The emerging big data analytics and IoT in supply chain management: a systematic review

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Abstract

Purpose – The purpose of this study is to provide insights into the way in which understanding and implementation of disruptive technology, specifically big data analytics and the Internet of Things (IoT), have changed over time. The study also examines the ways in which research in supply chain and related fields differ when responding to and managing disruptive change.

Design/methodology/approach – This study follows a four-step systematic review process, consisting of literature collection, descriptive analysis, category selection and material evaluation. For the last stage of evaluating relevant issues and trends in the literature, the latent semantic analysis method was adopted using Leximancer, which allows more rapid, reliable and consistent content analysis.

Findings – The empirical analysis identified key research trends in big data analytics and IoT divided over two time-periods, in which research demonstrated steady growth by 2015 and the rapid growth was shown afterwards. The key finding of this review is that the main interest in recent big data is toward overlapping customer service, support and supply chain network, systems and performance. Major research themes in IoT moved from general supply chain and business information management to more specific context including supply chain design, model and performance.

Originality/value – In addition to providing more awareness of this research approach, the authors seek to identify important trends in disruptive technologies research over time.

Keywords Systematic literature review, Disruption, Supply chain disruptions

Paper type Literature review

1. Introduction

First introduced by Christensen (1997), the concept of disruptive technology has become a popular topic in both academic research and business practices (Christensen, 1997; Obal, 2017). While sustainable technology makes incremental improvements to the business processes, disruptive technology shakes up an industry or enables a business model that creates a completely new industry, even though these technologies may be unfavorable to the users at the early stage (Bower and Christensen, 1995; Christensen, 1997). Disruptive technologies "dominate industries with new, exciting features that are differentiated from existing technologies" (Obal, 2017, p. 42). Business models based on disruptive technologies are typically more efficient, more productive and more convenient than those established on the incumbent technology (Christensen, 1997). For example, Internet of Things (IoT) has radically changed warehouse and inventory management by tightly coupling distribution center, transportation and customer management system (Yang *et al.*, 2013; Banker, 2014; Parry *et al.*, 2016a). As a result, IoT could not only reduce operational cost but could also provide more customized, responsive and innovative customer service (Zhou *et al.*, 2015).

Although supply chain executives have drawn extensive attention to disruptive technologies such as IoT, big data analytics, three-dimensional (3D) printing, drones and cloud computing, they are facing great challenges to disrupt established systems and processes with innovative technologies when designing supply chains (Rowe and Pournader, 2017). One big challenge is that disruptive technologies are associated with uncertainty, cost and complexity. Technologies considered disruptive may not make an immediate impact on the mass market (Tellis, 2006). Hence, investing in a disruptive technology is likely to carry significant risk in supply chain management. In addition, disruption also means adaptation to radical changes, which can be painful and punishing within an

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organization and across the supply chain (Tellis, 2006). It may take years before supportive and aligned organizational and supply chain systems, processes and knowledge assets become mature. The potentials of disruptive technology cannot be realized to create competitive advantages unless they are strategically built into a supply chain (Pérez *et al.*, 2017). Finally, Danneels (2004) emphasized that the core of disruptive technology is that it changes the bases of competition. Given the widespread understanding that game-changing disruption is inevitable, there is little theoretical or practical perspective on how disruptive technologies will revolutionize traditional manufacturers and suppliers, potential new players, regulators, consumers, markets and the supply chain.

The review of existing literature on disruptive technology revealed several inadequacies, including conceptual issues and methodology issues. On one hand, while the definition lies in the term of "disruptive", how it is defined and applied in different contexts is vague. The ambiguity may be a result of the assumption that technology considered to be disruptive does not make an immediate impact on the supply chain or the disruptive effect does not occur in the industries in which the technology arises. In other words, "disruptive" should be understood from a process perspective that it is not the technology itself which is disruptive, but its impact on strategy or business models (Christensen *et al.*, 2003). This ambiguity further complicates theory building and operational model validation around disruptive technology (Sood and Tellis, 2011). On the other hand, as Christensen *et al.* (2015) noted, it is when the technology becomes a common feature of large-scale operations and market that disruption has occurred (Christensen, 2015). Because technology is no longer just a tool but a critical driver to strategy, theories and practical guidance are needed to implement disruptive technologies in supply chain strategically. The existing studies largely focus on what happens after a disruptive technology hits a supply chain. There is relatively little research on why some disruptive technologies are adopted and how to best exploit opportunities ahead of the competition through disruptive technology (Goldsby and Zinn, 2016).

The current study used a state-of-the-art methodology to conduct a systematic review on disruptive technology literature in the past 20 years. Disruptive technologies follow the growth of internet technologies, thus covering the past 20 years sufficiently covers the research published in these streams. The objective of this paper is to understand the evolution of research on disruptive technology in supply chain and other contexts as well. However, disruptive technologies are the focus of several research disciplines, for example, computer science, management science and information systems. To better understand the context of these research areas, we distinguish the research aimed to contribute in business discipline versus research that falls outside of the business research domain. We believe that the answers to the following research questions will provide a good insight into the way in which understanding and implementation of disruptive technology have changed over time and the keys when responding to and managing disruptive change in supply network and supply chain contexts:

RQ1. What are the definitions and applications of disruptive technologies in supply chain and relevant fields?

RQ2. How has disruptive technology trend evolved over years in business supply chain research?

RQ3. What are the semantic differences of themes between the communities of business supply chain research versus non-business supply chain research?

2. Disruptive technologies

Technology is changing at a very rapid rate today. Executives wrestle with a variety of technological initiatives that are set to build the foundation of outperforming supply chains. As disruptive technology increases supply chain efficiency and control through data, data are regarded as a driver of disruptive technology (Rowe and Pournader, 2017). Relevant and timely pieces of data are the foundation upon which disruptive technologies are built. The current study focuses on the two recently most popular disruptive technologies – big data analytics and IoT. The IoT consists of numerous internet-connected sensors and switches that collect, send and receive data that can be used to provide real-time visibility into operations to reach a higher level of efficiency and effectiveness. Turning disruptive technologies into a strategic advantage is to transform data into real-life applications through big data analytics. The core values of both technologies enable an organization to access new opportunities of disruptive improvement in this dynamic business world by using the power of data.

2.1 Big data analytics

Big data was first documented as a problem by scientists in NASA in 1997 when they encountered significant challenges for computer systems to manipulate and process large data sets. The fast-paced technology evolution in the past decade has enabled business communities to take the challenges to capture, store, analyze, manage, share and transfer voluminous and complex digital resources. Now, data grow at a rate of almost 50,000GB a second compared to a rate of 100GB a day 25 years ago. Although the discussion of how to define big data is still ongoing in industry and academia, volume (Jin *et al.*, 2015; Richey *et al.*, 2016; Russom, 2011), variety (Jin *et al.*, 2015; Richey *et al.*, 2016; Russom, 2011), veracity (Jin *et al.*, 2015; Richey *et al.*, 2016; Russom, 2011; Beulke, 2011) and value (Wamba *et al.*, 2015; White, 2012), the five Vs are the general characteristics defined in previous literatures.

1 Volume – the large amount of generated and stored data. The size of the data determines the value and potential insight.
2 Variety – data come in a large variety of formats including structured, numeric data in traditional database and unstructured data such as text documents, video and audio. Data are also generated from multiple sources, making it hard to transform and integrate data across systems.
3 Velocity – data stream must be generated and dealt with in a timely manner. The speed at which the data are generated and processed to meet the demands can be

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highly variable. Daily, seasonal and event-triggered peak data loads can be challenging to manage.

4 Veracity – inherent unpredictability of some data requires analysis of big data to gain reliable prediction.
5 Value – the extent to which big data generate economically worthy insights and or benefits through extraction and transformation.

Although data are the key to turn technology into a strategic tool, it is not the amount of data that matters but what organizations do with the data that drives changes in how we manufacture and move goods. In recent years, the value of big data analysis has been generally acknowledged in a variety of industries and business functions. More than ever before, marketing is faced with streams of data flooding in from various channels. Big data analytics has proved to be of tremendous potential in revolutionizing marketing and sales (Svilar *et al.*, 2013). Manyika *et al.* (2011) estimated the value potential of big data in healthcare in the USA, focusing on productivity and efficiency saving. Richey *et al.* (2016) conducted a qualitative study to investigate the impact and challenge of big data in supply chain management. Opresnik and Taisch (2015) explored the role of big data in developing new competitive advantages of servitization in manufacturing industries (Opresnik and Taisch, 2015). Supply chain professionals continuously seek novel ways to produce useful insights or products and services of significant value from big data. Since the 1990s, many leading retailers have been using point-of-sales data to optimize forecasting and merchandise planning and increase distribution and logistics efficiency. Nowadays, at Walmart, the power of big data is realized by a state-of-the-art analytics hub to model, manipulate and visualize internal and external data for business decision-making. The power of data is effectively harnessed to accurately forecast demand, track and predict inventory levels, create highly efficient resource allocation, manage service response logistics and improve decision-making for enhancing firm performance (Opresnik and Taisch, 2015; Wamba *et al.*, 2015; Richey *et al.*, 2016). Therefore, supply chain executives recognize big data analytics is shifting the competitive landscape of an organization's future on the ability to deliver great data accuracy, clarity and insight across supply network and to integrate big data analytics into optimization and decision tools. The winning supply chains will be those that make the most out of big data to create new competitive advantages.

2.2 Internet of Things (IoT)

First introduced in 1999 by Kevin Ashton and several other scholars at Massachusetts Institute of Technology (Ashton, 2009; Giusto *et al.*, 2010), the IoT has drawn wide attention because of its potential to offer convenience, efficiency and competitive advantages to the business world (Borgia, 2014' Li and Li, 2017; Parry *et al.*, 2016b). Similar to the way the internet connects individual computers, the IoT connects individually identified products, machines and people together to provide optimized solutions, through sensor devices, data storage and analysis equipment and decision-making tools.

Gartner Research predicts that by 2020, the IoT will extend to about 26 billion connected devices (Rivera and Goasduff, 2014), and Cisco estimates the market value of the IoT to be $19 trillion dollars (Kharif, 2014). Many focal companies and their supply chain members have started to invest in the IoT to optimize their supply chain processes. For example, by using the IoT technologies in their trucks, United Parcel Service (UPS) successfully reduced the idling time and maintenance costs and increased efficiency and safety (Mika, 2017). Coca-Cola's Freestyle beverage machine can record customer-designed receipts and identify customers' favorite tastes for their future product design (Burkett and Steutermann, 2014). Disney uses MagicBand, an IoT-supported wristband, to reduce waiting times and improve customers' satisfaction (Lee and Lee, 2015).

Recently, many researchers and practitioners have started to investigate the impact of the IoT on supply chain management from different perspectives and have realized the necessity of developing new supply chain strategies responding to the new business environment. Some relevant studies are supply chain risk management (Li *et al.*, 2018; Weinberg *et al.*, 2015; Yang *et al.*, 2013), social responsibility (Kiritsis, 2011; Weber, 2009; Parry *et al.*, 2016b), supply chain innovations (Li and Li, 2017; Tan *et al.*, 2015), agriculture supply chains (Yan *et al.*, 2017; Verdouw *et al.*, 2016) and healthcare supply chains (Paschou *et al.*, 2013; Montgomery, 2016). Extending from previous literature, we summarized the various definitions and identified the supply chain-related applications and challenges of the IoT in Table I.

3. Methodology

A considerable body of work seek to identify research focus and trends in technology and supply chain management by performing content analysis on existing literature. In particular, a growing number of scholars have advocated and emphasized the importance of structured and systematic review in different disciplines (Rousseau *et al.*, 2008; Tranfield *et al.*, 2003; Shukla and Jharkharia, 2013). Systematic review is a process of "synthesizing research in a systematic, transparent, and reproducible manner to inform policy and decision making" (Tranfield *et al.*, 2003, p. 209). This study follows a four-step systematic review process suggested by Mayring (2003), which consists of literature collection, descriptive analysis, category selection and material evaluation. In the following section, we briefly describe how we followed this four-step systemic review process.

1 *Literature Collection*: The first step in our research study involves the collection of literature related to supply chain management, big data analytics and IoT. Using multiple online databases including EBSCO Business Source, Emerald, ProQuest ABI/Inform, Science Direct, Palgrave and Web of Science, we conducted extensive searches to identify research papers on Big Data and IoT, in the context of supply chain from the peer reviewed academic journals in supply chain, management information systems and logistics. We searched on terms such as *SCM, Supply Chain Management, Supply Chain, Supply Management, Purchasing, Logistics* and *Operations Management* in the full-text of papers appearing in these journals. We limited our search to the articles published from the year 2000-2017. The specific search terms and restrictions we used for big data and supply chain

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Table I Summary of the IoT definitions and SCM applications and challenges

Key aspect in defining IoT	Source	Year	Definition of the IoT	Applications and Challenges in SCM
IoT as a network of interconnected objects	International Telecommunication Union (ITU, 2005)	2005	"A new dimension has been added to the world of information and communication technologies: from anytime, anyplace connectivity for anyone, we will now have connectivity for anything."	Radio-frequency identification (RFID), wireless sensor network, and robotics in supply chains of different industries, such as automotive, medical, and aerospace; the ecosystem of the IoT
	Weber (2010)	2010	An evolution from interconnected computers to interconnected objects	New data security and privacy challenges
	Bardaki *et al.* (2012)	2012	A network of "readable, recognizable, locatable, and manageable" objects over the Internet	Promotion management and dynamic pricing in retail services
	Zhou *et al.* (2015)	2015	A world where objects are "connected, monitored, and optimized through wired, wireless, or hybrid systems"	Operational process improvement; Costs and risks reduction; Need for new supply models
IoT as a capability	European Research Cluster on the Internet of Things (CERP-IoT, 2009; IERC, 2016)	2009	"A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network."	Inventory management optimization; Carbon footprint of logistics; Grocery shopping experiences such as automatically checking out using biometrics, allergen detection and personalized marketing
	Gubbi *et al.* (2013)	2013	"The interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications"	Optimizing the supply and demand in the utility industry; Realizing supply chains' environmental and social sustainability
	Li *et al.* (2018)	2018	"a platform where physical objects are equipped with sensors and interconnected in a worldwide unifying network, so that real-time information is collected, stored, transmitted, accessed, and analyzed through the internet to support decision-making"	Supply chain risk identification, mitigation, response, and recovery
IoT beyond technology to interact with environment	(Rivera and Goasduff, 2014)	2014	"The network of physical objects accessed through the Internet that contain embedded technology to sense or interact with their internal states or the external environment"	Product design; Service differentiation; Demand and channel management; Importance of developing new supply chain strategies
	Krotov (2017)	2017	"a network comprised of various nodes belonging to the technological, physical, and broad socioeconomic environments"	Creating sustaining value and disruptive value for the firms and their customers

management articles are as follows: *"big data"* AND *(SCM OR supply chain OR logistics OR operations); Peer Reviewed; Published Date: 20010101-20180131; Publication Type: Academic Journal; Document Type: Article*. Similarly, when searching IoT and supply chain management articles, we used the following terms and restrictions*: IOT* AND *(SCM OR supply chain OR logistics OR operations); Peer Reviewed; Published Date: 20010101-20180131; Publication Type: Academic Journal; Document Type: Article.* Using the above criteria we developed, the initial search yielded 815 papers.

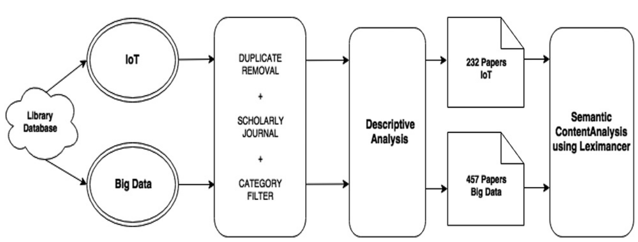
2 *Descriptive analysis:* After completing the literature collection, we then screened all the papers to ensure that the found papers actually focus on supply chain contexts; thus, we excluded the papers that mention these terms but did not really investigate supply chain related issues. Although this manually screening process is very time consuming, it increased the reliability of qualified articles for literature review. The manual screening reduced the number of papers to 689 including 232 and 457 papers on IoT and big data, respectively. We conducted descriptive analysis by presenting the research question related

statistics, such as the number of publications per journal, publication rate and publication trend on Big Data and IoT. The detailed results are reported in Section 4.

3 *Category Selection:* Following descriptive analysis, we examined the research segmentation in terms of journal types and publication years, to understand the trend evolving over years in the research domain of big data analytics and IoT. To facilitate the following content analysis that would show how big data analytics and IoT have developed over years in supply chain and other disciplines, papers were then classified according to journal types and publication years.

4 *Material Evaluation:* The last stage of our research involved content analysis using Leximancer. For each of the retrieved papers, we created a spreadsheet showing basic bibliographic details of the study: title, author names, journal name and publication year. We also created two consolidated files; one for an initial growth period where there were steady but slow growth in number of publication, and second period where number of articles published grew rapidly. Each consolidated file contains the paper title, abstract and keywords of all papers belonging to that time period. Next, we excluded common "stop words" (e.g. and, not, with, or), and instructed Leximancer to merge word variants (e.g. organize, organization and organizations; also, project, projects and projected). Once these parameters for the stop words and merge words were set, we allowed the software to analyze the entire consolidated file, consisting of papers titles, abstracts and keywords from one-time period at a time. We then interpreted the overall concept map containing the themes generated by Leximancer. These themes were further examined with the underlying evidence word set. We matched these evidence words against our data sets. In summary, we examined the themes, underlying concepts and evidence words that make up these concepts. We scrutinized each evidence word that makes up these concepts against our data set and removed the dataset that were irrelevant. For the last stage of analyzing focus, relevant issues and trends in the literature, the latent semantic analysis method was adopted using Leximancer, which allows more rapid, reliable and consistent content analysis (Aryal *et al.*, 2014; Crofts and Bisman, 2010; Rooney *et al.*, 2006). Figure 1 describes the review process followed for this study.

Figure 1 Review process



3.1 Latent semantic analysis using Leximancer

Human beings unconsciously perform semantic analysis on a daily basis. We filter all the context in the surrounding text, identify the relevant elements and compare to what we already know to understand practical meaning of the content at hand. However, it becomes a challenge for human beings to analyze large bodies and/or unstructured context. Two obvious weaknesses of traditional way of conducting extensive review of publications have been noted (Vaivio, 2008; Lee and Fielding, 1996). One is that manually analyzing literature is very time-consuming and the context relevant to the research may be missed because of the limited information process capacity of human being. A growing number of scholars opt to use machine-driven semantic analysis method in a variety of research fields (Crofts and Bisman, 2010; Cretchley *et al.*, 2010). Many software tools, such as RapidMiner and Gate, are available for performing latent semantic analysis (LSA). However, these tools are mostly geared towards text mining and often require a predefined set of classification schemes. Our approach is not to pre-classify research work but to identify the key concepts within a large set of research related to disruptive technologies. For that research purpose, we selected a popular semantic analysis software, Leximancer. While we did not find supply chain related studies utilizing Leximancer, it has been used to analyze contents and relationships between concepts from contextual data in research of information system (Aryal *et al.*, 2014; Crawford and Hasan, 2006; Debuse *et al.*, 2008), accounting (Crofts and Bisman, 2010), social and cultural studies (Cretchley *et al.*, 2010) and education (Rooney *et al.*, 2006).

The overall process of latent semantic analysis in Leximancer is depicted in Figure 2. In the beginning of the text analysis process, texts are input from documents. In the phase of concept seed generation, Leximancer automatically creates document matrix to determine word frequencies and uses words that most frequently appear as keywords (Table II). In this matrix, each word is a row and each column can be a "block of text", a paragraph or a document. Table II provides a hypothetical document Metrix for a text analysis of domestic pets. Following the example, dog appears four times in Document 1, three times in Document 2, one time in Document 3 and three times in Document *n*.

Figure 2 Leximancer process – transforming words to themes

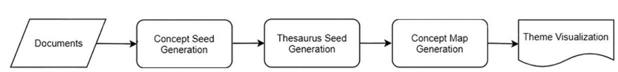


Table II Document matrix

Keywords	Documents			
	D1	D2	D3...	D_n
Cat	1	5	4	1
Dog	4	3	1	3
Bird	0	2	1	3
Hamster	1	4	2	3

The keywords are then weighted according to how frequently they occur within a two-sentence block of text containing the focal concept, as opposed to how frequently they occur elsewhere. Next, a collection of keywords is grouped together creating concepts that "generally travel together throughout the text, for example, a concept *building* may contain the keywords mill, warrant, tower, collapsed, etc." (Kivunja, 2013). Concepts then are clustered into higher-level themes.

Themes are composed of concepts that appear together often in the same block of texts. To generate thesaurus seed, a machine learning algorithm is used to find the relevant thesaurus words from the text data. Finally, Leximancer provides results in the form of visual maps, of the concepts, sub-concepts (keywords used in creating a concept) or themes. Themes where concepts are closely related are presented in hot colors (red, orange), themes, where concepts are weakly related are presented with cool colors (blue, green). In our analysis, we have included only the top themes and top concepts within those themes. Once the initial overall map is created, the analyst has the ability to customize the analysis; for example, the analyst can change the theme size to adjust the grouping of concepts to select fewer but broader themes or conversely, to drill down into more detail. The analyst thus selects the desired level of granularity.

4. Results

In this section, we report the findings from the research analysis organized into descriptive and semantic analysis sections. The descriptive analysis section presents the publications and journals related statistics, such as the number of publications per journal, the publication rate and the publication trend on Big Data and IoT in the context of supply chain management. In the semantic analysis section, we examine the major concepts, themes and evolution of those themes and concepts linearly. We first report the analysis from Big Data and IoT published in primary journals, and then we analyze Big Data and IoT research in the secondary journals.

4.1 Descriptive analysis

Descriptive analysis was carried out to evaluate the effort of researchers from various disciplines to shape the current understanding of application and the impact of big data analytics and IoT on supply chain management. Table III presents a list of primary journals that published research addressing big data analytics and IoT.

In this section, we first present the descriptive analysis of articles of Big Data and IoT publications in primary supply chain journals (Table III and Figure 3) and then report the analysis of non-supply-chain journals (Table IV and Figure 4).

The three journals that published the most articles related to big data are *Computers and Industrial Engineering*, *International Journal of Production Research* and *Production Planning and Control*, each with 12 articles. *Industrial Management and Data Systems Journal* tops the list on IoT with the publications of 11 followed by *Journal of Marketing Management* with a count of 7 (Table III).

Figure 3 captures the timeline distribution of papers. There is a steady increase in article publications on both big data analytics and IoT from 2012-2017. Year 2017 had the highest number of publications on big data analytics where 98 articles yield 36 per cent of all published papers since 2008. The highest number of publications on IoT occurred in 2017 with 50 articles.

The results of descriptive analysis on secondary supply chain journals are listed in Table IV. A total of 182 big data related research papers (Table IV) were published in in non-supply-chain journals compared to 275 papers (Table III) published in supply chain related journals. For Big Data, *PLoS ONE* has the highest number of publications with a total of seven articles, followed by *BMC Medical Research Methodology* with four publications. For IoT, *Sensors publications* has the highest

Figure 3 Papers in primary journals count by year

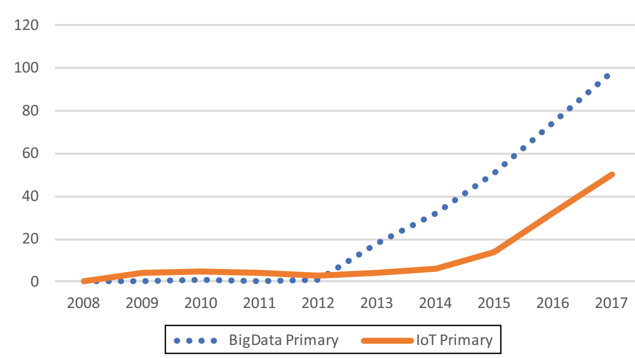


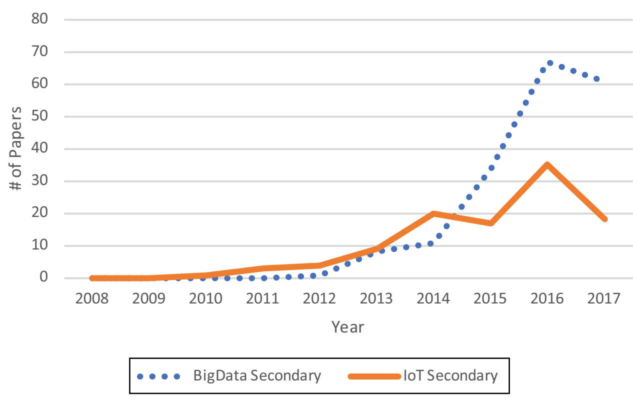
Table III Top 10 list of primary journals reviewed and papers count after year of 2000

Big Data		IoT	
Name of journal	# of papers published	Name of journal	# of papers published
Computers and Industrial Engineering	12	*Industrial Management and Data Systems*	11
International Journal of Production Research	12	*Journal of Marketing Management*	7
Production Planning and Control	12	*International Journal of Production Research*	6
International Journal of Production Economics	10	*Computers in Industry*	5
Marketing Insights	9	*International Journal of Production Economics*	5
Journal of Business Logistics	8	*IEEE Communications Magazine*	4
Journal of Cleaner Production	8	*Decision Support Systems*	3
Business Process Management Journal	7	*Computers and Industrial Engineering*	3
Asia-Pacific Journal of Operational Research	6	*Business Process Management Journal*	3
Industrial Management and Data Systems	6	*Business Horizons*	3

Table IV Top 10 list of secondary journals reviewed and papers count after year of 2000

Big Data		IoT	
Name of journal	# of papers published	Name of journal	# of papers published
PloS ONE	7	*Sensors*	9
BMC Medical Research Methodology	4	*International Journal of Distributed Sensor Networks*	5
Neurocomputing	4	*Mathematical Problems in Engineering*	4
Expert Systems with Applications	3	*Business Horizons*	3
Information Systems	3	*Internet Research*	3
International Journal of Advanced Manufacturing Technology	3	*Journal of Industrial Engineering and Management*	3
The International Journal on Media Management	3	*Personal and Ubiquitous Computing*	3
American Journal of Public Health	2	*Journal of Applied Mathematics*	2
British Journal of Clinical Pharmacology	2	*Information Systems*	2
Computers, Environment and Urban Systems	2	*Food Control*	2

Figure 4 Papers in secondary journals count by year



number of nine, and each of the rest has five or fewer publications.

The year 2016 has the highest number of Big Data related publications with 67 articles accounting for 36 per cent of the total. This 36 per cent breakdown is similar to the number of publications in Primary Supply Chain journals discussed prior. There is a steady increase in article publications from 2012-2016. In IoT, 2016 also has the highest number of publications with 35 articles, but the IoT-related research is in a steady increase from 2009-2014.

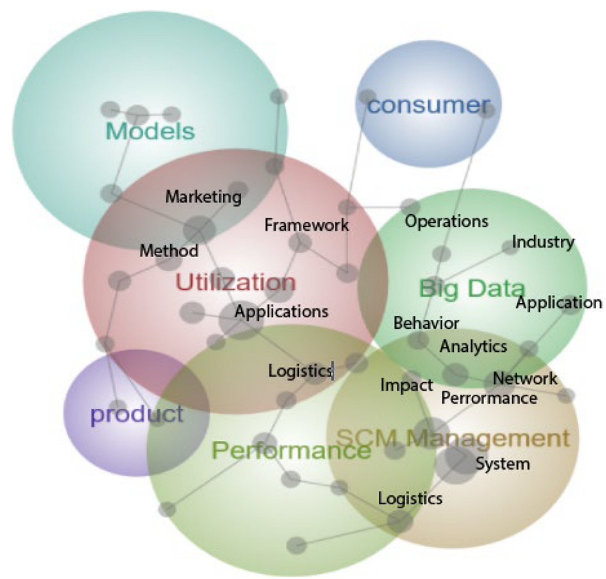
4.2 Semantic analysis in primary journals

4.2.1 Semantic analysis on big data in primary journals

In this section, we present the semantic analysis of Big Data and IoT published in primary journals. In other words, we analyze the top themes and concepts for Big Data and IoT published in primary journals. When we ran the Leximancer software with the title, key and abstract from supply chain primary journals related to big data, we observed the top three most important themes of Utilization, SC Management and Big Data. Other less significant themes identified are Performance, Products, Models and Consumer.

The map (Figure 5) provides conclusions that in the research of big data, the prominent theme of Utilization relates to *framework* and *method* for *application* in marketing and logistics.

Figure 5 Major themes in big data from primary journals



Similar to the SC Management theme, the theme of Utilization was also used in diverse context such as online analytical processing (OLAP) of multidimensional data cubes (Milliken, 2014) and use of big data to enhance operational performance (Matthias *et al.*, 2017). Interestingly, another term for utilization is leverage, which is used to note that more advanced and innovative business intelligence systems are needed for the supply chains in today's business environment (Vera-Baquero *et al.*, 2015). In their study, Gama *et al.* (2012) underlined the benefits of leveraging existing IoT architecture for monitoring objects along a supply chain (Gama *et al.*, 2012).

As our data source was supply chain journals concerning big data, it is not surprising that two other central themes were supply chain and big data. The Big Data theme mostly relates to the concepts of *operations, industry, applications, behaviors* and *analytics*. We observed that big data and its concepts were mostly used in defining the big data phenomenon. For example, Richey *et al.* (2016) in their research paper "A global exploration of Big Data in the supply chain" defined big data as "inclusive of four dimensions: volume, velocity, variety, and veracity". We also observed that utilization of big data for supply chain management issues such as supply chain performance, decision-making process were also presented.

> Working with the enormous volume of data (or Big Data, as it is popularly known) for extraction of useful information to support decision making is one of the sources of competitive advantage for organizations today (Biswas and Sen, 2016).

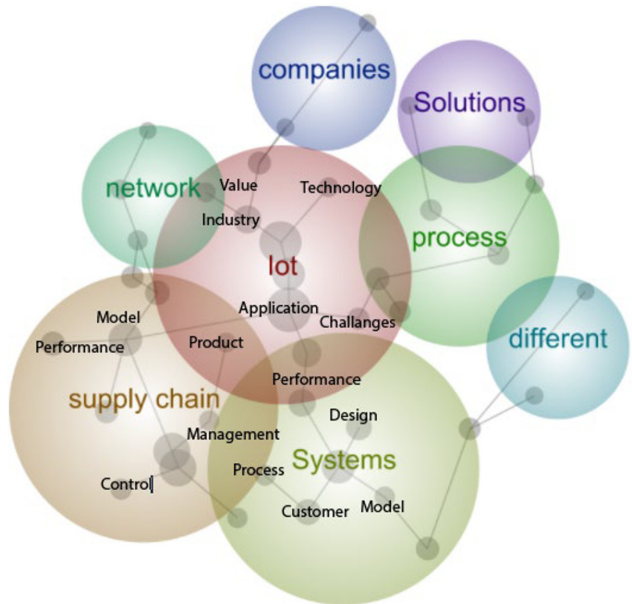
The SC Management is associated with concepts of *performance, impact, systems, logistics* and *network*. From Figure 5, we observe that SC Management and Big Data have overlapping maps, which indicate some common concepts connecting big data with SC management. As supply chain management is a large area of research, we observe that the use of big data, network and logistics concepts are quite diverse. The themes include predictive analytics, technology and impact on management. Gunasekaran *et al.* (2017) investigated big data and predictive analytics (BDPA) in achieving business value and firm performance (Gunasekaran *et al.*, 2017). Some studies such as Hahn and Packowski (2015) focused on utilizing analytics for decision-making as "Big data, advanced analytics, and in-memory database technology are on the agenda of top management since they are seen as key enablers for enhanced business decision-making" (Hahn and Packowski, 2015). Biswas and Sen (2016) credited SC for achieving business success and proposed a Big Data-centric architecture for SCM to achieve business excellence in supply chain. The Big Data-centric architecture enables exploitation of technology of data analytics. Figure 5 also demonstrates that themes of supply chain management and big data overlap. Performance, impact and industry are key concepts in both the supply chain management and big data theme. Overall, the results reflect the study of impact of big data on supply chain performance.

4.2.2 Semantic analysis on IoT in primary journals

IoT, Systems and Supply Chain are identified as the top major themes in the analysis of IoT research using Leximancer (Figure 6). The IoT theme includes concepts such as *value, technology, industry, applications* and *challenges*. It is noted that technology and value creation are emphasized in research for business process management. For example, through a literature review on IoT, Del Giudice (2016) identified the IoT as a key driver for business process management and concluded that IoT systems' value to business process management is determined by easy installation, configuration, installation, standardization, stoutness, configuration and servicing. Whether the IoT can create higher value to customers and supply chain members is identified as another main research stream. For example, by surveying users of IoT technology in the retail setting, Balaji and Roy (2017) found significant evidence to support that value co-creation results from the interaction between customers and the IoT technologies.

The Systems theme is composed of concepts *performance, design, process, model* and *customer*. The theme "systems" could be used for network system, information systems or organizational system in general. Kafle *et al.* (2016) presented several prospective system requirements for developing satisfying IoT infrastructures. Furthermore, some research pointed out the inadequacy of using old models for IoT,

Figure 6 Major themes in IoT from primary journals



"Internet of Things (IoT) are such that traditional models of trust developed within interpersonal, organizational, virtual and information systems contexts may be inappropriate for use within an IoT context" (Harwood and Garry, 2017). In addition to design of models and processes under the system theme, the overlap between IoT and System also discloses that the performance benefits and challenges are both prominent in application of IoT system.

The Supply Chain theme includes concepts such as *management, model, performance, product* and *control*. Zhou *et al.* (2015) described three areas of IoT study in supply chain: developing business models, deployment of IoT to decision-making and RFID-based inventory management. This theme is used in various industry contexts, such as pharmaceutical supply chain (Papert *et al.*, 2016) and perishable product supply chain (Yan *et al.*, 2017). Although IoT can overcome shortcomings of some areas of logistics, building profitable logistics models upon IoT still encounters many difficulties (Tadejko, 2015). As one of main sensors connecting to objects in a supply chain, "RFID has been successfully implemented in supply chain management, automated toll collection, and inventory control" (Slettemeås, 2009). However, Slettemeås (2009) called for more research to better understand consumer-oriented RFID and indicated some influencing factors may have severe impact on performance.

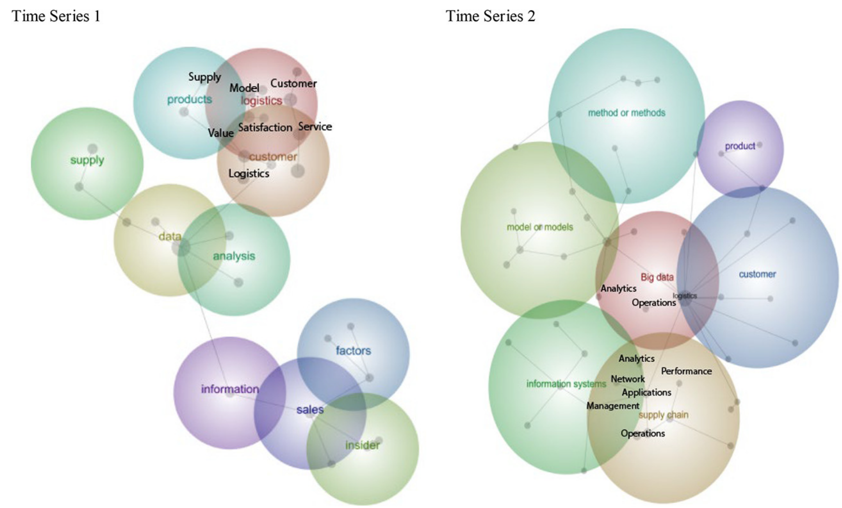
4.3 Semantic analysis of themes evolution

After the analysis of the overall themes, we separated data set into two series. Time Series 1 was for the years 2010-2013 and Time Series 2 was for the years 2014-2017. To recap, Time Series 1 represents slow steady increase and Time Series 2 depicts rapid growth (Figures 3 and 4).

4.3.1 Semantic analysis of themes evolution in big data

From Figure 7, we observe that themes in Time Series 1 were not tightly connected but separated into three clusters.

Figure 7 Themes evolution of big data in primary journals



Logistics, Products and Customer are the three most prominent themes in the overall big data analysis between 2010 and 2013. Examining the theme of Logistics, we found that associated concepts were *satisfaction, model, customer, service* and *value*. Logistics were mostly associated with customer satisfaction and technology. Lan *et al.* (2016) studied where various logistics and their customer satisfaction models were proposed and evaluated. Apart from customer satisfaction, the theme of logistics is associated with operations and technology. For example, "resources are converted into smart manufacturing objects (SMOs) [...] to create a RFID-enabled intelligent shop floor environment. In such PI-based environment, enormous RFID data could be captured and collected" (Zhong *et al.*, 2017). The second central theme, Product, contains concepts of *model, supply* and *value*. Some common phrases in this research include product life cycle (Fawcett and Waller, 2014) and green product in supply chain (Zhao *et al.*, 2017). The third theme Customer, is comprised of concepts of *satisfaction, logistics* and *service*. As customer satisfaction is very important to manufacturing and logistics enterprises because of its time constraints, Lan *et al.* (2016) acknowledge the importance of innovative evaluation model for customer satisfaction in logistics operations for value adding services. Logistics overlapped with Customer and Products, indicating common concepts exist among these themes. Supply and Data also appeared as moderately important themes, but they were not related to the three most prominent themes. This analysis showed that in earlier years when business started realizing big data will fundamentally change the way they compete and operate, big data was investigated in scattered places.

As Figure 7 indicates, in recent years (2014-2017), Big Data was the most prominent, followed by the themes Supply chain and Information systems. Top prominent themes Customer and Products in earlier years retained in recent years but lost prominence. Top concepts for Big Data are *operations, logistics* and *analytics*. In some contexts, big data and big data analytics are used as interchangeable terms. Some articles use big data and predictive analytics in the same phrase, for example, "Big Data and Predictive Analytics (BDPA)" in Gunasekaran *et al.* (2017). Although logistics is no longer a theme, it appeared as a key concept for Big Data. The complex and dynamic nature of logistics, along with the reliance on many moving parts in warehouses and on the road, make logistics a perfect use case for big data. A Zhong *et al.* (2015) explores "Big Data approach to excavate frequent trajectory from massive RFID-enabled shop floor logistics data with several innovations". Theme Supply Chain emerged with concepts of *performance, analytics, network, applications, operations* and *management*. The intersection of supply chain and big data is illustrated by Gunasekaran *et al.* (2017), where they argued "the impact of BDPA assimilation on supply chain (SCP) and organizational performance (OP) has not been thoroughly investigated". Similarly, the relationship of big data and supply chain is highlighted in the article titled "Predicting online e-marketplace sales performances: A big data approach" (Zhong *et al.*, 2015). Others have used big data in general supply chain. Richey *et al.* (2016) conducted a qualitative analysis across six nations to develop central grounding of definition, dimensions and the issues related to big data in the future of supply chain strategy and performance.

Interestingly, Information Systems appeared as a new theme. While the original focus is analytics to derive value from data, big data life cycle begins with data gathering and management. As for many industries, the availability of relevant data at the right time becomes a challenge. Information systems need to catch up the unprecedented growth rate of big data analytics in terms of the ability to capture and store vast amounts of data and to aggregate and analyze disparate volumes of data for better and smarter decision-making. This new theme reflects more systematic and structured studies on big data characteristics and analytics. Indicated by the overlap between information systems and supply chain management in the map, the trend of studies on the application of information systems for big data analytics across supply chain network is evident.

4.3.2 Semantic analysis of themes evolution in IoT

In this section, we present findings of our analysis when we divided the IoT data set into two series, Series 1 data set (2009-

2015) and Time Series 2 data set (2016-2017) (refer to Figures 3 and 4). Similar to the earlier analysis, Time Series 1 is considered as a slow and steady growth period, while Time Series 2 is an explosive growth period.

In Time Series 1, major themes are Supply Chain, IoT and Systems. Top theme Supply Chain is composed of concepts such as *management*, *information*, *network* and *environment*. For example, Zhou *et al.* (2015) defined IoT as:

> [...] a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network.

Similarly, Li *et al.* (2017) stated that "the Internet of things, mobile Internet, cloud computing and big data technologies build a sensing environment for all kinds of businesses". The general understanding of the role of IoT in supply chain is to enable closed-loop supply chain and enterprise networks integration. In addition, some organizational issues related to supply chain are also identified by the analysis, such as "the impact of perceived privacy risks on organizations' willingness to share item-level event data across the supply chain" (Eurich *et al.*, 2010).

The theme IoT overlaps with supply chain and contains the concepts of *RFID, technology services* and *challenges*. At this time period, the IoT is described mainly from technical standpoints, such as combining heterogeneous service technologies for building an IoT middleware (Gama *et al.*, 2012) or a new technology paradigm consisting of globally connected machines and devices (Lee and Lee, 2015). The technological characteristics of IoT make it capable of interacting with each other in management and logistics. The term IoT was first coined by the RFID community over a decade ago; therefore, it was not surprised that RFID appeared among the most prominent.

The theme Systems contains the concepts of *customer, decision* and *support*. The systems have multiple conflicting goals, Ondemir and Gupta (2014) claimed that the IoT system is beneficial to achieve multiple conflicting financial, environmental and quality-based goals (Ondemir and Gupta, 2014). In a different context, IoT system can be used to collect data to replace manual employee evaluation system in the smart industry (Kaur and Sood, 2015).

In Time Series 2, theme IoT is still evident and prominent. This theme includes the definition of the IoT (Kafle *et al.*, 2016) and the new opportunities (Agrifoglio *et al.*, 2017). Agrifoglio *et al.* (2017) reported a case study on an open technology marine service enabling sailors to personalize their experience on board. This is a great example that IoT represents a novel paradigm that is rapidly affecting on a variety of aspects of everyday-life and business. While technology continuously appears as one of the most important concept, RFID disappeared in the most prominent theme. IoT technology has now expanded beyond RFID tagging.

Supply theme is composed of concepts of *supply chain, model, logistics* and *design*. In this time series, IoT in supply chain is researched in a wide variety of areas from coordinating supply chain network to aquatic product supply and artificial intelligence. Significant changes in thought and practice in logistics and supply chain came with risks and opportunities. Yan *et al.* (2017) investigated IoT models, which were later solved by a computer simulation in analyzing aquatic product supply chain. Stawiarska (2016) elaborated how artificial intelligence supported the establishment and coordination of the dynamic supply network.

The theme Information overlaps with theme IoT and contains the concept of *systems*, which is mostly used for information systems. Different from traditional information service, a well-designed IoT system not only should have an ability beyond integrating enabling technologies used to access environmental data (Shang *et al.*, 2015), but also needs to develop a more comprehensive trust beyond the one within traditional models of information systems (Harwood and Garry, 2017). Qu *et al.* (2016) used "systems" to define cost-effective IoT solutions of the typical production logistic execution processes. Overall, the appearance of this theme in Time Series 2 reflects the continuous trend of IoT related information systems.

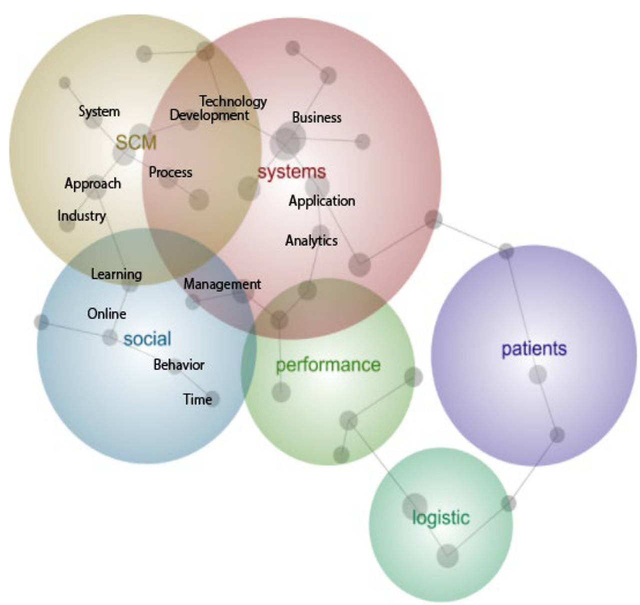
4.4 Semantic analysis in non-business supply chain journals

Following the same procedures as the ones used in analyzing business journals, we analyze the major themes emerging in big data and IoT research in the non-business journals. The main objective of analysis in this section is to compare previous research efforts on big data and IoT in non-business contexts with those in business settings.

4.4.1 Semantic analysis of big data in secondary journals

The most prominent theme emerging from the big data research in non-business journals is Systems, followed by the themes Supply Chain Management (SCM) and Social (Figure 8). The theme Systems contains core concepts of *technology, approach, industry, process* and *development*. Systems in the research were mostly about technical systems such as smart system (Pramanik *et al.*, 2017), cloud-based computing system (Yue *et al.*, 2015) and manufacturing execution systems

Figure 8 Major themes in big data from secondary journals



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including ERP systems (Subramaniyan *et al.*, 2016). The variety of systems related to big data is to facilitate process control and innovation (Figure 9).

The theme SCM contains *business, applications, process, analytics, development* and *technology*. Examples of business applications include potential risks posed by big data in supply such as:

> With the development of the supply chain network (SCN) and big data processing, a simple view at above two technologies separately has become unadvisable; this mainly reflected on the growing amount of data in the SCN nodes. Since the data processing is not timely, the potential risks may spread like dominoes to the entire network (Zou *et al.*, 2016).

Technology, applications, process and development are prominent concepts in theme supply chain management and theme systems as well.

The third most prominent theme is Social, containing concepts of *online, behavior, learning, management* and *time*. Research related to this theme depicts social networks, social media and social systems related to big data. The social network is very dynamic because of the intensive uses generating big data (Rechavi and Rafaeli, 2014). Ordenes *et al.* (2017) analyzed consumers' implicit and explicit languages for online sentiment expression and investigated the effect on readers' behavior on Twitter and Facebook. To address the dominant problem in big data application of efficient visualization of dynamic network structures, Li *et al.* (2017) presented a system that can efficiently support large-scale social and spatial network visualization.

As shown in Table V, SCM is emerged as an important theme in big data research in both primary and secondary journals. Big data is revolutionizing supply chain management in different ways. While there has been attention on utilization of big data as an end-all solution to supply chain problems in business research, scholars in other areas contributed to investigate innovative and scalable systems to collect and analytically process large volume of data and to explore the social dimension in best practices when using big data. Business cannot reap benefits of the most advanced analytical tools unless the users can leverage the tools towards to the right directions. Successful companies and their management need to integrate their people, process, technology and data at a strategical level, through effectively incorporating data into their business routines, strategy and daily operations.

4.4.2 Semantic analysis of IoT in secondary journals

Through analyzing the IoT in the secondary journals, we obtained the thematic map depicted in Figure 10, where the three main themes identified are IoT, Process and Supply. Concepts connected to the IoT theme are *technology, application, management* and *industry*. In these areas of research, the IoT is described with focus on technology applications:

> A wireless system in a market, along with rapidly growing IoT technology, can enable interesting applications such as automated electronic price tag updates, shopping-cart-based advertisements and information display, and automated inventory/stock management (Kim *et al.*, 2017).

The theme Supply contains concepts of *model, management, performance* and *product*. Similar to the IoT theme, the supply chain theme in the non-business research also provides more diverse and application-focused descriptions. For example, Bardaki *et al.* (2012) study focuses on fresh agricultural products (FAP) using IOT.

> Supply chain coordinates in IoT by considering the influence of FAP on market demand and costs of controlling freshness on the road and the question is how to measure supply chain specific risks and how to incorporate them "adequately" into mathematical models (Bardaki *et al.*, 2012).

The theme Process contains the concepts of *business, value, information* and *management*. The theme provides more business-centric descriptions. Examples include "Internet of Things and business processes redesign" (Lee and Lee, 2015) and "the volume of process-related data is growing rapidly:

Figure 9 Themes evolution of IoT in primary journals

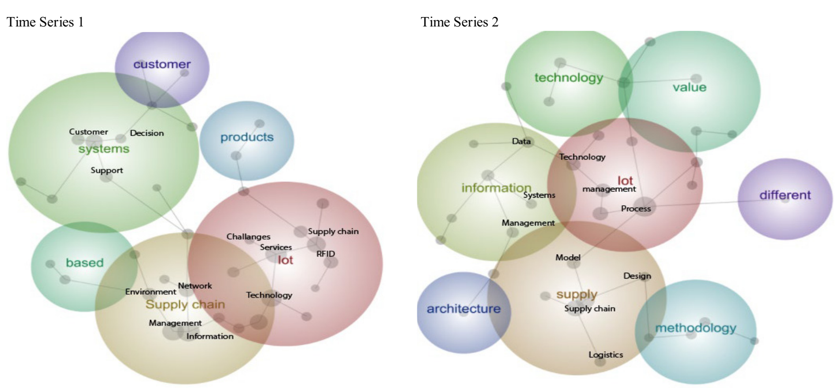
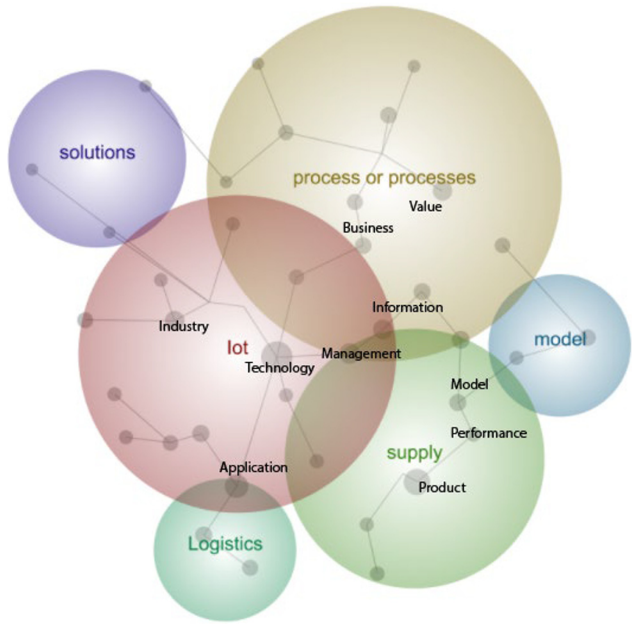


Table V Top themes in primary and secondary journals

Big Data		IoT	
Themes in primary journals	**Themes in secondary journals**	**Themes in primary journals**	**Themes in secondary journals**
Systems	Utilization	IoT	IoT
SCM	SCM	Systems	Process
Social	Big data	Supply chain	Supply

Figure 10 Major themes in IoT from secondary journals



more and more business operations are being supported and monitored by information systems" (Balaji and Roy, 2017).

5. Discussion

5.1 Research implications and future research

This paper contributes to research by providing a text mining analytics method for the literature review. The Leximancer software bridges the gap between the traditional qualitative approach and the state-of-the-art machine learning and text analytics approach. The traditional approach is suitable for providing a deeper context. However, traditional methods are not easy to replicate and explain. Text analytics are easy to replicate but does not offer the deeper contextual understanding. The Leximancer allows the analyst to set the parameter (such as removing words or combining terms) and provides easy to understand thematic maps. The implications from this approach are that the researchers could quickly analyze the practitioner's papers (white papers and other practitioners' publications) by using Leximancer to examine the current state in the industry. The second contribution of this research is the identification, compare and contrast between the themes in Big Data and IoT research. The initial themes were more techno-centric later became more refined and business specific. The result signifies that emerging technology is intertwined in innovation and other business processes. Researchers seeking to gain a thorough understanding of how these technologies transform business have to analyze both the technology and changing business processes.

The definitions and applications of big data and IoT in supply chain context imply that the development of supply chain is a shift away from digitally enabled to digitally led and process-centric as well. The infrastructural integration of big data and IoT technologies should coevolve with supply chain processes and managerial capabilities. The transition associated with the influx of data entails change management across supply chain. Making substantial investments in big data and IoT technology solutions do not guarantee to enhance a company's bottom line. Disruptive technologies should be leveraged to target improvements of supply chain processes at the strategic (e.g. supply chain network design), tactical (e.g. supply chain collaboration and team decision-making) and operational levels (e.g. order fulfillment). In contrast, innovation and improvement in supply chain processes without having a well-integrated complementary technology and managerial capabilities in place can be problematic. Recognizing this interplay between disruptive technologies and supply chain management processes and capabilities, future research explaining how they are aligned to develop a supply chain that is connected, intelligent and proactive would be an interesting contribution.

The second research question in this study inquires how disruptive technology trend has evolved over the years in business supply chain research. We observe that in the early years of Big Data research, themes were not tightly connected but separated into three clusters of logistics, products and customer. The Customer theme is ongoing, consisting of service, support, logistics, behavior and industry. Supply Chain, which consists of management, network, performance and systems, emerged as a new theme in later research on big data. Major themes of IoT research during the early years also included Supply Chain, which is composed of similar concepts in big data research such as management, information, business, challenges and environment. In the later years, we observed that Supply Chain remains as one central theme in IoT research, but it consists of new concepts of model, logistics, performance, design and smart. The analysis results indicate that IoT research started to become more specific in the later years. Following the systematic reviews, this study identified many current trends in the literature, which may inspire the scholars' interests in topics including the impacts of disruptive technologies on the overlapping among customer service, supply chain network and system performance. In addition, the innovative systematic methodology and tools introduced by this work could serve SCM researchers to explore other relevant topics, such as the relationship between SCM and blockchain, artificial intelligence or other future emerging disruptive technologies.

The growing body of research on big data and IoT in the past decade reflects the evolution from transactional to cognitive supply chain driven by the development of disruptive technologies. Technological advancements such as big data and IoT were first put in place to streamline routine activities and operations in logistics and customer support. Previous research have emphasized the critical role of using the accuracy and reliability of data to get real-time insights for supply chain decision making, process automation, integration and standardization. However, the data-to-insight conversion process remains unclear in the existing literature. There is a trend for supply chain scholars and practitioners to rethink end-to-end supply chain analytics with disruptive technologies, including inventory planning, fleet management, product proliferation, logistics optimization and customer service. Future studies exploring mechanisms to capture data from multiple systems and sources, make sense of it and apply the key insights to create organizational learning for supply chain management would be an interesting contribution.

The third research question deals with the semantic differences of themes between the communities of business supply chain research versus non-business supply chain research. Business and non-business supply chain research on IoT presents common major themes of technology, industry, value and management. In business SCM research, the Big Data mostly relates to the concepts of operations, industry, applications, systems, behaviors and analytics, while social, supply chain and systems are major themes in non-business research. It is interesting to note that the social aspect of big data is emphasized in non-business research. The social aspect contains concepts of online, behavior, learning, management and time. This result implies that there has been a growing body of research addressing the behavioral and cognitive aspect of disruptive technologies. Future studies can complement the traditional technical perspective with managerial cognition to take advantage of disruptive technologies. This stream of research would help practitioners to understand the critical role of cognitive and behavioral factors in explaining digitally led supply chain decision-making. For example, the efficiency and effectiveness of data-to-insight conversion will become the key to improve supply chain performance. The time needed for the data-to-insight conversion process may depend on employee attributes shaped by personal and professional experiences. Disruptive technologies are enablers to business success – not a guarantee of it.

5.2 Managerial implications

Businesses are facing an environment where continuous changes in operating models and skill sets are being driven by disruptive technologies at every level. It has been widely recognized that big data technologies and IoT enable capturing, storing, processing and sharing data in real time; further drive transparency and visibility in supply chains to make faster and more effective decisions. However, a recent Mckinsey report found that the implementation of digital strategy varies greatly across different functional areas within companies. Only 2 per cent of respondents report that their companies have digital strategies focusing on supply chains. There are also significant gaps between potential and actual gains from disruptive technologies (Bughin *et al.*, 2017). The findings from Mckinsey has highlighted the difficulty for many companies to seize in-depth opportunities with disruptive technologies to redefine supply chain processes and drive supply chain improvement. As many companies view disruptive technology implementation as a strategic decision to improve their competitive advantages, it becomes critical for the practitioners to gain a comprehensive understanding of the relationship between SCM and disruptive technologies before making the implementation decisions in supply chains.

This study demonstrates how rapidly the application of disruptive technologies evolve. Although not all disruptive technologies would fit a business model, supply chain professionals should stay alert by looking around to identify disruptive exogenous forces and looking in to assess resources and capabilities. Our research revealed that the disruptive technologies and big data are entwined in two ways. First, the big data tools and techniques are fueling the disruptive technologies. Second, the disruptive technologies are generating big data. However, practitioners still need to implement strategies and operational plan to leverage these disruptive technologies. Questions supply chain managers can explore to better plan for and adapt to disruptive technologies are what competitive advantages will disruptive technology give you? How much chaos could disruptive technologies cause within your supply chain model? What is the expected velocity of change? This study also provides the supply chain managers an evidence-based insight to recognize the strategic importance of coordinating SCM with disruptive technologies, and realize the potential challenges and issues. Although big data and IoT among other disruptive technologies sound attractive to many companies and their supply chains, disruptive technologies are not the silver bullets to solve all problems and guarantee a success in every supply chain. The effectiveness and efficiency improvement relies on the right combination and strategic integration of people, process and technology.

6. Conclusion

Disruptive technologies follow the same growth period as the internet technologies. This research covered the disruptive technologies that were the focus of several research disciplines, for example, computer science, management science and information systems. This study used a latent semantic analysis (LSA) methodology to conduct a systematic review of disruptive technology, specifically big data and IOT literature in the past 20 years. To better understand the context of this research, we distinguish the research that aimed to contribute to business discipline versus the research that falls outside of the business research domain. This paper analyzed major themes presented in that research. As research on disruptive technology has evolved, the themes have evolved as well.

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