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International Journal of Production Research

ISSN: 0020-7543 (Print) 1366-588X (Online) Journal homepage: http://www.tandfonline.com/loi/tprs20

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To cite this article: Konstantina Spanaki, Zeynep Gürgüç, Richard Adams & Catherine Mulligan (2017): Data supply chain (DSC): research synthesis and future directions, International Journal of Production Research, DOI: 10.1080/00207543.2017.1399222

To link to this article: http://dx.doi.org/10.1080/00207543.2017.1399222

Published online: 09 Nov 2017.

International Journal of Production Research, 2017
https://doi.org/10.1080/00207543.2017.1399222

Data supply chain (DSC): research synthesis and future directions

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(*Received 12 February 2017; accepted 15 October 2017*)

In the digital economy, the volume, variety and availability of data produced in myriad forms from a diversity of sources has become an important resource for competitive advantage, innovation opportunity as well as source of new management challenges. Building on the theoretical and empirical foundations of the traditional manufacturing Supply Chain (SC), which describes the flow of physical artefacts as raw materials through to consumption, we propose the Data Supply Chain (DSC) along which data are the primary artefact flowing. The purpose of this paper is to outline the characteristics and bring conceptual distinctiveness to the context around DSC as well as to explore the associated and emergent management challenges and innovation opportunities. To achieve this, we adopt the systematic review methodology drawing on the operations management and supply chain literature and, in particular, taking a framework synthetic approach which allows us to build the DSC concept from the pre-existing SC template. We conclude the paper by developing a set of propositions and outlining an agenda for future research that the DSC concept implies.

Keywords: data flows; supply chain; innovation; outcome-driven; framework synthesis; systematic review

1. Introduction

The 'explosion of data' (Cukier and Mayer-Schoenberger 2013), facilitated by technological developments such as sensor and geo-locating devices, smartphones, the Internet of Things (IoT) as well as the associated metadata, has wide-ranging social, political, environmental, educational and economic implications (George, Haas, and Pentland 2014; van Knippenberg et al. 2015; George et al. 2016). The technology industry, managers, consultants and commentators have been quick to point to the potential of these data as a resource to contribute to competitive advantage and innovation opportunities for firms (McAfee and Brynjolfsson 2012; George, Haas, and Pentland 2014). Data constitute new raw materials for product and service development (Manyika et al. 2011) and needs to be sourced, generated, collected, stored and transformed by firms to lead to new value creation (Chen, Preston, and Swink 2015; Gupta and George 2016). In this context, understanding the role and flow of data in establishing competitive advantage becomes critical. Therefore, building on the theoretical and empirical foundations of the manufacturing Supply Chain (SC), we propose Data Supply Chain (DSC) to re-frame the SC in the context of the digital and knowledge economy and define DSC as a distinct type of SC along which data rather than material artefacts are moved, shared, re-configured and aggregated to provide both new opportunities for competitive advantage/business model innovation as well as management challenges (see Figures A1 and A2 in Appendix 1).[1]

The SC has become a well-established concept in operations management with strengthening theoretical and empirical foundations (Mentzer et al. 2001; Storey et al. 2006) and emergent disciplinary distinctiveness (Ellram and Cooper 2014). Mentzer et al. (2001, 4) provide a commonly accepted definition of the SC as '*a set of three or more entities (organisations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer'*. The purpose of SC Management is effectively and efficiently to procure raw materials, transform them and subsequently distribute finished products to end users (Borade and Bansod 2008). To date, research has focused primarily on the flow of physical materials through the SC wherein concern is expressed for raw material flow, inventory management and finished goods distribution (Ballou, Gilbert, and Mukherjee 2000), for example in the context of manufacturing and consumer goods (Burgess, Singh, and Koroglu 2006); however, little attention has been paid to the procurement, transformation and subsequent distribution of data artefacts within the SC context. In the DSC context, 'data' are not about improving process efficiency within the SC but are rather intermediate

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or even final goods within the process itself. Mentzer et al.'s (2001) definition specifically includes the flow of information within the SC: typically, this has been addressed in respect of the question of knowledge management practices for improving information quality and information management processes to facilitate greater SC efficiency and effectiveness (e.g. Sarac, Absi, and Dauzère-Pérès 2010; Hazen et al. 2014; Cerchione and Esposito 2016).

The current study distinguishes between data *about* the SC, where data are used to improve existing processes or physical artefacts themselves, and data that are the main artefact *moving through* the SC. The distinction raises important questions about whether or not and the extent to which the SC concept may need elaborating to encompass the digital. We develop the concept of DSC by means of systematic review (Tranfield, Denyer, and Smart 2003), adopting a framework approach to synthesis (Carroll, Booth, and Cooper 2011; Dixon-Woods 2011) enabling us to build the DSC conceptualisation from the existing SC template.

The paper is structured as follows. First, we describe our review methodology that enables us to identify, collate and analyse the evidence relating to the emergent phenomenon DSC. Second, we briefly review the theoretical foundations of SC to provide an initial framework, the scaffolding on which a conceptualisation of DSC can be built (Gough, Thomas, and Oliver 2012). Third, on the basis of the evidence, we iteratively populate and refine the initial framework to develop our conceptualisation of DSC, teasing out its distinctive characteristics compared to the traditional SC concept. Fourth, our findings suggest emerging areas of interest and we discuss the implications of these in relation to scholarship and management practice. Finally, we make recommendations for practice and outline a research agenda.

The paper makes three original contributions. First, through the definition and identification of the characteristics of DSC as a distinct type of SC, distinguished and distinguishable from SCs of physical artefacts and hybrid physical artefact/DSCs. Second, we make a conceptual contribution by framing and drawing a research agenda on DSCs. Finally, the paper makes a methodological contribution by adopting a framework synthetic approach for the literature review, used for the first time, to the best of our knowledge, in the SC and operations management fields.

2. Methodology

To develop the concept DSC, we adopt a systematic review methodology (Tranfield, Denyer, and Smart 2003) to synthesise recent theoretical, conceptual and empirical literature reporting studies in which data are the artefact moving through the SC. Additionally, to draw out the distinctiveness of the concept, we contrast the DSC against the literature in which data related to SC process efficiency are the focus. According to Denyer and Tranfield (2009), whose precepts we follow, the systematic review process consists of five stages: Question formulation; Locating and collating primary studies; Study selection/evaluation; Analysis and synthesis; and the reporting and use of results.

Our analysis and conceptual development are framed in terms of an initial framework of the SC concept upon which we build to identify the distinctive and distinguishing characteristics of DSCs (see Sections 3 and 4). Our purpose in this study is to discover whether or not the concept DSC is meaningful in the context of the Knowledge Economy (Teece 1998): by 'meaningful' we mean comprised of distinctive characteristics distinguishing DSC from the traditional SC concept of the material artefact and having consequent specific theoretical and management implications. In this way, our approach is consistent with framework synthesis as described by Barnett-Page and Thomas (2009) and Thomas and Harden (2008).

To achieve this, we explore recent theoretical, conceptual and empirical studies in the Operations, SC, Manufacturing and Information Management literature published in English and peer-reviewed journals. Adams, Smart, and Huff (2017) make a case for, under certain conditions, the inclusion of the grey literature in reviews but not where the substantive purpose of the review is bounded by academic conversations as it is in the current study. Consequently, we exclude the grey literature from our review. Our selection criteria are further framed by date limiters 2010–2017 (first quarter only). 2010 was chosen as our departure point following a brief scoping study that failed to identify any relevant studies[2] prior to this date. We searched three databases for relevant studies, ScienceDirect, Scopus and EBSCO Business Source Complete, utilising a set of keywords and search strings[3] designed and tested to identify articles addressing the issue of data moving through SCs in manufacturing, industrial and service sectors; articles discussing concepts and theories around the notion of DSC; and those empirical studies which focused on the transformation of traditional manufacturing landscapes through the use of data for innovation and production. The search of electronic databases was supplemented with a hand-search of journals and a citation/snowballing search (Contandriopoulos et al. 2010).

This initial search yielded a total of 5761 initial articles. Following filtration on the basis of inclusion and exclusion criteria, this number was ultimately reduced to a final total of 71 selected studies (Figure 1). Our selected literature is categorised in terms of their focus on data and SC management in Table A1 (Appendix 1).

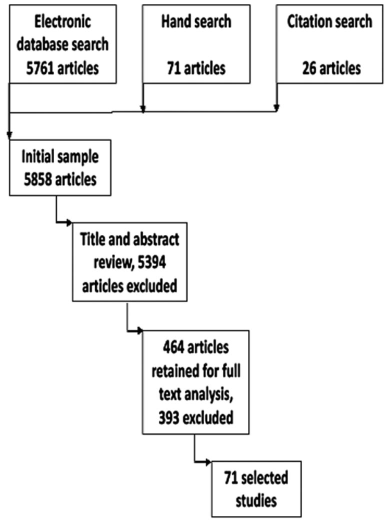

Figure 1. Search strategy.

Analysis and synthesis follow the framework synthetic approach (Thomas and Harden 2008; Barnett-Page and Thomas 2009): this is similar to framework analysis (Ritchie, Spencer, and O'Connor 2003) but applied to the literature (Dixon-Woods 2011). Following Carroll, Booth, and Cooper's (2011) prescriptions, we begin with a broad conceptualisation of the SC so as to promote inclusivity in our analysis which through iteration and augmentation in the light of selected studies, we develop the DSC concept. By means of this process, we are able to suggest a novel conceptualisation of the DSC which simultaneously reflects its SC origins as well as the evidence of the selected studies.

In total, 71 articles are included in our review and the results of our search indicate a rapidly growing interest in the phenomenon of data as the artefact moving through the SC and data-intensive SCs, with a marked acceleration in the years following 2013 (see Figure 2). The cut-off point for inclusion in this study was end of March 2017. In the first 3 months of 2017, we were able to find 10 published, relevant studies, compared to 24 in the whole of the previous year. Although the topic remains young, early indications are that it is attracting considerable and growing attention.

Selected articles are drawn from 31 different journals, 14 of which provide two or more articles (see Figure 3). Figure three also indicates that the scholarly conversation is taking place in diverse communities, including: operations and technology management; human resource management; management; and information management.

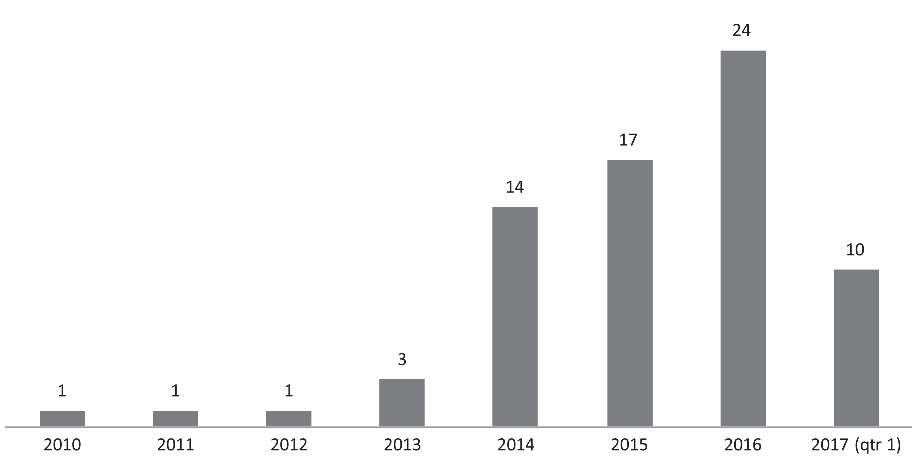

Figure 2. Included studies by year.

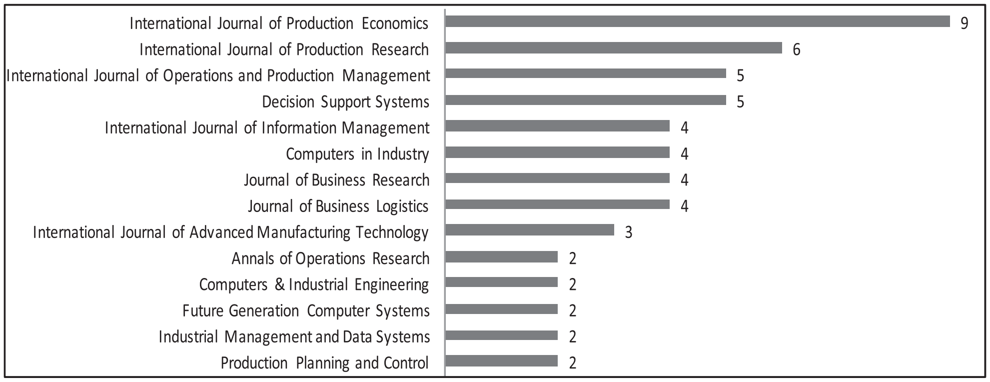

Figure 3. Included studies by journal (>2 publications).

3. From SC to DSC

The concept of the SC as a phenomenon of scholarly interest has attracted attention since the early 1980s. In this section, we briefly review this literature to provide an initial architecture, the scaffolding on which a conceptualisation of DSC can be built.

A search through the EBSCOHost database[4] for the term 'SC' in the titles of papers published in peer-reviewed journals returns over 8000 articles, the earliest with a 1985 date of publication. Scattered at regular intervals within this corpus are articles that either question or find indications of a cognate SC disciplinary distinctiveness (Giannakis and Croom 2004; Burgess, Singh, and Koroglu 2006; Harland et al. 2006; Ellram and Cooper 2014), efforts largely prompted by the diversity of perspectives from which the phenomenon was, and continues to be, approached. As a consequence, we notice a plethora of definitional, framework, conceptual and paradigmatic propositions which indicate a continuing search for the field's disciplinary distinctiveness as well as a structure(s) within which to frame research.

Burgess, Singh, and Koroglu (2006) observe, through an analysis of definitions and constructs relating to the SC concept, that *SCM constructs generally fall into two broad groups: the 'soft' people-focused constructs that deal with social relationships; and the 'hard' system-dominated constructs that deal with technological and infrastructural issues*, the latter having generally received more attention than the former. However, missing from their analysis, though, is any reflection on the artefact being moved through the SC.

Giannakis and Croom (2004), for example, propose a 'SC paradigm' consisting of three dimensions: the physical structure ('synthesis'), human interaction ('synergy') and the coordination and control of operational processes ('synchronisation') of SCs. Review papers, of which there are many including Croom, Romano, and Giannakis (2000), Burgess, Singh, and Koroglu (2006) and Borade and Bansod (2008), provide competing lists of definitions of the term.

The idea of data moving through SCs as the primary artefact of interest (i.e. not material artefacts) has gained a little traction in the scholarly literature, and we believe ours is the first, and timely, attempt formally to synthesise this body of evidence into a coherent conceptualisation of the phenomenon. The conceptualisation of the DSC can set the basis of our 'initial framework' adopted from the study of Storey et al. (2006) which examined the idealised characteristics of traditional/conventional manufacturing SCs from previous studies of SC field (Cooper, Lambert, and Pagh 1997; Croom, Romano, and Giannakis 2000; Lambert and Cooper 2000). Accordingly, we define the DSC as *the upstream and downstream flow of multisource, multiform data artefacts from inbound and outbound activities of the firm, forming innovation opportunities and value outcomes in production/service development as a core business area of the firm* and contend that SCs and DSCs differ in several important respects around four characteristics namely: (a) the element of exchange, (b) the strategy, (c) the integration and (d) the tools/methods applied for the DSC context. Each of these is further developed below.

While in SC literature we find studies around information processing, sharing, integration or knowledge management and development (Frohlich and Westbrook 2001; Hult, Ketchen, and Slater 2004; Fiala 2005; Fawcett et al. 2007; Flynn, Huo, and Zhao 2010; Cerchione and Esposito 2016), as well as the role of Electronic Data Interchange (EDI) in facilitating information sharing and increasing competitiveness (Benjamin, David, and Morton 1990; Webster 1995; Cachon and Fisher 1997; Power 2005; Prajogo and Olhager 2012), we believe there is still a distinction to be made between data *about* the SC and data that are the artefact *moving through* the SC. Additionally, smart SCs are utilising technologies such as IoT, smart machines and intelligent infrastructure, and capabilities such as interconnectivity, fully enabling data collection and real-time communication across all SC stages, intelligent decision-making and efficient and responsive processes to better serve customers (Wu et al. 2016).[5] The context of smart SC is close to DSC, as they are interconnected, intelligent, integrated and data-oriented; however, there is a major difference between these two as DSC uses data as raw material while smart SCs support physical raw material flows and improve these flows through the use of real-time data.

Additionally, the concept of 'Collaborative Supply Chains'[6] (CSCs) is relevant to this study as it focuses mostly on gaining competitive advantage and value from the end-customer and CSCs are categorised as outcome-based SCs (Melnyk et al. 2010). Outcome-based SCs, contrary to traditional SCs (which were strategically decoupled and price driven), are new forms of SCs strategically coupled and value driven (Melnyk et al. 2010). For Melnyk et al (2010), the SC should be designed and managed to deliver specific outcomes. Outcome-based perceptions are forming a new way of data-based decision-making, disrupting the business landscape while moving from the world of 'making things' to a 'world of outcomes' (Ng, Maull, and Yip 2009). The outcome-based approach in the context of SCs is not only based on collaboration, but also value co-creation (Normann and Ramirez 1993; Vargo and Lusch 2004; Lusch and Vargo 2006); towards this direction the smart SC is also an outcome-based SC (Wu et al. 2016).

3.1 *Element of exchange*

Central to many conceptualisations of the SC is the notion of an artefact moving through it or along it. Mentzer et al. (2001) as well as others (e.g. Cooper and Ellram 1993; La Londe and Masters 1994) define the SC context as that set of firms passing materials forward (Cooper and Ellram 1993) aligned to bring products or services to market through manufacturing to deliver them into the hands of the end user (La Londe and Masters 1994). Ahi and Searcy (2013) state specifically that the SC contemplates the product from initial processing of raw materials to delivery to the end user. Croom, Romano, and Giannakis (2000) describe this artefact as the element of exchange. This is about the 'what' that is being transacted (the artefact) and the 'how' of its transaction (relationships between actors).

In their review of 569 SCM papers, Soni and Kodali (2011) note that previous research has largely focused on the asset and information dimensions. Assets are typically conceived as artefacts with a material form and that require inventory and transportation management, from warehouse design to forms of shipping. The information dimension relates to the flows between supply-chain partners that facilitate co-ordination, often supported by electronic media (Croom, Romano, and Giannakis 2000).

Xu (2011), for example, focuses on a number of novel technologies, in particular what he calls service-oriented architecture such as RFID, agent, workflow management and the IoT, as a means to significantly improve the performance of SC quality management. Promoting the use of these and other technologies for SCM improvement is a common theme in the literature (see, for example, Fiala 2005; Fawcett et al. 2007; Cerchione and Esposito 2016; Sanders 2016).

Here, we re-emphasise the distinction between the current paper and previous studies. Unlike those studies cited in Soni and Kodali's review, our interest is not in information *about* the SC, information that supports the operation, management and analysis of SC functionality, but in information that is the asset being moved within it. In spite of the rapid growth in importance of data as a raw material for product development and innovation, little attention has been paid to its upstream, downstream and network flows through the SC (Gobble 2013; Tan et al. 2015). That is, as well as distinguishing between information about the SC and information as the artefact of exchange, we contend that the distinction between information and physical materials as the artefact of exchange has important implications for the conceptualisation of DSC.

3.2 *Strategy*

Through a focus on upstream supply, network or chain processes and downstream customers, the aim of the SC strategic orientation is to satisfy customers and gain competitive advantage in the market (La Londe and Masters 1994). Notwithstanding the importance attributed to SC strategy in the literature, it has, for a long period, remained ill-defined and poorly operationalised (Cigolini, Cozzi, and Perona 2004).

Addressing this gap through a nine-year action research study, Perez-Franco et al. (2016) propose a working definition of SC strategy as the collection of general and specific objectives set for the SC, and the policies and choices put in place to support them, with the purpose of supporting the business strategy, given the (business unit's) context and environment. Scholars have proposed a variety of strategic orientations. For example, Fisher (1997) proposes a 2-by-2 matrix in which four SC strategies emerge from the dichotomisation of product type (functional or innovative) and SC type (efficient or responsive) which can be used as an aide to evaluate whether or not a firm's product matches or mismatches its underlying SC process: such as unresponsive chains trying to deliver innovative products.

Extending Fisher's (1997) typology, and based on in-depth case studies, Qi, Boyer, and Zhao (2009) identify three types of SC strategy: lean strategy, agile strategy and lean/agile strategy.

Broadly, studies such as these support the general conclusion that lean strategies are associated more with functional products while agile strategies are more associated with innovative products. Given the novelty of big data and that firms are still working out ways of dealing with it profitably, it is not clear that such observations continue to hold.

3.3 *Integration*

The integrative perspective pervades SC scholarship and has frequently been associated with performance (Ataseven and Nair 2017), though the quality of the evidence supporting the relationship has been questioned (Fabbe-Costes and Jahre 2007). To implement SC management, some level of integration and co-ordination is necessary both within and beyond organisational boundaries (Cooper, Lambert, and Pagh 1997). Beyond the immediate boundaries of the firm, the requirement for integrated processes and practices extends to include upstream suppliers and downstream customers and the extent to which they are beneficially aligned (Stevens 1989; La Londe and Masters 1994; Frohlich and Westbrook 2001; Ataseven and Nair 2017). However, integration also takes an internal perspective and considers the internal functions relevant to SC management (Cooper and Ellram 1993; Lambert and Cooper 2000). As such, SC Integration can be understood as the degree to which a manufacturer strategically collaborates with its SC partners and collaboratively manages intra- and inter-organisational processes (Flynn, Huo, and Zhao (2010).

Frohlich and Westbrook (2001) identify five different SC integration strategies characterised by different 'arcs of integration' representing the direction (towards suppliers and/or customers) and degree of integration activity and note that, consistently, the widest degree of arc of integration with both suppliers and customers had the strongest association with performance improvement. Flynn, Huo, and Zhao (2010) conceptualise integration in three dimensions, internal, customer and supplier integration, positively relating them from configurational and contingency perspectives to both operational and business performance though indicating that internal and customer integration were more strongly related to improving performance than supplier integration.

Digital technologies and big data have opened new avenues for the design of business models by enabling firms to change fundamentally the way they organise and engage in economic exchanges, both within and across firm and industry boundaries and also with consumers and users (Zott et al. 2011). This has important implications for the management of multiple specialised technological, creative and user inputs to the innovation process and the management of value co-created across multiple platforms. It represents significant opportunities for new value constellations (Normann 2001), value ecosystems (Van der Borgh et al. 2012), activity systems (Zott and Amit 2010) and business model innovation (Baden-Fuller and Morgan 2010), the echoes of which perhaps being reflected in the collaborative SC clusters that scholars are now beginning to identify and describe (e.g. Storey et al. 2006; Stevens and Johnson 2016).

3.4 *Tools and methods*

Optimising the flows through the SC cannot be accomplished without implementing a process approach (Lambert and Cooper 2000) and, increasingly, to manage the processes of flow as well as relationships amongst SC actors, managers have been making use of a range of tools and techniques (Storey et al. 2006). Historically, the focus has been placed on the 'newest concern' (Ballou, Gilbert, and Mukherjee 2000, 8) of managing product flows, and so it is that Lambert and Cooper (2000) identify eight key SC processes, including:

- Customer relationship management
- Customer service management
- Demand management
- Order fulfilment
- Manufacturing flow management
- Procurement
- Product development and commercialisation
- Returns

Maintaining a strictly material artefact focus, Cigolini Cozzi and Perona (2004) categorise SC techniques according to whether or not they relate either to the configuration of a SC (the physical structure of the chain) or to its management (how the chain operates). Consequently, the tools and techniques are selected for their potential to optimise upon the traditional manufacturing-oriented methods such as for product design, transportation fleet design and so forth.

Although companies expect to broaden and deepen the use of new information and communication technologies for improving SC operations (Olhager and Selldin 2004; Wang et al. 2016), we speculate that there will be differences between the flow process management for material artefacts compared against data. For example, a critical consideration for many SCs in the context of material artefacts has been to understand lead times, define where to position inventory and how much to stock at each point (Scott and Westbrook 1991). Much of Scott and Westbrook's (1991) discussion is framed in terms of competing logics of SCs: holding inventory versus the Just-in-Time (JiT) approach. The juxtaposition of the two logics forced managers to confront challenging questions about their own SC practices, in particular relating to the combinations of physical and information processing tools, techniques and practices for SC optimisation. As data become the 'flowing artefact', these questions resurface.

For example, lead times and inventory management take on different characteristics in the knowledge economy. Data can be available nearly instantaneously, require comparatively little space to store[7] and follow a different regulatory framework for their storage and access control than physical materials. As a consequence, new sets of tools and techniques are likely to be required by managers who want to realise the business improvement potential and innovation opportunity that the data artefact promises for competitive advantage.

3.5 *Data Supply Chain (DSC)*

Based on the previous brief review of the literature, we propose to build a conceptualisation of the DSC around an initial framework of four dimensions as presented in Table 1.

4. DSC conceptualisation

4.1 *Element of exchange*

Content represents the element of exchange of the DSC which is usually data, but also can be metadata, information, knowledge and depends also in which stage of processing we find the data raw materials. Information and knowledge extraction from data is a major focus of the new manufacturing approaches. The advent of APIs, cloud technologies, IoT and the related advances of technology has transformed and disrupted traditional manufacturing structures and approaches for achieving intelligent and smart ways of production and distribution while using data as the raw material for the development of new products and services.

Data have become more accessible and ubiquitous, and this move necessitates the right approach and tools to convert data into useful, actionable information and knowledge (Lee et al. 2013). Analytics is a very popular technique lately for exploiting insight available from multiple data streams as technology helps capture rich and plentiful data on phenomena in real time while enhancing dynamic/adaptive capabilities (Erevelles, Fukawa, and Swayne 2016). There are also related studies where social media information landscapes are mapped by collecting and collating entire data-sets in social media (Ch'ng 2015) as well as using web crawling and scraping data-sets – sentiment analysis from online data for sales prediction (Chong et al. 2016). The advances in sensor technology, the Internet, wireless communication and inexpensive memory have all contributed to the explosion of data (Lee, Kao, and Yang 2014; Zhong, Newman

Table 1. An initial framework for the DSC concept.

Dimension	Supply chain
Element of exchange	The 'what' that is being transacted (the artefact) and the 'how' of its transaction (relationships between actors) (after Croom, Romano, and Giannakis (2000))
Strategy	The collection of general and specific objectives set for the SC, and the policies and choices put in place to support them, with the purpose of supporting the business strategy, given the (business unit's) context and environment (after Perez-Franco et al. (2016))
Integration	The degree to which an organisation strategically collaborates with its SC partners and collaboratively manages intra- and inter-organisational processes (after Flynn, Huo, and Zhao (2010))
Tools/methods	The tools and techniques utilised to optimise flows through the SC (after Lambert and Cooper (2000); Storey et al. (2006)

et al. 2016). The rapid growth of the data environment imposes new challenges that traditional knowledge discovery and data mining process models are not adequately suited to address (Li, Thomas, and Osei-Bryson 2016).

4.1.1 *Emergent areas*

Data heterogeneity: Manufacturing sites generate enormous data on a daily basis, such data are so complex, abstract and variable and it is difficult to make full use of the information and knowledge these data flows carry (Zhong, Lan, et al. 2016); Gandomi and Haider (2015) specifically refer to the problem of unstructured heterogeneous data, which constitute 95% of the available data and highlight the challenge to extract valuable outcomes.

Data quality: Data quality issue is often highlighted in the literature as poor data quality may influence the effectiveness of knowledge discovery processes, thus making the development of the data improvement steps a significant concern (Mezzanzanica et al. 2015). Data quality challenge often depends on the information systems which give business value to the quality of data and information produced and stored (Ji-fan Ren et al. 2016) and the data value chain management through these systems (El Kadiri et al. 2016).

Data privacy and security: Hossain and Dwivedi (2014) explain the privacy concerns in public applications of citizen data as data collected by a government agency would offer serious threats if shared among third parties. Ways to prevent data privacy issues could be anonymisation of the data-sets for privacy preservation (Zhang et al. 2014) or enhancing the trust between actors enabling to secure data sharing and data sharing control (Rehman et al. 2016). Moreover, data security concerns can influence customer's willingness to share personal data and information (Kache and Seuring 2017).

4.2 *Strategy*

Strategy for DSC represents the goals and the motivation that formed this specific SC. The DSC strategy is shaped around planning, sourcing, making and delivering outputs and therefore value from the data and knowledge using various processes, tools and methods. Strategy around the DSC seems to be innovation-led, as it is formed through ideas, practices and business models; value for DSC is not solely created from an information product/service but also through the disruption of the existing business and operational models (Ng et al. 2015; Opresnik and Taisch 2015; Li, Nucciarelli et al. 2016).

Strategic decisions for DSC are formed around internal and external data usage for improvement of the innovative capability of the firms and data analytics capabilities associated with database searching, mining and analysis for value creation (Kwon, Lee, and Shin 2014). Managers increasingly view data as an important driver of innovation and a significant source of value creation and competitive advantage (Tan et al. 2015). DSC strategy is formed more around the outcome and the value proposition of this outcome, an outcome-driven approach with a value focus. Value creation is presented as the value from the data itself as the raw material or data value-in-use (Merino et al. 2016) or even data value-in-reuse (Alvarez-Rodríguez, Labra-Gayo, and de Pablos 2014) more than ever before.

4.2.1 *Emergent areas*

Data generation and exploitation: The DSC strategy formulation usually follows goals as how data are generated and how they are exploited so as to provide competitive advantage and therefore creation of new revenue streams through business model innovation (Opresnik and Taisch 2015) or through closer interactions with consumers (Ng et al. 2015). Customer-centred product development approaches reveal that customer involvement can provide valuable input for developing tailored information products/services (Zhan et al. 2016) while data generation from smart interconnected objects provide platforms for data sourcing for innovation and product development (Zhong, Newman et al. 2016).

Innovation (business model and product/service development): DSCs enable firms to create new products and services, enhance existing ones and invent entirely new business models (Opresnik and Taisch 2015) – for example through data obtained from the use of actual products (Ng et al. 2015), improving the development of the next generation of products (Li, Tao et al. 2015) and creating innovative after-sales service offerings (Boone et al. 2016). DSCs can have an impact by utilising all the data points and turn them into informed decisions and actions that improve peoples' lives (Dobre and Xhafa 2014) as well as environmental and social sustainability outcomes (Dubey et al. 2016) following triple-bottom line perspectives (Hazen et al. 2016). The focus of DSCs can be on socio-economic development (Njuguna and McSharry 2017), natural hazards management (Belaud et al. 2014), climate change solutions (Schnase et al. 2014), resilience (Papadopoulos et al. 2016), environmental monitoring and emergency response (Yang, Yang, and Plotnick

2013) or solving urban problems (Li, Nucciarelli et al. 2016; Wang and Li 2016), through the development of information products and services for these challenges.

4.3 *Integration*

Integration represents the relationships and collaborative pattern each SC maintains internally and externally. For DSC, the integration can be observed as the combined data-sets of different sources, processed by different organisational entities (Janssen, van der Voort, and Wahyudi 2017). The data raw material collected from different sources can have various data qualities and is processed by various organisational entities resulting in the creation of the DSC (Janssen, van der Voort, and Wahyudi 2017). Inbound and outbound data sources can result in value creation when the data sources are handled in an integrated collaborative pattern (Rehman et al. 2016).

The use and re-use of information and data across tools and processes (Alvarez-Rodríguez, Labra-Gayo, and de Pablos 2014) as well as the data integration, used and re-use via analytics systems and modules demand flexible and agile integration architectures (Chen, Li, and Wang 2015). A common problem arising from the integration of DSC is a lack of interoperability among tools, tangled dependencies between processes or difficulties to exploit existing data and information to name a few that are preventing a proper use of the new dynamic and data-based environment (Alvarez-Rodríguez, Labra-Gayo, and de Pablos 2014).

4.3.1 *Emergent areas*

Multisource data: Distributed manufacturing across SCs has transcended vast organisational boundaries among webs of SC information sharing practices (Radke and Tseng 2015) and therefore data integration across analytics systems and processes seems a crucial challenge(Chen, Li, and Wang 2015). The same problem of handling multisource data is highlighted in the studies of Zhang et al. (2015) with sensor-generated manufacturing data and Lee (2017) with diverse data sources for knowledge extraction from shipping industry, where they discuss the problems of huge integrated data-sets difficult to handle with traditional methods.

Interconnectivity: DSC is formed through the interconnection of data raw materials, organisational entities and relationships, analytics/tools, processes, systems, products and services (Ng et al. 2015; Kang et al. 2016; Wu et al. 2016). The veracity (manipulation, noise), variety (heterogeneity of data) and velocity (constantly changing data sources) amplified by the size of the data call for relational and contractual governance mechanisms to ensure data quality and enable firms to contextualise data while working in a complex interconnected pattern (Janssen, van der Voort, and Wahyudi 2017).

4.4 *Tools/methods*

Tools and methods refer to the technological context applied for each SC. There are various techniques and industrial applications of data in service and manufacturing sectors, and their use is increasing sharply as new technologies are developed for storage, data processing, data visualisation and analytics (Zhong, Newman et al. 2016). Data exploitation methods, advanced analytics and in-memory database technology are seen as key enablers for enhanced top management decisions around the use of data (Hahn and Packowski 2015). With an aggressive push towards 'IoT', data have become more accessible and ubiquitous, and this move necessitates the right approach and tools to convert data into useful, actionable information (Lee et al. 2013).

In order to become more competitive, manufacturers need to embrace emerging technologies, such as advanced analytics and cyber-physical system-based approaches (Lee et al. 2013) and enhance their production with new ideas and innovative products/services. To get the most out of the enormous data (in combination with a firm's existing data), a more sophisticated way of handling, managing, analysing and interpreting data is necessary (Tan et al. 2015). Innovative approaches of information and knowledge extraction are presented in various studies about data extraction from smart objects (Zhang et al. 2011; Yang, Yang, and Plotnick 2013; Ng et al. 2015; Zhong, Huang, et al. 2015; Zhong, Xu, et al. 2015; Zhong, Lan, et al. 2016; Zhong, Newman, et al. 2016); the data generated daily in real-time from service and manufacturing sectors are increasing sharply and lift up a growing enthusiasm for the use of these data streams for value and innovation. In their paper Zhong, Newman, et al. (2016) investigate representative applications of these data streams from typical services like finance and economics, health care, SC Management (SCM) and manufacturing sector – by introducing new products and services formed through the utilisation of these data-sets.

4.4.1 *Emergent areas*

Data collection, processing, storage methods/tools and provenance: Current challenges, opportunities and future perspectives such as data collection methods, data transmission, data storage, processing technologies, data-enabled decision-making models, as well as data interpretation and application are highlighted as major concerns (Zhong, Newman, et al. 2016). Nowadays, data analytics, which requires managing an immense amount of data rapidly, presents challenges and difficulties for information processing related to the large amounts of data, high dimensionality and dynamical change of these data (Chong et al. 2016). Efficiency in SC is about process, whereas in the DSC context efficiency concept relates to access and storage of data.

Data Analytics: Analytics are the tools used for extracting information, building a knowledge base using the derived data and developing optimisation, visualisation and forecasting models around these data (Tannahill and Jamshidi 2014). To get the most out of multiple data-sets (in combination with a firm's existing data), a more sophisticated way of handling, managing, analysing and interpreting data is necessary for their competitive advantage by enhancing their innovation capabilities (Chae et al. 2014; Tan et al. 2015). For example, data visualisation techniques enhance data interpretation and increase trust in data completeness and validity (Bendoly 2016).

5. Discussion

The review presented the concept of DSC through its characteristics, focusing on distinguishing the flow of data artefacts as a supply chain of its own with specific (a) element of exchange, (b) strategy, (c) integration and (d) tools/methods. The purpose was to unfold the conceptual distinctiveness of DSC and identify the emerging areas of interest arising within the context of Knowledge Economy. Within this context, we argue that data can be 'raw materials' triggering processes and creating value through their flows across organisational boundaries, while developing new information products/services as well as disrupting existing business models to facilitate such a change. The literature could not allow us to find a conceptualisation of this emergent phenomenon, although there is a progressively increasing number of studies focusing on data artefacts, the ways firms can create value from them and how strategies should be formed around these 'raw materials'.

The framework synthesis approach allows us to depict the differences of DSC compared to conventional manufacturing SC around four respects: their element of exchange, strategy, integration and tools/methods. The comparison (as it appears also in Table 2) shows that a unique characteristic of DSC is the content. The element of exchange of DSC is

Table 2. DSC characteristics and emergent areas.

SC	Characteristics	DSC	Emergent areas
Flow of physical artefacts (materials, products, services) from initial source(s) to final customer	Content	Flow of multisource, multiform data artefacts (or even processed data, information or knowledge) from inbound and outbound activities of the firm	Data heterogeneity Data quality Data privacy and security
Demand-led SC (only produce what is pulled through), targeting in production maximisation, revenue and value creation, quality, service, safety, etc.	Strategy	Innovation-led (through ideas, practices and business models; value for DSC is not solely created from an information product/ service but also through the disruption of the existing business and operational models)	Data generation and exploitation Innovation (business model and product/ service development)
Price-driven (strategically decoupled and price driven)		Outcome-driven (strategically coupled and value driven)	
Shared information across the whole chain (end to end pipeline visibility). Collaboration and partnership (mutual gains and added value for all)	Integration	Integration of multiple data sources (internal and external to the focal firm). Collaboration, interconnection and value co-creation (value through business model innovation)	Multisource data Interconnectivity
IT enabled; Physical manufacturing systems; agile and lean; mass customisation methods	Tools/methods	Analytics-enabled; Cyber-physical manufacturing systems; agile, lean and real-time; tailored customisation methods	Data collection, processing, storage methods/tools and provenance Data Analytics

usually data, but can also be information and knowledge (processed data raw materials). Data artefacts flowing from inbound and outbound activities of the firm (and not solely from internal databases) integrated and combined in ways that can provide value for the focal firm (through information product/service development) introduce innovative business and operational models.

The strategy formed around DSC is innovation-led and outcome-driven, meaning that contrary to the traditional SC where demand is triggering the production, for DSC innovative ideas and practices can create value for the development of products and services. Traditional approaches of SC are usually decoupled and price-driven, focusing on profit increase while for DSC the driver of the production is the outcome of this process which focuses on the value through coupled value co-creation. The integration of multiple sources (data, information, processes, practices, etc.) across the immediate boundaries of the firm can be observed in SC in general; however, in DSC, the integration is mostly focusing on the combination of the data from internal and external sources (along with the integration as it is perceived in traditional SCs). The methods and tools used for DSC seem as the fourth distinct characteristic which warrants further investigation; data-oriented methods for information product/service development introduce new patterns of work which rely on analytical skills as well as the reliability mostly on cyber-physical, IoT and cloud-based systems – for the collection, processing, storage and utilisation of data through the SC.

Future research towards this direction could focus in understanding further the emergent areas around the DSC context as these were identified through the framework synthesis (Table 2). Previous studies have indicated that indeed data as 'raw materials' can be multiform and multisource; therefore, new approaches are required for value extraction and creative industrial use and processing of these heterogeneous data. Data processing and manufacturing approaches should be investigated for the path to better data quality, along with new frameworks to describe and track data manufacturing processes in different industrial applications. In addition to data quality, data privacy is an emerging concern around DSC, as often serious threats arise when these data-sets are shared among third parties. Ways to prevent such issues open a new research agenda around trust and shared responsibility among the DSC actors and entities. Furthermore, data collection, processing, storage techniques and methods and data provenance is a research area which is worth expanding. Data generation and exploitation strategies can also focus on the organisational aspects as well as the capabilities and skills the firms should acquire for building innovative DSCs. The outcome-driven approaches DSCs follow can set a strategic way of coupling multisource data in different innovative ways, producing outcomes and value for the firms through products/services or business model innovation.

With this paper, we introduced the concept of DSC presenting an interesting yet challenging field of research within the notion of data evolution and knowledge economy. Without neglecting the important role of data in SCs, which has been a more widely explored research area, we draw specific attention to SCs of data. A field's development is shaped by the clarity of its constructs and underlying assumptions (Bansal and Song 2016); therefore, we provide a conceptual framework for DSC and believe there is still a big research gap in this highly emergent area. Such research highlights the value and new research directions in exploring beyond the immediate boundaries of a firm to a collaborating pattern of using data and creating value opportunities while disrupting the already existing business and operational models.

Additionally, our methodological contribution is adopting a framework approach for the literature review synthesis, used first time for the SC and operations management fields. However, Dixon-Woods (2011) describes as a limitation of framework-based synthesis its tendency to generate results about which there may be some ambiguity, not least because the a priori framework may restrict reviewers' scope of vision. We attempt to address this limitation using a broadly specified conceptualisation of SC as our starting point but recognise that facets of the DSC phenomenon may, nevertheless, have been missed. We recommend that future research empirically test the validity of our proposal.

6. Conclusion

DSCs have emerged relatively recently[8] as data evolution expands business scope, disrupts existing operating models, changes industries and provides opportunities to work solely on data as the main 'raw material'. Evolution of data and its processing, exchange and reselling transform the organisational and operational landscape and render the conceptualisation of DSC highly relevant.

Waller and Fawcett (2013) proposed the use of data in SC management for improvement and expansion of the production (through the use of analytical skills for optimisation and visualisation of the SCs of their core business). Although data can be used along with the core business processes in different industries where we find data about the SCs, we put our specific focus on data around the SCs; and we emphasise the difference between data utilised to improve SC processes vs. data used as the main artefact. We find that the literature that considers data as the main artefact focuses on technical solutions and challenges around data and SC management but lacks discussion on the organisational, operational and industrial consequences of DSC (see Appendix 1).

An important distinction is to be made when data are the main artefact: data are not consumed nor do they perish in the process of production, nor do data necessarily depreciate. Moreover, data have atypical characteristics compared to physical raw materials in a SC: data can be inputs, intermediate goods as well as end products themselves. Therefore, DSC can be an iterative process where data lead to expansive value creation. As El Kadiri et al. (2016) suggests, data product cycle is not a closed loop system and more data iteratively feedback into different decision-making phases. These characteristics of data in the DSC lead to several consequences for the industrial and organisational setting. Collaboration, coordination and transparency within industries become more prevalent (Li, Nucciarelli et al. 2016; Janssen, van der Voort, and Wahyudi 2017) compared to persistence of competition and secrecy in SCs around physical goods. Sharing data is generally beneficial and creates positive externalities for processes and organisations (Kwon, Lee, and Shin 2014; Li, Nucciarelli et al. 2016; Janssen, van der Voort, and Wahyudi 2017). Moreover, we find that data transform SC management into demand chain management by decreasing the need for excessive inventories and increasing customer response (Christopher and Ryals 2014). Finally, we also find that DSC should allow for flexibility and adaptability since data lead to a more inductive logic in processing rather than a deductive one (Erevelles, Fukawa, and Swayne 2016).

These highlighted facts emphasise that DSC needs to be tackled with a fundamentally different approach to data used about a physical SC. There are, however, several ways in which the DSC approach can learn and benefit from the physical SC literature. Models utilised in SC can be transformed to create the foundational framework for the operation of DSC. Such research would help scholars advance DSC models and inform practitioners in such contexts.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Engineering and Physical Sciences Research Council (EPSRC – Research Councils UK) [grant number EP/K039504/1].

Notes

1. Please see Figures A1 and A2 in Appendix 1 for a visual comparison of SC vs. DSC as well as an example of DSC, respectively.
2. On the basis of title and abstract evaluation.
3. Available from the corresponding author.
4. June 2017.
5. Addo-Tenkorang and Helo (2016) discuss the literature on Big Data applications in operations and SCM, in other words the smart SC literature.
6. Following the view of networked, inter-organisational, interconnected relationships among SCs, Davis and Spekman (2004) and Spekman and Davis (2016) proposed the 'Extended Enterprise' (EE) concept, which was revisited recently providing the context for 'Collaborative Supply Chains'.
7. Certainly, data warehousing exists but compared to physical products they require less space, though perhaps greater energy resources, different security management procedures, etc.
8. With the advent of Open APIs and the Web 2.0 paradigm.

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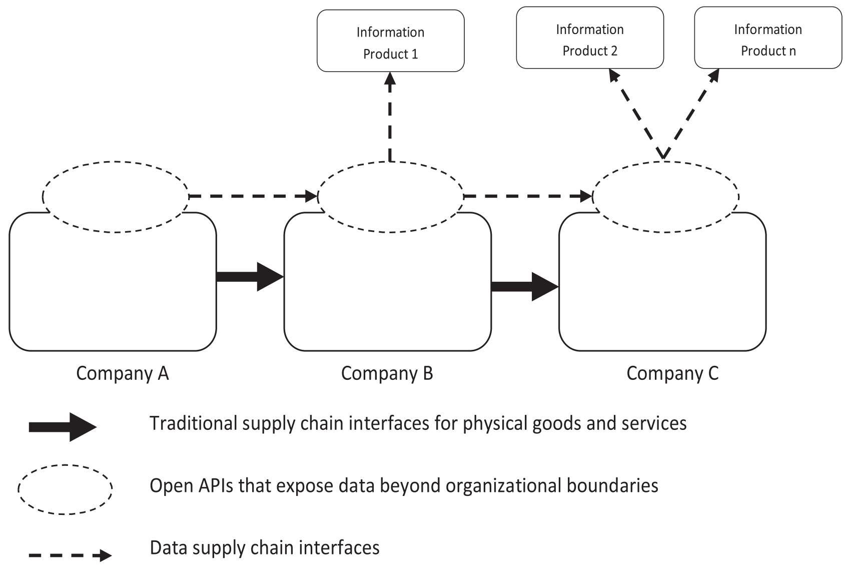

Figure A1. DSC vs. SC (Spanaki et al. 2016).

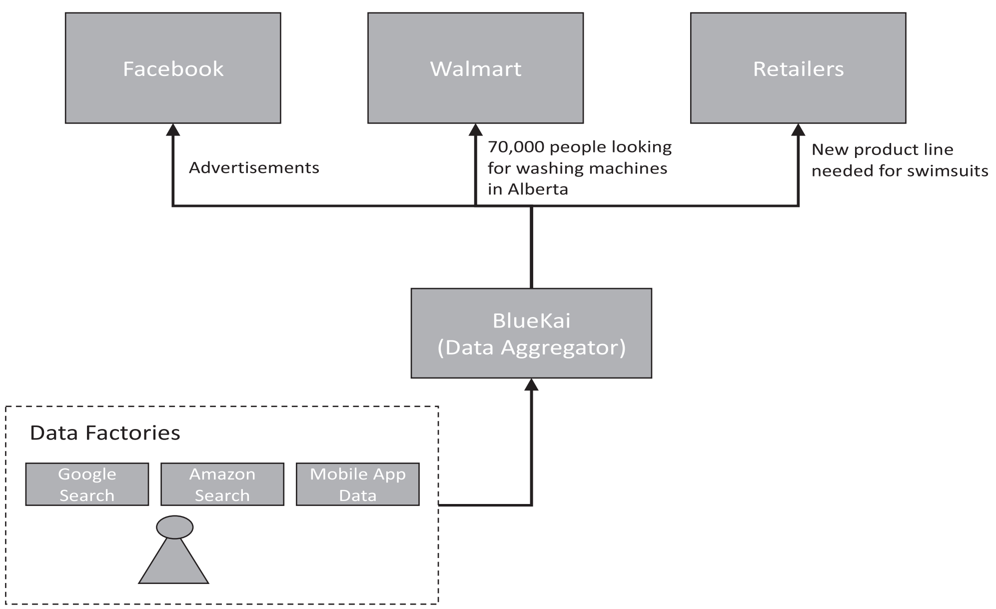

Figure A2. An Example of DSC (Mulligan 2013).

Table A1. Focus of selected literature.

	Selected Literature	Focus: Smart SCs Data are used to create process efficiency for physical flows	Technical Necessary technical advances for DSC and data challenges	Hybrid forms Physical artefact/data SCs, servitisation	Data as artefact Data are the main artefact moving through the SC
1	Alvarez-Rodríguez, Labra-Gayo, and de Pablos (2014)	X	X		
2	Belaud et al. (2014)		X		X
3	Bendoly (2016)	X	X		
4	Boone et al. (2016)	X			
5	Cenamor, Sjödin, and Parida (2017)		X	X	X
6	Chae et al. (2014)	X			
7	Chen, Li and Wang (2015)		X		X
8	Ch'ng (2015)		X		X
9	Chong et al. (2016)	X	X	X	
10	Christopher and Ryals (2014)	X		X	X
11	De Oliveira, McCormack, and Trkman (2012)	X		X	
12	Dobre and Xhafa (2014)		X		X
13	Dubey et al. (2016)	X	X	X	X
14	El Kadiri et al. (2016)		X		X
15	Ellram and Tate (2016)	X	X	X	
16	Erevelles, Fukawa, and Swayne (2016)	X	X	X	X
17	Gandomi and Haider (2015)		X		X
18	Giannakis and Louis (2016)	X	X	X	X
19	Groves et al. (2014)	X	X		
20	Gunasekaran et al. (2017)	X		X	
21	Hahn and Packowski (2015)	X	X	X	
22	Hazen et al. (2014)	X	X		
23	Hazen et al. (2016)	X	X	X	X
24	Hofmann (2015)	X	X	X	
25	Hossain and Dwivedi (2014)		X		X
26	Janssen, van der Voort, and Wahyudi (2017)		X		X
27	Ji-fan Ren et al. (2017)	X	X		
28	Kache and Seuring (2017)	X	X	X	
29	Kang et al. (2016)	X			
30	Kumar et al. (2016)	X		X	X
31	Kwon, Lee, and Shin (2014)		X		X
32	Lee (2017)	X	X	X	
33	Lee, Kao, and Yang (2014)	X	X	X	X
34	Lee et al. (2013)	X	X	X	
35	Li, Luo et al. (2015)	X	X	X	
36	Li, Nucciarelli et al. (2016)	X	X	X	X

(*Continued*)

Table A1. (*Continued*)

	Selected Literature	Focus			
		Smart SCs Data are used to create process efficiency for physical flows	Technical Necessary technical advances for DSC and data challenges	Hybrid forms Physical artefact/data SCs, servitisation	Data as artefact Data are the main artefact moving through the SC
37	Li, Tao et al. (2015)	X	X		
38	Li, Thomas, and Osei-Bryson (2016)		X		
39	Matthias et al. (2017)	X		X	X
40	Mehmood et al. (2017)		X	X	X
41	Merino et al. (2016)		X		X
42	Mezzanzanica et al. (2015)		X		X
43	Ng et al. (2015)	X	X	X	X
44	Njuguna and McSharry (2017)		X		X
45	Öberg and Graham (2016)	X	X	X	X
46	Opresnik and Taisch (2015)	X	X	X	X
47	Papadopoulos et al. (2016)		X	X	X
48	Radke and Tseng (2015)		X		X
49	Ramanathan, Subramanian, and Parrott (2017)			X	X
50	Rehman et al. (2016)		X		X
51	Schnase et al. (2014)		X		X
52	Schoenherr and Speier-Pero (2015)		X		
53	Souza (2014)	X		X	X
54	Tachizawa, Alvarez-Gil, and Montes-Sancho (2015)	X		X	X
55	Tan et al. (2015)		X		X
56	Tannahill and Jamshidi (2014)		X		
57	Trkman et al. (2010)	X	X	X	X
58	Waller and Fawcett (2013)	X	X	X	X
59	Wang et al. (2016)	X			
60	Wang and Li (2016)		X		X
61	Wu et al. (2016)	X	X	X	
62	Yang, Yang, and Plotnick (2013)			X	X
63	Zhan et al. (2016)	X		X	
64	Zhang et al. (2014)		X		
65	Zhang et al. (2011)	X	X	X	
66	Zhang et al. (2015)	X	X	X	
67	Zhong, Huang, et al. (2015)	X	X	X	
68	Zhong, Lan, et al. (2016)	X	X		
69	Zhong, Xu, et al. (2015)	X	X	X	
70	Zhong, Newman, et al. (2016)	X	X	X	