Finally, BDA also supports financial service industry in risk management and regulatory reporting (Connors, Courbe, & Waishampayan, 2013). For a Chief Financial Officer (CFO) who is the key unit for strategic decision making, big data offers huge data sets to achieve more knowledge, trends, and information. To this end, a business intelligence and analytics tool proposed the use of big data to assist Chief Financial Officer (CFO) to improved data accuracy, provide greater value and make better decisions (Chen, Chiang, & Storey, 2012). A big data approach was also proposed to calculate VPIN (Volume-synchronized probability of informed trading) to examine the market volatility in financial markets (Wu, Bethel, Gu, Leinweber, & Ruebel, 2013). Predictive Modeling and real-time decision making play a vital role; they result in a competitive advantage for the dynamic financial markets (Peat, 2013).

Barclays is a financial firm that has the history of using big data. Barclays see big data not only as supporting activity but primary competency. They apply big data in many areas such as treasury, financial crime, intelligence, risk and finance (Barclays, 2015). Deutsche Bank also has recognized the benefit of applying big data in their businesses. Deutsche Bank has set up a Data Lab that provides internal data, analytics consultancy, test-out business idea, and technology support to other division and business function (Deutsche Bank, 2014).

4.2. Healthcare

The healthcare industry historically has generated large amounts of data, driven by record keeping, compliance & regulatory requirements, and patient care. Big data in healthcare is overwhelming not only because of its volume but also because of the diversity of data types and the speed at which it must be managed. The totality of data related to patient healthcare and well-being make up "big data" in the healthcare industry. A report delivered to the U.S. Congress in August 2012 defines big data as "large volumes of high velocity, complex, and variable data that require advanced techniques and technologies to enable the capture, storage, distribution, management and analysis of the information". Big data encompasses such characteristics as variety, velocity and, with respect specifically to healthcare, veracity. Existing analytical techniques can be applied to the vast amount of existing (but currently unanalyzed) patient-related health and medical data to reach a deeper understanding of outcomes, which then can be applied at the point of care. Feldman, Martin, and Skotnes (2012), one of the early publications that discussed big data application in healthcare. Healthcare data is growing from personal medical records to laboratory instrument reading, radiology images, human genetics and population data. BDA can reduce healthcare cost, and by improving the quality and effectiveness of healthcare system. Bort (2012) reported on combating influenza based on flu report by providing near real-time view. Other big data initiatives were to monitor inhaler usage and reduce the risk of the asthma attack and cancer (Nambiar, Bhardwaj, Sethi, & Vargheese, 2013). BDA can also help health insurance companies to identify fraud and anomaly in a claim which is difficult to detect by the common transaction processing system (Srinivasan & Arunasalam, 2013). Groves, Kayyali, Knott, and Van Kuiken (2013) defined several values from big data application in healthcare: there are right living, right care, right provider, right value and right innovation. (Nambiar et al., 2013) proposed a focus on preventive care and population health management as the future big data application in healthcare. The potential of BDA in healthcare is great; however, there are many challenges such as improvement in the available platform to better support the data processing, a menu driven and easy friendly package, and more real times. Issues on ownership, data acquisition continuity, data cleansing, and standardize data are other challenges (Raghupathi & Raghupathi, 2014).

4.3. Manufacturing

For all the attention Big Data has received, many companies tend to forget about one potential application that can have a huge impact on their business – the employee experience. When done right, it can it help track, analyze, and share employee performance metrics. Applying Big Data analytics to your employees' performance helps you identify and acknowledge not only the top performers but the struggling or unhappy workers, as well. These tools allow companies to look at real-time data, rather than just annual reviews based on human memory. Since in the computer era, manufacturing industry has user data and information technology to drive productivity in design, production, and delivery of products. Approximately, manufacturing industry stores 2 exabytes of new data in 2010 (Nedelcu, 2013). A massive amount of data flooded manufacturing sector since various electronic devices, sensors, and digital machineries such as RFID technology are used in shop floors, production lines, and factories. Therefore BDA can support manufacturer building intelligent shop floor logistics system (Zhong, Xu, Chen, & Huang, 2017; Zhong et al., 2015). A massive amount of data also come from design and manufacturing engineering activity in form of CAD, CAM and CAE models, product failure data, process performance data, internet transaction, etc. Efficiency, defect tracking and product quality, improvement in product manufacturing process and supply planning are some benefits of big data in manufacturing (Wang & Alexander, 2015b).

Manufacturing firms, such as Raytheon Corp. has develop smart factories which are based on the powerful capacity of handling big data from different sources such as instruments, sensors, Internet transactions, CAD models, digital records, and simulations in the company that enable the real-time control of multiple elements of the production process (Noor, 2013). General Electric, creating effective and efficient servicing strategies by viewing big data from sensors in manufactured products including, in GE's case, locomotives, jet engines, gas turbines, and medical imaging devices (Davenport, 2013). A German truck body and trailer maker, Schmitz Cargobull, uses sensor data, telecommunication and BDA to monitor cargo weight and temperatures, routes, and maintenance of its trailers to minimize their usage breakdown (Chick, Netesine, & Huchzermeier, 2014). In 2016, Toyota Motor Corporation launches Toyota Connected as their Big Data Business Unit to significantly improve their data management capabilities. Toyota also initiates connected car platform to collect vehicle big data for creating new business and service such as adding safety and security service, traffic information service, create mobility service, and feedback to design (Toyota Motor Corporation, 2016). The integration of BDA into manufacturing system design should move from a descriptive into a predictive system performance model over a period of time, such as using what-if analysis, cause- effectmodel and simulation (Cochran, Kinard, & Bi, 2016).

5. Managerial implications

Big data analytics has become a hot topic in many industries including the supply chain management. There is much scope for advancement in the use of the right analytics techniques. In earlier pieces of literature (Souza, 2014; Trkman et al., 2010; Wang et al., 2016a), there are different methods and potential application of various analytics (e.g. descriptive, predictive, and prescriptive). In our review paper, we examined thoroughly the big data analytics in the supply chain management aspects and discussed recent updates of these methods and application in supply chain management that are important for managers. Big data analytics has important applications across the end-to-end supply chain. From the demand data at the POS, retailer data, delivery data, manufacturing data, until supplier data. Big data analytics supports all the supply chain activities, it includes strategic sourcing, network design, product design and development, demand planning, procurement, production, inventory, until logistics and distribution, as well as the reverse. The effective use of big data sources leads to an abundance of process improvement in the supply chain. Further big data analytics can support the development of responsive, reliable, and/or sustainable supply chain. Big data analytics able to handle huge sets of data in a complex global supply chain. We also emphasize the application of big data analytics for various supply chains, such as finance/banking, healthcare, and manufacturing industry. Other industries such as technology, energy, hospitality industry, and other service industry will also take advantage of big data analytics. Depending on their strategies requirements, the choice of big data analytics, methodologies, and key performance indicators varies from organizations to organizations. The environment, culture, politics, and the management team within the organization plays a very critical role in decision making. Sufficient resources with analytics capabilities become the biggest challenges for many supply chain. Supply chain needs to create tight and ongoing links between data experts and business function, to answer the question of how data can help drive supply chain result. Cross collaboration among firms in a supply chain is one alternative to overcome the challenge.

6. Limitations and further research directions

This paper has a number of limitations:

- The findings of the literature review are based on Harzing Publish or Perish software which is very sensitive to the input keywords. Literatures which have slightly different keywords may be missed out.
- Our review on the current literatures does not consider the quality of the literature except that the literature has been cited at least once. We focused on considering the latest research of big data analytics in supply chain management. Nevertheless, we believe it is comprehensive as it covers many highly ranked academic journals.
- Our additional keyword and classification are adapted from Wang et al. (2016a). Our choice was based on the fact that it reflects the common views of academia in supply chain management.

Based on our review and findings, this study recommends future research in the implementation of big data analytics in specific industry application. All other aspects of supply chain management should also be studied with real data, especially big data analytics for strategic sourcing, network design, procurement, and inventory management, as well as big data analytics that supports supply chain coordination, agility, and sustainability.

7. Concluding remarks

The present paper provides a comprehensive literature review on the studies done in the field of big data analytics in supply chain management. To do so, we systematically reviewed and analyzed papers in the respective categories to identify the major advances and highlight the research gaps. The increasing number of data in supply chain management requires tools to utilize the big data. Big data analytics has shown to be an important discipline that can provide the possible solutions to extract more useful information and wisdom for decision-making. With the current big data analytics methodologies and applications in supply chain management, opportunities and future perspectives from the supply chain management aspects are highlighted. Academia and industrial practitioners can be inspired to transform the supply chain management with the help of big data analytics. The present review paper can provide insights to both academia and practitioner in their application of big data analytics in supply chain management.

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