ENTERPRISE INFORMATION SYSTEMS, 2017
VOL. 11, NO. 6, 828–858
http://dx.doi.org/10.1080/17517575.2015.1091950

Information technology for sustainable supply chain management: a literature survey

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ABSTRACT

In supply chain management (SCM), two topics have gained importance over the last years. On the one hand, sustainable SCM (SSCM) has become increasingly relevant and many publications have contributed to the topic. On the other hand, information technology (IT) is being progressively considered as a key enabler for efficiency in supply chains. Several research efforts have contributed to the field of IT for SSCM. However, this paper is the first recent attempt to summarise the current state of the art of how IT can affect SSCM in any structured way and to compare it with IT for 'general' SCM to give guidance for future research. This paper surveys 55 peer-reviewed articles that were retrieved through keyword searches (until May 2014). The analysis identifies research deficits as well as a lack of scientific discourse employing empirical techniques and a lack of investigations on the social sustainability. Additionally, possible topics for further research were derived by comparing the survey's results with the current research on IT for 'general' SCM following the analysis of 631 articles. Six fields could be identified, namely output/effects of IT, machine communication and multiagents, inputs and IT-supported processing, IT-enabled interorganisational exchange, quantitative IT approaches and a sector focus.

ARTICLE HISTORY
Received 2 December 2013
Accepted 4 September 2015

KEYWORDS
Sustainable supply chain management; environmental sustainability; social sustainability; information technology; literature survey

1. Introduction and terminology

1.1. *Introduction*

This paper presents a structured, updated perspective on how information technology (IT) can improve sustainable supply chain management (SSCM). The analysis is based on a literature survey and provides a comparison of IT for SSCM with IT for 'general' SCM, suggesting directions for future research. Over the last few years, sustainability has become a major topic in the domain of SCM.[1] This is reflected by the increased number of academic publications on SSCM over the past decade (Hassini, Surti, and Searcy 2012; Seuring and Müller 2008). The term 'sustainability' first entered the public consciousness with the definition of 'sustainable development' established by the Brundtland Commission in 1987: 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Environment and Development 1987, 43). To achieve this, sustainability needs to be incorporated into decisions in a wide array of fields. The 'triple bottom line' coined by Elkington (1999), which is widespread in literature (Carter and Easton 2011), splits sustainability into three dimensions of equal importance: an economic, an environmental and a social dimension.

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In the past, the focus of scientific investigations in SCM was primarily placed on economic sustainability, usually due to profitability considerations. Over the last two decades, however, environmental or 'green' factors have become increasingly incorporated into analyses in all fields. This also holds true for SCM, where environmental concerns have been of special significance (Seuring and Müller 2008; Winter and Knemeyer 2013). Nevertheless, we have to emphasise that research on social sustainability in supply chains is still very limited (Seuring and Müller 2008).

The role of IT for SCM has been highlighted in the past as, for example, integrated information systems can lead to improved business performance of companies in a supply chain (e.g. Gonzálvez-Gallego et al. 2015; Li 2012). More sustainability-related, other work covered how IT can help in improving the reliability of supply chains (e.g. Lam and Ip 2012). In general, sustainability and IT are interlinked in two ways: IT itself can become more sustainable or sustainability can be improved through the use of IT (Schatten 2009). This duality has been observed and supported by various researchers. For example, Piotrowicz and Cuthbertson (2009) stress the necessity of also considering the effects on sustainability in the evaluation of IT systems. Melville (2010) acknowledges the potential of IT for improving environmental sustainability, and Srivastava (2007) highlights that IT will play an important role in the future of 'green' (i.e. environmentally friendly) SCM. Nevertheless, the current state of research in the domain of IT for the broad area of SSCM is still quite diffuse. So far, there appears to be no consolidated survey of academic approaches of how IT is seen to drive sustainability in supply chains (see related work section below).

This paper seeks to address the lack of a clear view of the state of research at the intersection of IT and SSCM by combining the three above-mentioned fields and aims to deliver an updated perspective of how IT can be used to improve sustainability in supply chains (illustrated in Figure 1). The purpose of this paper is to provide a structured view of the suggestions made in literature from multiple angles and, in particular, identify areas for future research. It, therefore, first presents a literature survey of the field of IT for SSCM introducing a framework with multiple dimensions and then uses the literature in the general domain of IT for SCM to compile a list of research topics that have not yet been addressed in the field of IT for SSCM. These are derived from a keyword-based analysis that does not only focus on sustainability. It is the first paper to provide this combined perspective. As economic sustainability has been the focus of research in the past, we restrict the analysis to environmental and social sustainability.

This paper covers literature up to May 2014. Section 1.2 presents related reviews, while Section 1.3 discusses the context of the paper. Section 2 gives an overview of the methodology.

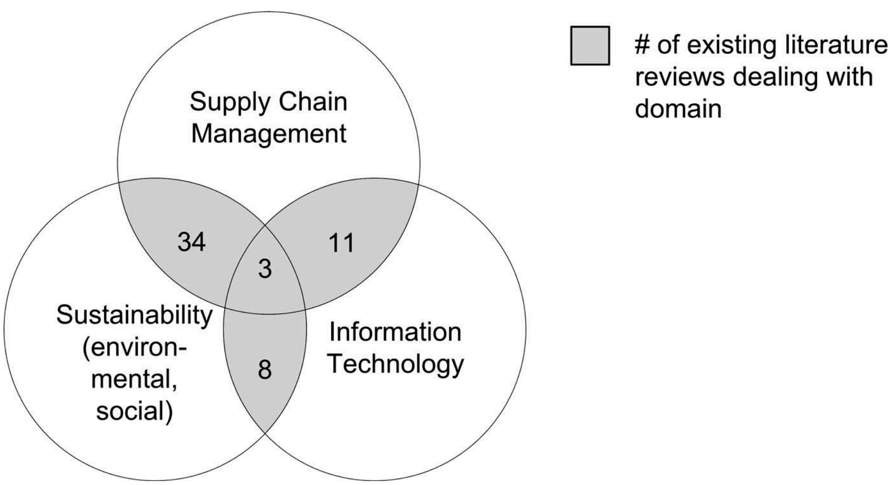

Figure 1. Overlap area of SCM, sustainability and IT including related literature reviews and number of papers analysed.

Based on this, Section 3 addresses major characteristics of the papers analysed. Section 4 presents a discussion of the conceptual framework introduced in the methodology. Section 5 analyses keywords of the overarching domain of IT in SCM in order to identify potential areas for further research. Finally, Sections 6 and 7 discuss the results and summarise the findings with some concluding remarks.

1.2. *Related work*

This section discusses literature papers that have been presented in the context of this work, summarising 56 articles after 2008. A complete list can be found in Table A1 in Appendix 1. (For reference, the papers have been indexed by their categories a–d and a consecutive number).

Previous work has mainly focused on the intersections of any two of the domains of sustainability, IT and SCM. Altogether, 34 articles cover the intersection of sustainability and SCM (a), while 9 of these particularly aim to give a broader review of the domain (1, 2, 7, 8, 10, 12, 13, 19, 32). Min and Kim (2012) published the last general keyword search-based article. Teuteberg and Wittstruck (2010) specifically include some IT elements in their discussion.

At the intersection of IT and SCM (b), three studies deal with the wider domain by addressing the use and effects of IT for SCM and logistics (1, 3, 5), while other papers address narrower domains such as secure collaboration or radio frequency identification technology (RFID). However, no in-depth connection to sustainability issues can be identified in these studies. Eight review papers, published between 2008 and 2014, deal with the interaction between sustainability and IT (c). Few of them present more general overviews of the domain. Elliot and Binney (2008) published a first article giving a brief overview. Melville (2010) focuses on information system innovation to develop a conceptual framework. While Brooks, Wang, and Sarker (2012) and Tushi, Sedera, and Recker (2014) address ‘green’ IT in general, Harmon and Moolenkamp (2012) limit their research to IT services. Loeser (2013), in his review, combines Green IT with Green IS (information systems). A broader view is presented by Dao, Langella, and Carbo (2011), who take a resource-based view and discuss the integration of IT with human resources and SCM to develop sustainability capabilities. Nevertheless, their focus is on resources, and SCM is a subcategory of the analysis and treated equally as human resources management. Finally, Jenkin, Webster, and McShane (2011) present a multilevel research framework with their review.

Three articles cover all three areas. One deals with green logistics specifically (Frehe and Teuteberg 2014), while another attempt focuses on RFID (Thoroe, Melski, and Schumann 2009). The article by Kurnia, Mahbubur, and Gloet (2012) is closest related to this paper. However, their focus is more on developing the roles that IT (or information systems) may play in SSCM and less on studies where IT is presented and evaluated for this purpose. They develop these roles based on scientific papers with an IT/information systems background published in the years before 2011.

All in all, none of the previous articles directly surveys the papers at the intersection of IT and SSCM including both environmental and social sustainability. To remedy this, the following section will present the specific emphasis of this paper.

1.3. *Context of the paper and keywords used*

In general, this paper focuses on peer-reviewed literature that covers how IT may be used within SCM to improve either environmental or social[2] sustainability in supply chains. The fundamental question is how IT can be used to positively affect supply chain sustainability.

This approach excludes papers where IT is only used as a tool and the use of IT itself is not addressed in the research (e.g. papers that only use software packages, such as MATLAB, to enable calculations). The sustainability dimensions are treated similarly: as stated, only academic papers in which either environmental or social sustainability are affected by IT are taken into account.

Moreover, papers that focus solely on sustainability aspects of the IT domain are not included (e.g. the lifecycle assessment of a laptop).

To identify SCM-relevant papers, the high-level keywords of *supply chain* and *SCM* are used. Further, the keyword *logistic** is included, as logistical activities are particularly important in SCM. Asterisks ('*') represent wildcards that allow the automatic search for different but similar words.

The IT perspective in SCM is closely linked to the information flow in supply chains. Hence, the *Oxford Dictionary* defines IT as 'the study or use of systems (especially computers and telecommunications) for storing, retrieving and sending information' (Oxford Dictionary 2012). Therefore, *information technology* is used as another keyword. For better coverage, we added *information system, ICT* (information and communication technology), *information management system* and *software* as additional 'information' keywords. To include 'common' technologies relevant in the context of SCM that can be expected to be used in abstracts, the set of keywords was extended by *Internet, Web service, e-technology, e-communication, e-service, data exchange* and *data hub* – these are all keywords that are very much linked to the online world. Specific technologies were not included as we assume that relevant papers also include one of the more general terms listed above in the metadata fields analysed.

While research in the past has focused on economic sustainability, this paper addresses the two other dimensions of environmental and social sustainability. Environmental impacts can include carbon emissions, noise or waste, whereas social impacts cover improvements for the individual or society. The general term *sustainab** and dimension-specific terms such as *green*, carbon, environment*, ecolog*, social* and *ethic** were also used as keywords for the literature research.

To generate the search strings, the keywords for SCM, IT and sustainability were combined separately using 'OR'. In a second step, the three resulting strings were connected using 'AND'.

2. Research methodology

The aim of this paper is to provide a structured view of how IT can positively affect SSCM based on the current literature. Furthermore, it seeks to suggest directions for future research.

The first objective of this paper can be achieved through a literature survey. According to the Association for Computing Machinery, a survey paper is '[A] paper that summarizes and organizes recent research results in a novel way that integrates and adds understanding to work in the field. A survey article assumes a general knowledge of the area; it emphasizes the classification of the existing literature, developing a perspective on the area, and evaluating trends' (The Association for Computing Machinery 2015). In contrast, '[a] literature review is an assessment of a body of research that addresses a research question' (Garson et al. 2012). A literature review steps beyond a survey as it also assesses the current literature, which means 'to estimate or judge the value, character, etc., of' (Dictionary.com 2015) the existing work. Here, we aim to provide an overview and structure of how IT can be used for SSCM based on existing work. Consequently, we follow the definition of a survey and first retrieve current work in a structured way. We then use a multidimensional framework to classify the research and analyse the suggested relation between IT and SSCM from several angles.

The second objective of this paper, to derive areas for future research, can initially also be based on the results of the literature survey. However, this only makes it possible to identify general directions of research as no normative areas of research have been introduced. Therefore, we suggest using a keyword-based analysis of the domain of IT and 'general' SCM without a focus on sustainability, based on the assumption that research in this area is further advanced and detailed than in the specific domain. This analysis is titled 'expanded discussion'. Comparing the themes of recent research conducted in the more general domain with those in the area of sustainability allows us to derive opportunities for research.

The detailed methodologies for the two approaches are discussed in Section 2.1 for the literature survey and in Section 2.2 for the expanded discussion using the keyword analysis.

2.1. *Approach for literature survey*

For the survey, we followed a content analysis as introduced by Mayring (2003). Content analysis builds on two layers: 'The first level analyses the manifest content of texts and documents by statistical methods. On a second level, latent content of the text and documents is excavated requiring interpretation of the underlying meaning of terms and arguments' (Seuring and Gold 2012, 546). Seuring and Müller (2008), as well as Seuring and Gold (2012), using Mayring's (2003) work, outline a four-step process to follow when conducting a content analysis (Figure 2). Its general, structured approach makes it possible to derive reliable and, hence, reproducible results for literature-based analyses, particularly also in the SCM domain (Seuring and Gold 2012). The analysis on the second level has been used to generate insights on how IT influences SSCM.

Following the method depicted in Figure 2, which was adapted for this paper, we first collected research articles in a structured way. This was followed by a descriptive, formal analysis of the material and its general metadata. The third step delivered a (theory-led) selection and definition of structural dimensions for categorisation. Initial categories for a structured discussion were defined deductively and later adapted based on inductive ideas (Mayring 2003). The last step uses these categories to analyse the papers and document the results. Therefore, steps 3 and 4 were performed iteratively multiple times to ensure a balanced approach and to reduce the risk of miscategorisation.

The following two subsections detail the methodology of the literature search (the first step in Figure 2) and present the final dimensions of analysis (the third step in Figure 2). The results for steps 2 and 4 of Figure 2 are presented in Sections 3 and 4.

2.1.1. *Delimitations and the search for literature*

The scientific publications in this survey originate from a variety of different peer-reviewed journals in English. Thompson Reuters SCI and SSCI indexes[3] served as the main sources for the survey and were supplemented with other established academic sources: EBSCO Business Sources Premier,[4] T&I ProQuest[5] and SciVerse ScienceDirect.[6] Restricting the search to several domains of interest (e.g. computer or decision science) allowed us to minimise the number of false positives. The literature search used the data fields title, abstract and keywords (if available; including non-author keywords). Relevant papers could also cover the domain of interest only in parts.

The authors analysed all retrieved papers in a first cross-reading of abstracts to identify mismatches. These can occur, for example, due to popular constructions in other contexts such as 'logistic regression'. In total, 55 papers made up the final selection of the literature survey.

E-commerce is one topic linked to IT and SCM that stands out in the discussion. E-commerce relates to the end user and to many intermediate steps in the supply chain. This investigation addresses how IT affects sustainability in a given supply chain and not how IT-enabled e-commerce requires changes in supply chains. Therefore, the authors excluded papers without a focus on e-commerce as a tool in the interorganisational Business to Business (B2B) parts of the supply chain.

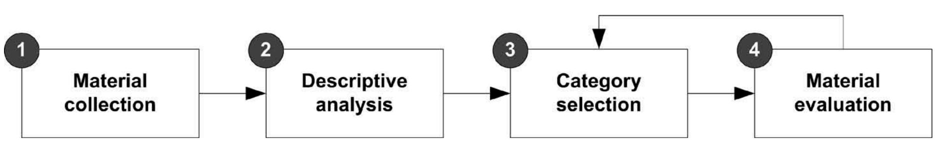

Figure 2. Four-step approach according to Seuring and Müller (2008) and defined by Mayring (2003).

2.1.2. *Dimensions for content analysis*

Figure 3 presents the perspectives structuring this paper's analysis of literature on IT for SSCM. By structuring the literature along different dimensions, we can gain insights on how IT can positively affect SSCM. The dimensions, thus, provide different perspectives on the same question.

The first dimension of categorisation (detailed in Section 4.1) follows classic supply chain discussions. A supply chain can be split into a forward and a backward (often also called 'reverse') flow of materials and goods with the consumption by customers in between these flows (García-Rodríguez, Castilla-Gutiérrez, and Bustos-Flores 2013). Occasionally, neither the forward nor the backward network is the focus of interest within SCM. Thus, a product-centric view or an over-arching view can also be present. The second dimension (Section 4.2) distinguishes three different IT perspectives: systems for strategic or tactical management, systems for supply chain execution and monitoring and, at an overarching level, the supporting frameworks or general setting (e.g. policies) for IT within SCM. As a third perspective (Section 4.3), we differentiate the impact of IT along the environmental and social dimensions of sustainability. Finally (Section 4.4), we distinguish two types of effects on the relationships of IT with sustainability. This relationship can be either direct (when the use of IT aims directly and explicitly at a change in at least one dimension of sustainability) or indirect (when the use of IT influences an intermediary variable such as efficiency that causes improvements in sustainability, and sustainability is not the primary focus).

A detailed discussion of all dimensions based on the key papers is provided in Section 4.

2.2. *Approach for expanded discussion*

To identify relevant articles that focus on IT for SCM, the expanded discussion uses the search terms given in Section 1.3 (omitting the sustainability-related keywords). Thomson Reuters' SCI and SSCI indexes[7] and SciVerse ScienceDirect[8] allow automated exporting of author-suggested keywords and were used to retrieve relevant papers. The analysis covers papers from 2008 until the end of 2013, so as to only consider complete years. The papers were filtered as in the literature survey and the final analysis covered keywords from 631 research papers.

We combined the data sets of ScD and WoK and eliminated duplicates. Keywords were accessed via a database tool together with Zotero.[9] During the merge, WoK served as the master source

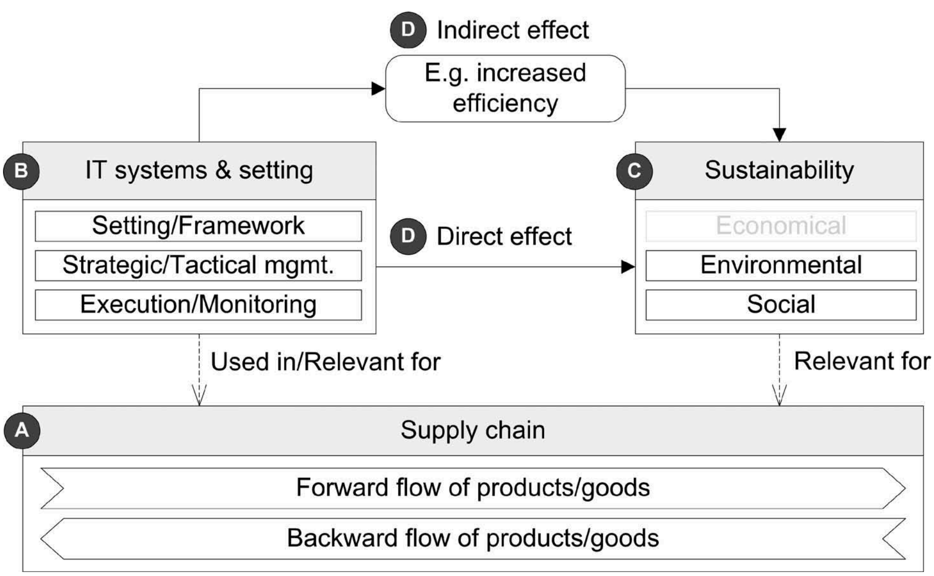

Figure 3. Overview of the classification dimensions.

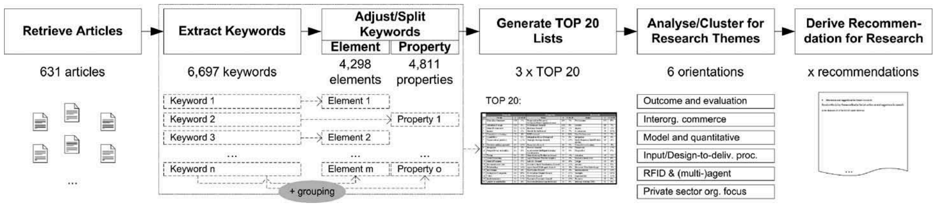

Figure 4. Overview of expanded analysis.

(including the automatically added keywords of WoK). If a keyword occurred twice within the same paper, it was deleted (e.g. full word and abbreviation).

We cleaned this initial list of keywords syntactically to achieve unified orthography. Moreover, we adjusted singular and plural forms, allowing slight semantic differences that were considered in the interpretation of the results. Two steps yielded the final keywords:

(1) Keywords were split into elements/objects and properties. For example, the keyword 'intelligent agents' was split into the object 'agents' and the property 'intelligent'. Noun premodifiers were defined as a property if they did not belong to a common group (e.g. supply chain was seen as a common group). To improve grouping, single-word keywords (e.g. inventory) that had also been identified as a property in a different keyword (e.g. inventory in 'inventory management') were handled as a property and named accordingly (e.g. 'inventory-focused'). If a noun had several premodifiers, separate entries were created (e.g. 'green product design' was split into 'green design' (property + element) and 'product-focused design' (property + element)). Adjectives were considered properties. Geographical and industry classifications were filtered from the content analysis.
(2) In a second step, the elements/objects were grouped into three layers to allow an additional analysis. This was iterated multiple times for improved consistency. Instead of grouping them in a multilevel hierarchy, properties were combined if they had comparable meanings (e.g. 'agile' and 'flexible' were combined into 'agile/flexible'). We attempted to ensure that the outcome of this grouping process would be mutually exclusive as far as possible given a bottom-up approach.

Figure 4 presents an overview of the process – the figures provided will be detailed in Section 5. The methodology is limited by semantic ambiguity in the keywords, as specific words can have different meanings in different contexts. This was taken into account as much as possible, first and foremost in the interpretation of the results. Furthermore, papers vary in the number of keywords used, which may affect statistical results.

3. Descriptive analysis according to survey

In total, we identified 55 papers using the process outlined above (see Table A2 in Appendix 1 for the full classification). The first of these papers were published in 1999, with few new

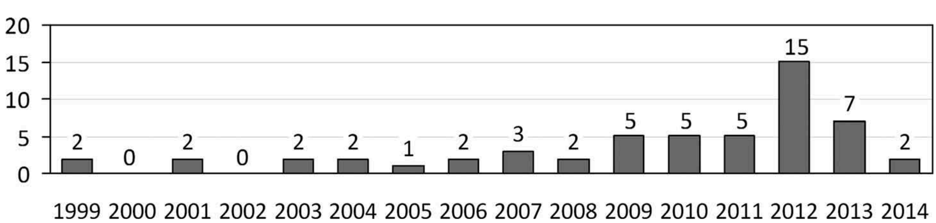

Figure 5. Time-distribution of papers in scope (n = 55).

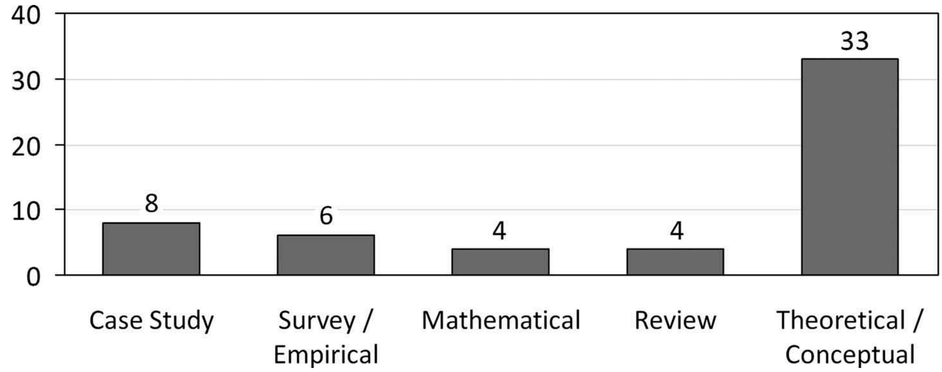

Figure 6. Methodological focus of papers in scope (n = 55).

papers being published until 2008 (Figure 5). However, there was a significant increase in the number of publications in the sample in 2009 that lasted until 2012 (by final publication date). A significant spike can be noted in 2012 with 15 papers. This number declined to seven papers in 2013. In 2014, two papers had been published by May.

All in all, the 55 papers were published in 37 different journals. Hence, there is a wide variety of viewpoints on the subject. Three journals, however, show higher publication rates than the others. These are the *International Journal of Production Economics* with five publications and *Expert Systems with Applications* as well as *Procedia – Social and Behavioral Sciences* with four publications each.

As depicted in Figure 6, most identified papers (33 out of 55) have a theoretical or conceptual primary focus. All other categories, except for case studies, show similarly low publication numbers with 4–6 peer-reviewed articles each. Some of the theoretical and conceptual papers also include some type of software implementation.

4. Information technology for SSCM

The following sections discuss how IT can influence SSCM along the dimensions of (Figure 3).

4.1. *Focus on the supply chain*

IT for SSCM can affect different parts of the supply chain. Most papers discussing IT in SSCM deal with the forward flow, take a product perspective or address an overarching viewpoint. Only some papers consider IT in the context of the backward/reverse flow. Here, the reverse flow specifically deals with the questions of reuse, recycling and end of life, while transportation activities are discussed in the forward flow. In any of these contexts, IT is especially discussed in the context of information flow in a supply chain in addition to the physical movement of goods.

4.1.1. *Forward flow*

Literature addressing the forward flow mainly focuses on the influence of IT on transportation and the calculation of its environmental impacts. IT planning tools that allow the calculation of carbon emissions (e.g. see Sourirajan et al. 2009) have already led multiple companies to enlarge their warehouses and shorten their travel distances (Schiller 2012). Other suggested software tools take an even broader range of environmental effects of transportation into consideration (Guenther and Farkavcová 2010). In an effort to improve precision, Iacob et al. (2013) propose a reference architecture for a transportation carbon calculation and management system based on true fuel consumption.

Another aspect seen in the investigated literature is that IT can improve sustainability at a vehicle-routing level. In 1999, Hasle presented a tool to improve vehicle-routing efficiency that explicitly considers the environmental impact. In a different approach, Suh, Smith, and Linhoff (2012) focus on the last-mile delivery problem and how the current standard system of door-to-door delivery can be improved using a social network. A similar focus on routing can be seen in intelligent transportation systems that enable truck drivers to bypass potential bottlenecks (Marett, Otondo and Taylor 2013).

Some papers address how IT can improve the sustainability of nodes in a supply chain network and where nodes such as production facilities are located. Verma and Chaudhuri (2009) show how the complete Indian agricultural value chain has been changed by IT. They highlight that the largest effects on sustainability are at the production and consolidation levels due to improved and directed information, while transportation is least affected. Other authors discuss comparable issues in India's agricultural sector (Rao 2007; Ali and Kumar 2011). Nevertheless, significant sustainability impact may be achieved by choosing optimal facility locations with the support of IT. This topic is addressed by several authors (Ayoub et al. 2006 for production or storage facilities; Guyon et al. 2012 for city logistics platforms; and Bosona et al. 2013 for warehouses).

4.1.2. *Reverse flow*

Supply chains have close links to sustainability if they cover reuse and recycling activities. Some IT approaches specifically address these functions to improve their efficiency. Some start with lightweight, Web-based systems for information exchange (Edwards, Lyons, and Kehoe 2004), and they are particularly important in more complex reverse logistics scenarios (Dhanda and Hill 2005). García-Rodríguez, Castilla-Gutiérrez, and Bustos-Flores (2013) show that in less developed countries (management) information systems can have a significant impact on the implementation of a reverse logistics system for raw. Performance improvement of the reverse flow may unfold in measuring and assessing reverse logistics chains using IT. This can be supported by RFID (Trappey, Trappey, and Wu 2010) or more general IT systems (Olugu and Wong 2012).

4.1.3. *Product*

Current product-related work can be divided into two streams. On the one hand, suggestions for IT-driven sustainability ensure that products (Chen, Tai, and Hung 2012) or suppliers meet environmental/ecological standards (Lai, Hsu, and Chen 2012). For this purpose, Taghaboni-Dutta, Trappey, and Trappey (2010) propose a green-parts information platform that covers sustainability information relevant for the product design process.

On the other hand, IT systems can help improve shortcomings in calculating product-specific sustainability impacts. McKinnon (2010) accused current product-specific carbon labelling of being too inaccurate and, by using existing lifecycle assessment or RFID data, highlights the potential of IT to help mitigate this issue. This is similar to what Björk et al. (2011) developed for the specific case of a wood supply chain. As an individual company may not have a sufficient level of detailed lifecycle information internally, product-specific lifecycle assessment can require an exchange between organisations (Barrett, Strunjaš-Yoshikawa, and Bell 2007).

4.1.4. *Overarching supply chain perspective*

IT systems that aim to improve sustainability on an overarching supply chain level have been purposed in multiple areas, with both topic- and system-driven approaches. Bullinger, Steinaecker, and Weller (1999) describe an early IT system for environmental production management that includes lifecycle information and is based on overarching data models. Current papers suggest ontologies for the exchange of product-specific sustainability data (Muñoz et al. 2013; Borsato 2014) or cover the whole supply chain or life cycle in multiple industries (Koh et al. 2013).

Industry-specific papers deal with multiple areas. Trienekens et al. (2012), for example, focus on the food supply chain. They describe how an information system focused on information exchange along the value chain could satisfy a broad array of information needs from different stakeholders. Lehmann, Reiche, and Schiefer (2012) highlight that an increased use of IT at all stages of the agricultural supply chain can improve efficiency as well as environmental and social performance. They postulate that the sustainability information (e.g. use of pesticides) needed by consumers is very similar to that which is needed by enterprises along the value chain. In addition, Sigala (2014) discusses the potential use and impact of social media on sustainability in tourism supply chains, and Toh, Nagel, and Oakden (2009) address the sustainability of cities.

Overarching viewpoints may also be driven by international institutions such as the European Union (EU). Research in the EU-funded project 'SuperGreen' specifically discusses IT technologies that enable environmental sustainability in freight transport corridors in Europe (Clausen, Geiger, and Behmer 2012; Fozza and Recagno 2012).

4.2. *Focus topic in IT*

Different IT systems are designed to support supply chain sustainability on different management levels. Therefore, we may distinguish systems for strategic and tactical management purposes and systems for execution and monitoring tasks in a supply chain. A third aspect can be identified in the environment or framework that supports the use of IT systems on a meta level.

4.2.1. *Systems for strategic and tactical management*

Sustainability factors usually affect route and network planning directly, particularly if network decisions include the IT-supported calculation of carbon emissions (Sourirajan et al. 2009). Besides, planning systems often make use of geographical information systems (GIS) that could help improve sustainability of production activities and of transportation links (e.g. in agriculture, see Rao 2007; or for warehouse locations, see Bosona et al. 2013). For example, Ayoub et al. (2006) utilise a GIS as the primary tool for mapping locations along the value chain, which allows expert users to consider environmental and social factors when optimising the overall network.

Additionally, several expert systems have been suggested as support in environmental sustainability-related situations. Vannieuwenhuyse, Gelders, and Pintelon (2003) developed an interactive online tool to choose modes in a transportation network. Iakovou (2001) proposed a decision support system for risks in crude oil maritime transport operations. Chen, Tai, and Hung (2012) promote an expert system that allows optimum component selection in 'green' supply chain settings, especially given hazardous material regulations. The system by Koh et al. (2013) allows collaborative identification of carbon emission hot spots, as well as options for intervention (e.g. estimated impact).

Some authors specifically focus on e-commerce. E-commerce typically enables SCM activities before a physical product is sent along the supply chain (Davies, Mason, and Lalwani 2007). In the B2B context, e-commerce can have three sustainability effects in supply chains (Abukhader and Jönson 2004): it can (1) enable smoother operations, thus reducing, for example, energy and material consumption; (2) increase the use of energy-consuming hardware equipment; and (3) bring about change in consumption behaviour. The total effects are still unclear (Abukhader 2008). Even the sometimes attributed effects of increased efficiency in processes are still under discussion (Abukhader and Jönson 2004; Dotoli et al. 2006). Nevertheless, Walker and Brammer (2012) investigate e-procurement as an option to improve sustainability, while Lee (2003) mentions e-manufacturing in connection with the greening of processes.

In contrast, lifecycle management systems specifically help manage and minimise the detrimental environmental effects of goods and services sourced. Thurston and Eckelman (2011) postulate that feasible software tools are already publicly available, and proposals that support this notion have been made, for example, a data model for the exchange of lifecycle assessment data between organisations (Barrett and Strunjaš-Yoshikawa 2007). Data exchange in supply chains may also support designing sustainable products. With their integrated data platform, Taghaboni-

Dutta, Trappey, and Trappey (2010) try to show how part-specific environmental information can improve sustainability by making it easier to select 'green' parts for product development. In a different approach, Sigala (2014) considers the potential of involving customers in sustainable supply chain decision-making through the use of social media.

4.2.2. *Systems for execution and monitoring*

IT systems can also be used to improve sustainability in the operational execution of supply chains and for monitoring activities, especially those activities that enable decisions. One example is the agricultural sector in India, where farmers' input is used to monitor production activities (Rao 2007). In Europe, information exchange is regarded as one of the major drivers for more sustainable European transport systems, which is based on IT-supported single-transport documents and (intermodal) route planning with tracking and tracing (Zografos, Sedlacek, and Bozuwa 2012). Carlson, Forsberg, and Pålsson. (2001) propose the exchange of environmentally relevant data between supply chain partners and combine this with an integrative data perspective. Meacham et al. (2013) even underline that real-time exchange of data in a supply chain is a prerequisite for an environmental management system.

Information needs with regard to sustainability can also come from the public, as Trienekens et al. (2012) highlight. This led them to promote a common software infrastructure based on defined standards. Edwards, Lyons, and Kehoe (2004) propose using Web technology to implement cost-effective planning systems.

Moreover, multiple RFID systems have been discussed in the context of SSCM to enable further improvements through their tracking and tracing options (see also McKinnon 2010). These systems allow the monitoring of sustainability performance (Björk et al. 2011 for the whole wood supply chain) or enable sustainability-relevant performance improvements, for example, in reverse logistics (Trappey, Trappey, and Wu 2010) or waste management (Martínez-Sala et al. 2009). Even consumer health may be improved when tracking livestock in food supply chains (Wognum et al. 2011). Similarly, sensor networks embedded in an 'Internet of Things' may secure food supply chains in cities (Zhang et al. 2013).

A further category encompasses intelligent transport systems (ITS) that use technology to improve transportation and, thus, potentially sustainability (Zografos, Sedlacek, and Bozuwa 2012). This is not only true for the commonly known systems in road transport (Iacob et al. 2013; Marett, Otondo, and Taylor 2013), but also for new systems; for example, in rail infrastructure, like the European Rail Transport Management System. Benz et al. (2012) present several applications and a test bed to optimise network-level greenhouse gas (GHG) emissions in a general logistics network.

Finally, expert systems can be used to analyse the operational performance of supply chains (Olugu and Wong 2012) or for ad hoc improvements (Suh, Smith, and Linhoff 2012). Suh, Smith, and Linhoff (2012) show how the combination of a social network with location-based information of participants can be used to improve last-mile package delivery in real time.

4.2.3. *General framework and setting*

Not only IT systems themselves, but also the general framework and setting (e.g. policies) contribute to how IT affects sustainability in supply chains. Zografos, Sedlacek, and Bozuwa (2012) analyse European policies and compare them with the current status of policy implementation and direction in the member states. They stress that, next to other factors, improvements in IT can enhance Europe's sustainability. In the EU-funded project 'SuperGreen', Clausen, Geiger, and Behmer (2012) develop general recommendations (application and infrastructure) regarding which IT technologies can help enable ecological sustainability along multiple freight corridors within the EU. Toh, Nagel, and Oakden (2009) underline the importance of IT as an infrastructure that enables (sustainable) logistics by allowing shifts in freight movement within cities and, therefore, increases environmental sustainability.

4.3. *Focus dimension of sustainable development*

IT can affect SCM either in the environmental dimension of sustainability, in the social dimension of sustainability, or in both dimension at the same time. Figure 7 presents the distribution of the papers in the survey across these dimensions. The results are comparable to Seuring and Müller (2008), who also identified a strong spike in environmental sustainability. Moreover, 26 out of the 55 papers discuss not only GHGs, but also broader environmental effects. In contrast, the influence of IT on the social dimension is not widely acknowledged, with only one paper addressing the dimension specifically and 16 papers addressing it in addition to environmental concerns.

4.3.1. *Environmental focus*

Two major substreams can be identified in research on IT for environmental sustainability in supply chains. One stream focuses on the elimination and reduction of GHG emissions and is strongly driven by recent regulations (e.g. European Commission 2012). The other stream also takes a multitude of other environmental concerns into account, such as noise or particle pollution. Here, the drivers are different regulations such as restrictions on the use of certain hazardous substances (RoHS) in electrical and electronic equipment, or registration, evaluation, authorisation and restriction of chemical substances (REACH).

IT systems supporting the optimisation of environmental impacts strongly focus on GHG emissions (Sourirajan et al. 2009; Schiller 2012; Guenther and Farkavcová 2010). In particular, some authors suggest an effect of IT on carbon emissions of road freight traffic (Benz et al. 2012; Suh, Smith, and Linhoff 2012; Iacob et al. 2013; Bosona et al. 2013). Also, Shi et al. (2012) attribute their efforts to improve reverse logistics information flow to the goal of establishing a low-carbon environment.

Nevertheless, several authors also consider a wider perspective by including the analysis of congestion (Vannieuwenhuyse, Gelders, and Pintelon 2003), particle emissions (Clausen, Geiger, and Behmer 2012) or a multitude of environmental factors (Carlson, Forsberg, and Pålsson. 2001; as well as the domain ontologies of Muñoz et al. 2013; Borsato 2014). Reverse SCM also covers broader effects when recycling and end-of-life management of products is considered and promoted, thus, for example, reducing waste (Olugu and Wong 2012; García-Rodríguez, Castilla-Gutiérrez, and Bustos-Flores 2013; Martínez-Sala et al. 2009; Trappey, Trappey, and Wu 2010). As early as 1999, Bullinger, Steinaecker and Weller already considered material reuse and other environmental factors in their product life-cycle model.

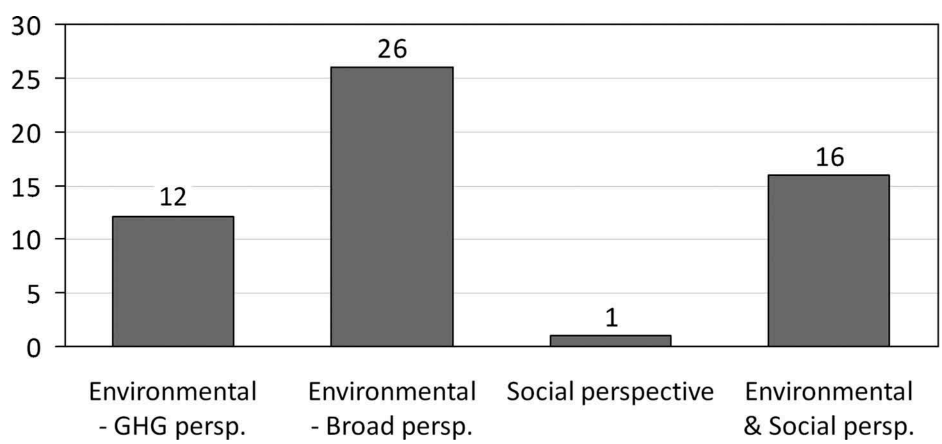

Figure 7. Environmental and social sustainability focus in the papers analysed (n = 55).

IT systems supporting the verification of standards have as wide an environmental scope as the standards they verify. As standards usually take an approach beyond GHG, a wider environmental perspective is ensured (e.g. see the systems described by Lai, Hsu, and Chen 2012 or Chen, Tai, and Hung 2012).

4.3.2. *Social focus*

Although social sustainability is a broad concept, only one paper specifically addresses social issues in sustainability. Ali and Kumar (2011) focus on agricultural efficiency in developing countries and draw a connection to social issues. They underline that an information system in an agricultural supply chain can improve the efficiency of production. Hence, it can also increase the income level of farmers in the long run, while also reducing the risk of social unrest. However, an advanced level of education of participants is required to ensure efficiency effects through the use of IT.

4.3.3. *Environmental and social focus*

A significant number of papers address IT's influence on both environmental and social sustainability together. Given that sustainability is affected in a more general sense, the focus in this subsection is on the approaches. In particular, three areas are discussed: IT systems to fulfil multidimensional information needs, IT systems for sustainable agriculture in developing countries and IT systems to improve the sustainability of public procurement.

Customer information usually needs to touch on all dimensions of sustainability as government and consumers both want to be well informed. Therefore, companies in the food or agricultural supply chain, for example, need a high level of transparency in order to fulfil these demands, which is only possible using IT (Trienekens et al. 2012; Lehmann, Reiche, and Schiefer 2012; Zhang et al. 2013). Additionally, although Koh et al. (2013) primarily consider carbon emissions, they also consider the social implications of evaluating carbon reduction measures in their system. In a different sense, including customers and their understanding of sustainability can expand the discussion even more (Sigala 2014).

Some authors discuss the use of IT for sustainability as a developmental aspect based on the Indian agricultural domain. Rao (2007) describes the role of ICT in improving the growth of agriculture and links this to environmental aspects, population growth and income levels. Verma and Chaudhuri (2009) instead suggest that e-commerce reduces farmer exploitation by reducing information asymmetries. Walker and Brammer (2012) show empirically that in developed countries e-commerce can also lead to improvements in environmental supply practices and of some (labour, safety and health), but not all (community, philanthropic activities and buying from minority-owned small- and medium-sized enterprises (SMEs)), social aspects in public procurement. In another food supply chain setting, Wognum et al. (2011) define social sustainability mainly as safeguarding the health of consumers.

Only one paper explicitly combines environmental and social factors with an IT system optimising them: Ayoub et al. (2006) address environmental and social factors in dealing with optimal locations of facilities along the supply chain. Implicitly, this is also what the system by Guyon et al. (2012) is intended to enable. Nevertheless, within the scope of this survey, no IT system enables combined environmental and social optimisation in supply chains.

4.4. *Immediacy of IT's influence on sustainability*

This literature survey distinguishes between direct and indirect effects of IT on sustainability. Often direct effects mean environmental or social effects that occur as a result of providing an IT system. These primary effects result from the use of IT devices and, for example, the material and energy needed for production. In contrast, secondary or indirect effects are driven by the use of IT (Piotrowicz and Cuthbertson 2009). However, in this paper we use a different definition of direct effects: direct effects are created by IT systems that explicitly aim to reduce negative environmental and social effects, while indirect effects result from the use of IT systems that improve intermediary variables, such as efficiency. While the latter improve sustainability, sustainability is not the primary focus. This is a 'chicken and egg problem' (i.e. does the increase in efficiency lead to emissions reduction or does emissions reduction lead to efficiency increase). Therefore, we consider the primary aim of the IT-based improvement.

4.4.1. *Direct effects*

Most direct effects mentioned in the papers are related to environmental and not social sustainability. Only one paper focuses directly on social effects by describing IT as an enabler for communicating knowledge about diseases to improve social issues in the respective community (Rao 2007). Transmitting sensor data for food safety could be understood in this sense (Zhang et al. 2013). Direct environmental effects of IT can be attributed to the optimisation of carbon emissions as implemented in the IBM carbon tool (Sourirajan et al. 2009) or in the SCEnAT tool for supply chain decarbonisation (Koh et al. 2013). Other tools aim to directly improve energy consumption in transport (Guenther and Farkavcová 2010) or road freight networks (Benz et al. 2012), for example, on the basis of lifecycle inventory data.

Moreover, IT systems can help assess environmental impacts. The RFID system by Björk et al. (2011) allows the direct optimisation and analysis of environmental effects. Olugu and Wong's (2012) approach describes how an environmental assessment can be conducted using fuzzy values in the context of closed-loop SCM. Another topic is the direct exchange of data on sustainability factors among companies to improve sustainability along the value chain (Carlson, Forsberg, and Pålsson. 2001; Trienekens et al. 2012; Meacham et al. 2013). Beneficial effects can even already be found when the exchange within a company receives better support (Muñoz et al. 2013; Borsato 2014).

Direct optimisation of environmental effects also occurs when the product's complete life cycle, until disassembly, is considered (Bullinger, Steinaecker, and Weller 1999). Enhanced models like multicriteria optimisation integrated into IT systems include 'soft' parameters if the environmental impact cannot be quantified (Vannieuwenhuyse, Gelders, and Pintelon 2003).

Another form of direct impact results from avoiding negative sustainability effects with the help of an IT system; for example, by complying with international regulations (Chen, Tai, and Hung 2012) or by improving e-procurement (Walker and Brammer 2012).

4.4.2. *Indirect effects*

Many papers only focus on the indirect effects created by increased efficiency in supply chain processes. Indirect effects on sustainability can vary in their 'level of indirectness'. 'Very indirect' relations can be seen when increased IT usage improves the educational level of supply chain participants or other capabilities, which in the end (e.g. through better usage of resources) leads to improved sustainability (Rao 2007; Dao, Langella, and Carbo 2011). For example, e-commerce in agricultural supply chains can be a catalyst for growth and development (Verma and Chaudhuri 2009). Another remote link is described by Lehmann, Reiche, and Schiefer (2012), who underline consumer awareness as a mediating factor.

Nevertheless, most papers that point to indirect effects of the use of IT on sustainability in SCM address performance improvements, primarily environmental improvements, through optimised operation (Hasle 1999; Melville 2010). The already mentioned EU research project 'SuperGreen' (Clausen, Geiger, and Behmer 2012; Fozza and Recagno 2012) also uses ICT as an enabler for increased efficiency in the use of transport resources.

In a similar sense, the effects of e-commerce on the environment are typically indirect as IT improves the performance of processes (Abukhader and Jönson 2004). Davies, Mason, and Lalwani (2007) show how e-commerce and IT affect general haulage in the United Kingdom. The impact of

IT is driven by improved visibility and planning accuracy along the supply chain and reductions in transaction, administrative and raw material/service costs. Furthermore, Dotoli et al. (2006) show that e-links in supply chains can increase agility and reconfigurability, thereby improving environmental sustainability. In reverse logistics, increased information exchange can lead to indirect positive sustainability effects through efficiency and reduced waste (García-Rodríguez, Castilla-Gutiérrez, and Bustos-Flores 2013).

Finally, risk can be seen as an indirect effect. Iakovou (2001) presents an interactive solution methodology to minimise the risks of environmental pollution in maritime shipment of petroleum. In a related context, Wognum et al. (2011) highlight the importance of transparency in achieving sustainability, and Lai, Hsu, and Chen (2012) suggest an information system that allows the verification of environmental certificates.

5. Expanded discussion and comparison with work on IT for 'general' SCM

Given the increase in the number of papers in recent years, IT for sustainable SCM can be regarded as a rather new and developing area of research. In order to propose possibilities for further research, this section broadly analyses the current direction of research in IT for 'general' SCM and combines it with insights from the literature survey above. Hence, the discussion relaxes the constraint of sustainability. To allow a brief but broad overview of the field, this approach focuses on the keywords of the papers in the domain.

In total, the analysis includes 631 papers with 6697 keywords split into 4298 topic-specific elements/objects and 4811 properties as depicted in Table 1 (for an overview of the categories derived see Table A3 in Appendix 2). The compound annual growth rate (CAGR) of keywords from 2008 to 2013 (full years) was almost zero. Hence, high CAGRs for individual keywords can very likely be explained by an increased use of the term. Moreover, Table 1 shows the highest grouping level for elements/objects. Most items fall under management, followed by scientific concept-related and resource/service-related terms.

Table 2 shows the top 20 elements, properties and keywords. It excludes lines that were used as search terms in the database queries in order to allow an improved focus on relevant research directions. The deepest level of grouping is shown for all elements.

Table 3 presents the coverage of the items of Table 2. While only 55% of elements and 56% of properties are left unexplained, around 70% of keywords remain unexplained.

Altogether, six areas of research appear to emerge from the top 20 list for the domain of SCM and IT as depicted in Table 2:

(1) *Outcome and evaluation orientation*: Several terms, such as performance, adoption, usage, impact, competitive advantage and value, seem to indicate that papers focus on the outcome – that is, the usefulness and performance of IT together with SCM – and try to analyse its state. In light of this, we can also see a marked decrease in the use of strategy-related tagging terms.

Table 1. Total frequency and CAGR of elements, properties and keywords.

	Year							
Items	2008	2009	2010	2011	2012	2013	Total	CAGR (%)
Elements/objects total	682	620	756	674	846	720	4298	1
Management related	377	343	445	348	444	359	2316	−1
Resource/service-related	110	108	101	124	153	152	748	7
Scientific concept-related	195	169	210	202	249	209	1234	1
Properties total	775	734	852	763	903	784	4811	0
Keywords total	1057	1001	1198	1077	1293	1071	6697	0

Table 2. Frequency and CAGR of top 20 elements, properties and keywords (CAGR 2008–2013).

	Elements			Properties			Keywords		
ID	Items	#	CAGR (%)	Items	#	CAGR (%)	Items	#	CAGR (%)
1	General performance	133	5	Organisation/enterprise/company/firm/corporate-focused	204	1	Performance	103	8
2	Adoption and usage	112	0	Performance-focused	131	8	Models	88	7
3	General commerce	101	−12	Business-focused	107	1	Impact	87	−2
4	Impact	95	2	Model-driven/focused	94	7	E-commerce	79	−15
5	Competitive advantage	78	−4	RFID-focused	85	13	Firm performance	72	5
6	Capabilities	71	8	Integration-focused/integrated	75	8	Integration	66	4
7	Framework and practices	64	−13	Strategic/strategy-focused	71	−24	Radio frequency identification (RFID)	63	18
8	Decision-making approach	63	−10	Operations-focused	66	5	Competitive advantage	56	−8
9	Integration	63	−2	Product-focused	63	−14	Framework	52	−17
10	Perspective and orientation	63	−3	Autonomous/intelligent/learning/collaborative	58	0	Perspective	49	0
11	Design	61	−5	Manufacturing/production-focused	55	−4	Adoption	46	15
12	Model/modelling	57	−5	Agile/dynamic/flexible/adaptive	53	−5	Resource-based view	45	8
13	General business	51	−7	Industry-focused	49	−9	Design	43	−9
14	Resource-based view	51	8	Inventory/stock/warehousing-focused	45	−20	Industry	43	0
15	Relationship	50	−16	Agent-based/multiagent-focused	42	−8	Electronic data interchange	40	−3
16	Interchange	49	−4	Knowledge-focused	39	−6	Implementation	35	−24
17	Enterprises/companies	44	19	Distribution/channel-focused	35	−13	Strategies	35	−40
18	Value	43	25	Network-focused	35	15	Organisations	31	−13
19	Implementation	42	−15	Customer/consumer-focused	34	−10	Business	30	0
20	Quality and satisfaction	41	−4	Decision/decision support-focused	34	6	Interorg. systems (IOS)	30	4

Table 3. Coverage of items in top 20 table.

	Elements		Properties		Keywords	
Group	#	%	#	%	#	%
Items contained in top 20	1332	31	1375	29	1093	16
Items excluded as search terms*	618	14	1921	40	1042	16
Other items (not explained here)	2348	55	1515	31	4562	68
Total	4298	100	4811	100	6697	100

Note: * Before last top 20 items only.

(2) *RFID and (multi-)agent orientation*: Two types of approaches have been highlighted in the literature –RFID, on the one hand, and autonomous and intelligent (multi-) agents, on the other hand.

(3) *Input and design-to-delivery process orientation*: Papers tagged with design, integration, operation, manufacturing/production, implementation or resource-based view suggest the topic of best operational delivery. This includes the use of resources as well as operational processes for a product.

(4) *Interorganisational commerce orientation*: With terms such as relationship, interchange, (e-) commerce, electronic data interchange or interorganisational systems, a focus on entities and their (commercial) interaction appears evident and is inherently combined with SCM and logistics.
(5) *Model and quantitative orientation*: Highlighting items such as model/modelling, decision-making approaches and, to some extent, also frameworks, a push for model-based decision approaches emerges.
(6) *Private sector organisation focus*: Finally, multiple terms stress the focus on enterprises or comparable organisations in the private sector. These keywords include enterprises/companies, industry and business.

6. Discussion and suggestions for future research

IT can influence sustainability in multiple ways. In our paper, the analysis first focused on how IT can influence SSCM. Discussing the content of 55 papers along four dimensions leads to a detailed view on different aspects of how IT can drive sustainability as presented by different authors: first, IT may improve different elements of the supply flow (Section 4.1). The sustainability of transportation and enhanced coordination between companies are stressed in particular. Second, IT can support SCM on different levels by providing and improving respective IT systems. On a strategic and tactical level, this can especially occur in network planning or by enabling B2B e-commerce. On an execution and monitoring level, especially the importance of data interchange (e.g. leveraging RFID) is underlined. On an overarching level, IT infrastructure, in general, can be an enabler for sustainability improvements. Third, IT can affect different elements of sustainability. In most cases, the improvement seen in the environmental dimension is either a narrow one, affecting only GHGs, or an improvement of a wider range of environmental sustainability elements. Mostly combined with environmental improvements, IT's positive effect on social sustainability is either argued for the supplier (e.g. farmers in developing nations) or the consumer side. Fourth, the effects of IT can either be direct, for example, when carbon emissions or other environmental effects are mathematically optimised with the use of IT, or indirect. In the latter case, suggested effects on sustainability mostly result from operational performance improvements.

These results provide a starting point for potential areas of future research, whose identification is the second objective of this paper. The structured discussion of IT for sustainable SCM reveals two insights in particular. In categorising along the supply chain (Section 4.1), little focus is placed on nodes and reverse activities. Furthermore, very few authors touch on social issues together with IT for SCM, as is also the case in previous studies in the general field of sustainability in SCM (Seuring and Müller 2008; Section 4.3). Indeed, only one paper specifically focuses on social issues, although some papers at least included social arguments in their discussions with an environmental focus.

Further areas can be identified by analysing the expanded analysis in the last chapter. The six key themes presented allow us to derive several suggestions for several areas that are under-represented in the papers included in this survey (Section 4).

First, given the limited amount of empirical work in the domain, research on the effects of IT in SSCM could be improved with more empirical studies. In contrast, the value and impact of IT has been under discussion for years in the general domain of IT for SCM. The argument is also strengthened by the fact that many of the papers have a particular focus (e.g. agriculture in less developed countries) that makes it hard to generalise. Case studies could help us understand why particular managers take the step to implement IT systems that optimise sustainability as these do not necessarily guarantee profit-optimal solutions.

Second, given the large number of studies in the general domain, a further prioritisation of machine communication (e.g. 'Internet of Things') as well as of agile and multiagent systems seems appropriate. The potential of the 'Internet of Things' in the SCM context has already been addressed to some extent (Zhang et al. 2013; also driven by RFID or cloud-based infrastructure). Despite the presumably great interest of this topic for the general domain of IT and SCM, only a few researchers appear to have researched the opportunities of applying multiagents. These areas will also need to discuss the associated privacy concerns.

Third, an input-oriented discussion within the domain could build on the resource-based view to advance research on the operational effects of IT on sustainability. Additionally, agility and flexibility are affected by IT, which may further pose consequences for SSCM.

Fourth, as shown above, several papers discuss (e-)commerce. However, given the discussion of interorganisational (commercial) exchange in the general field of IT and SCM, addressing this topic further in the context of sustainability could bring additional relevant insights. One option could be a deeper analysis of trade-offs between data-exchange investments and savings, including sustainability effects.

Fifth, only a few papers on IT for SSCM currently use models or have a quantitative approach. Moreover, the analysis of decision-making approaches and optimisation approaches (e.g. the application of fuzzy sets, multicriteria approaches, etc.) has been present only to a limited extent. This could also include the topic of risk analysis. A further application area for quantitative models could lie in supporting quantitative sustainability modelling or including 'big data' analytics.

Finally, the current discussion of IT for SCM as well as SSCM strongly focuses on the business domain, but significant sustainability improvements may also be possible in the public sector and its related economic entities.

Moreover, reflecting on the expanded discussion and the respective keywords, it appears interesting that popular keywords such as 'Cloud', 'Crowd', 'Swarm' or '(Linked) Open Data' do not appear in the top 20 list.

All in all, this survey touches upon a wide range of different topics. Nevertheless, as the relatively small number of papers suggests, the amount of research on the impacts of IT on sustainability in SCM appears to be limited and could be expanded in several areas.

7. Conclusion

This paper represents an attempt to depict the academic work at the overlap of three domains, SCM, IT and sustainability (environmental and social sustainability as elements of the triple bottom line), in order to present a structured overview of current scientific work on IT for sustainable SCM and suggest directions for future research. It is the first paper based on a literature survey on how IT drives sustainability in SCM and a keyword analysis of the general domain of SCM and IT.

To sum up, the amount of knowledge on how IT is used to affect sustainability in SCM is limited. Currently particularly studied effects of IT on SSCM include the fields of transportation, data exchange and transparency or coordination. Often the effects of IT on sustainability are only seen through indirect performance improvements. Altogether, this paper identifies 55 papers addressing this field. We hope that this paper will be an encouragement to increase the focus on this area and to further support the development of SCM in line with the goals of the Brundtland Commission (World Commission on Environment and Development 1987, 43).

Research appears to be lacking in three areas in particular: first of all, increased empirical research would enable a better understanding of how IT is currently used to support sustainability along supply chains. Second, a stronger quantitative focus could allow improved decision support. This may be combined with further research on machine communication-driven developments such as the 'Internet of Things' or 'big data'. Third, particularly the social dimension needs deeper understanding and requires better support through IT tools. This might again require novel analytical approaches.

The research presented in this paper is limited due to the rather small number of papers in the domain addressed. This also constrains the potential for generalisations. Furthermore, although the categorisation was done with the greatest of care, miscategorisations cannot be ruled out. Finally, as the chosen perspective was keyword-driven, relevant literature may be missing because the keywords chosen did not match them or relevant keywords may have been missed.

Acknowledgement

We would like to thank the anonymous reviewers for their highly constructive feedback to improve this work.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. In this paper, SCM is considered the 'design, planning, execution, control and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronising supply with demand and measuring performance globally' (APICS Dictionary 2012).
2. Social sustainability may consist of a large set of different parameters including factors such as health, wages, justice for all or the creation of social capital (Mani, Agrawal, and Sharma 2014).
3. http://apps.webofknowledge.com
4. http://web.ebscohost.com/
5. http://search.proquest.com
6. http://www.sciencedirect.com/
7. http://apps.webofknowledge.com
8. http://www.sciencedirect.com/
9. http://www.zotero.org/

References

Abukhader, S. M. 2008. "Eco-Efficiency in the Era of Electronic Commerce – Should 'Eco-Effectiveness' Approach Be Adopted?." *Journal of Cleaner Production* 16 (7): 801–808. doi:10.1016/j.jclepro.2007.04.001.

Abukhader, S. M., and G. Jönson. 2004. "E-Commerce and the Environment: A Gateway to the Renewal of Greening Supply Chains." *International Journal of Technology Management* 28 (2): 274–288. doi:10.1504/IJTM.2004.005066.

Ahi, P., and C. Searcy. 2013. "A Comparative Literature Analysis of Definitions for Green and Sustainable Supply Chain Management." *Journal of Cleaner Production* 52: 329–341. doi:10.1016/j.jclepro.2013.02.018.

Ali, J., and S. Kumar. 2011. "Information and Communication Technologies (ICTs) and Farmers' Decision-Making Across the Agricultural Supply Chain." *International Journal of Information Management* 31 (2): 149–159. doi:10.1016/j.ijinfomgt.2010.07.008.

Al-Odeh, M., and J. Smallwood. 2012. "Sustainable Supply Chain Management: Literature Review, Trends, and Framework." *International Journal of Computational Engineering & Management* 15 (1): 85–90. http://www.ijcem.org/papers012012/ijcem_012012_17.pdf.

Arzu Akyuz, G., and T. Erman Erkan. 2010. "Supply Chain Performance Measurement: A Literature Review." *International Journal of Production Research* 48 (17): 5137–5155. doi:10.1080/00207540903089536.

Ashby, A., M. Leat, and M. Hudson-Smith. 2012. "Making Connections: A Review of Supply Chain Management and Sustainability Literature." *Supply Chain Management* 17 (5): 497–516. doi:10.1108/13598541211258573.

Ayoub, N., T. Kefeng Wang, K. H. Seki, and Y. Naka. 2006. "A Planning Support System for Biomass-Based Power Generation." In *Computer Aided Chemical Engineering*, Vol. 21, edited by W. Marquardt and C. Pantelides, 1899–1904. Amsterdam: Elsevier. doi:10.1016/S1570-7946(06)80325-1.

Barrett, W. M., S. Strunjaš-Yoshikawa, and J. H. Bell. 2007. "Extension of Computer-Aided Process Engineering Applications to Environmental Life Cycle Assessment and SCM." In *Computer Aided Chemical Engineering*, Vol. 24, edited by V. Plesu and P. S. Agachi, 1187–1192. Elsevier. doi:10.1016/S1570-7946(07)80222-7.

Benz, T., N. E. Ghouti, F. Krietsch, P. Mathias, F. Peyeron, and P. Themann. 2012. "The eCoMove Simulation Test Bed." *Transport Research Arena 2012* 48: 1983–1992. doi:10.1016/j.sbspro.2012.06.1171.

Beske, P., A. Land, and S. Seuring. 2014. "Sustainable Supply Chain Management Practices and Dynamic Capabilities in the Food Industry: A Critical Analysis of the Literature." *International Journal of Production Economics* 152: 131–143. doi:10.1016/j.ijpe.2013.12.026.

Björk, A., M. Erlandsson, J. Häkli, K. Jaakkola, Å. Nilsson, K. Nummila, V. Puntanen, and A. Sirkka. 2011. "Monitoring Environmental Performance of the Forestry Supply Chain Using RFID." *Computers in Industry* 62 (8–9): 830–841. doi:10.1016/j.compind.2011.08.001.

Borsato, M. 2014. "Bridging the Gap between Product Lifecycle Management and Sustainability in Manufacturing through Ontology Building." *Computers in Industry* 65 (2): 258–269. doi:10.1016/j.compind.2013.11.003.

Bosona, T., I. Nordmark, G. Gebresenbet, and D. Ljungberg. 2013. "GIS-Based Analysis of Integrated Food Distribution Network in Local Food Supply Chain." *International Journal of Business and Management* 8 (17): 13–34. http://dx.doi.org/10.5539/ijbm.v8n17p13.

Brandenburg, M., K. Govindan, J. Sarkis, and S. Seuring. 2014. "Quantitative Models for Sustainable Supply Chain Management: Developments and Directions." *European Journal of Operational Research* 233 (2): 299–312. doi:10.1016/j.ejor.2013.09.032.

Brooks, S., X. Wang, and S. Sarker. 2012. "Unpacking Green IS: A Review of the Existing Literature and Directions for the Future." In *Green Business Process Management*, edited by J. Vom Brocke, S. Seidel, and J. Recker, 15–37. Berlin, Heidelberg: Springer.

Bullinger, H.-J., J. Von Steinaecker, and A. Weller. 1999. "Concepts and Methods for a Production Integrated Environmental Protection." *International Journal of Production Economics* 60–61: 35–42. doi:10.1016/S0925-5273(98)00137-6.

Carlson, R. M., E. P. Forsberg, and A.-C. Pålsson. 2001. "System for Integrated Business Environmental Information Management." *Advances in Environmental Research* 5 (4): 369–375. doi:10.1016/S1093-0191(01)00088-0.

Carter, C. R., and D. S. Rogers. 2008. "A Framework of Sustainable Supply Chain Management: Moving Toward New Theory." *International Journal of Physical Distribution & Logistics Management* 38 (5): 360–387. doi:10.1108/09600030810882816.

Carter, C. R., and P. L. Easton. 2011. "Sustainable Supply Chain Management: Evolution and Future Directions." *International Journal of Physical Distribution & Logistics Management* 41 (1): 46–62. doi:10.1108/09600031111101420.

Chen, L., J. Olhager, and O. Tang. 2014. "Manufacturing Facility Location and Sustainability: A Literature Review and Research Agenda." *International Journal of Production Economics* 149: 154–163. doi:10.1016/j.ijpe.2013.05.013.

Chen, M.-K., T.-W. Tai, and T.-Y. Hung. 2012. "Component Selection System for Green Supply Chain." *Expert Systems with Applications* 39 (5): 5687–5701. doi:10.1016/j.eswa.2011.11.102.

Clausen, U., C. Geiger, and C. Behmer. 2012. "Green Corridors by Means of ICT Applications." *Procedia - Social and Behavioral Sciences* 48: 1877–1886. doi:10.1016/j.sbspro.2012.06.1162.

Costa, C., F. Antonucci, F. Pallottino, J. Aguzzi, D. Sarriá, and P. Menesatti. 2013. "A Review on Agri-Food Supply Chain Traceability by Means of RFID Technology." *Food and Bioprocess Technology* 6 (2): 353–366. doi:10.1007/s11947-012-0958-7.

Dao, V., I. Langella, and J. Carbo. 2011. "From Green to Sustainability: Information Technology and an Integrated Sustainability Framework." *The Journal of Strategic Information Systems* 20 (1): 63–79. doi:10.1016/j.jsis.2011.01.002.

Davies, I., R. Mason, and C. Lalwani. 2007. "Assessing the Impact of ICT on UK General Haulage Companies." *International Journal of Production Economics* 106 (1): 12–27. doi:10.1016/j.ijpe.2006.04.007.

Dekker, R., J. Bloemhof, and I. Mallidis. 2012. "Operations Research for Green Logistics – An Overview of Aspects, Issues, Contributions and Challenges." *European Journal of Operational Research* 219 (3): 671–679. doi:10.1016/j.ejor.2011.11.010.

Dey, A., P. LaGuardia, and M. Srinivasan. 2011. "Building Sustainability in Logistics Operations: A Research Agenda." *Management Research Review* 34 (11): 1237–1259. doi:10.1108/01409171111178774.

Dhanda, K. K., and R. P. Hill. 2005. "The Role of Information Technology and Systems in Reverse Logistics: A Case Study." *International Journal of Technology Management* 31 (1/2): 140–151. doi:10.1504/IJTM.2005.006628.

APICS Dictionary. 2012a. "APICS Dictionary." The Association for Operations Management. Accessed December 4. http://www.apics.org/apics-search

Oxford Dictionary. 2012b. "Definition of Information Technology - Science and Computing (British & World English)." Oxford Dictionary. Accessed December 10. http://oxforddictionaries.com/definition/english/information%2Btechnology?q=information+technology.

Dictionary.com. 2015. "Assess | Define Assess." Accessed July 6. http://dictionary.reference.com/ browse/assess.

Dotoli, M., M. P. Fanti, C. Meloni, and M. C. Zhou. 2006. "Design and Optimization of Integrated E-Supply Chain for Agile and Environmentally Conscious Manufacturing." *IEEE Transactions on Systems, Man, and Cybernetics - Particle A: Systems and Humans* 36 (1): 62–75. doi:10.1109/TSMCA.2005.859189.

Edwards, J. W., A. Lyons, and D. Kehoe. 2004. "A Web-Enabled Demand Planning System (DPS) to Enable Coordinated Re-Manufacture of Automotive Components." *International Journal of Internet and Enterprise Management* 2 (4): 366–382. doi:10.1504/IJIEM.2004.005569.

Elkington, J. 1999. *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*. Oxford: Capstone.

Elliot, S., and D. Binney. 2008. "Environmentally Sustainable ICT: Developing Corporate Capabilities and an Industry-Relevant IS Research Agenda." In *Proceedings of Pacific Asia Conference on Information Systems*, Paper 209. PACIS '08. Atlanta: Association for Information Systems (AIS).

Esposito, E., and P. Evangelista. 2014. "Investigating Virtual Enterprise Models: Literature Review and Empirical Findings." *International Journal of Production Economics* 148: 145–157. doi:10.1016/j.ijpe.2013.10.003.

European Commission. 2012. "The 5 Targets for the EU in 2020. " European Commission. Accessed October 20. http://ec.europa.eu/europe2020/ europe-2020-in-a-nutshell/targets/index_en.htm

Fozza, S., and V. Recagno. 2012. "Sustainable Technologies and Innovation for Green Corridors: Survey and Application." *Transport Research Arena 2012* 48 (0): 1753–1763. doi:10.1016/j.sbspro.2012.06.1150.

Frehe, V., and F. Teuteberg. 2014. "The Role of ICT in Green Logistics: A Systematic Literature Review." In *Information Technology in Environmental Engineering*, edited by B. Funk and P. Niemeyer, 53–65. Berlin: Springer. doi:10.1007/978-3-642-36011-4_5.

García-Rodríguez, F. J., C. Castilla-Gutiérrez, and C. Bustos-Flores. 2013. "Implementation of Reverse Logistics as a Sustainable Tool for Raw Material Purchasing in Developing Countries: The Case of Venezuela." *International Journal of Production Economics*. doi:10.1016/j.ijpe.2012.09.015.

Garson, D., C. Lillvik, E. Sisk, E. Ewing, and M. Johnson. 2012. "Overview - The Literature Review: A Research Journey - Research Guides at Harvard Library." Accessed July 7, 2015. http://guides.library.harvard.edu/ literaturereview.

Gimenez, C., and E. M. Tachizawa. 2012. "Extending Sustainability to Suppliers: A Systematic Literature Review." *Supply Chain Management* 17 (5): 531–543. doi:10.1108/13598541211258591.

Giunipero, L. C., R. E. Hooker, and D. Denslow. 2012. "Purchasing and Supply Management Sustainability: Drivers and Barriers." *Journal of Purchasing and Supply Management* 18 (4): 258–269. doi:10.1016/j.pursup.2012.06.003.

Gold, S., S. Seuring, and P. Beske. 2010a. "Sustainable Supply Chain Management and Inter-Organizational Resources: A Literature Review." *Corporate Social Responsibility and Environmental Management* 17 (4): 230–245. doi:10.1002/csr.207.

Gold, S., S. Seuring, and P. Beske. 2010b. "The Constructs of Sustainable Supply Chain Management – A Content Analysis Based on Published Case Studies." *Progress in Industrial Ecology, an International Journal* 7 (2): 114–137. doi:10.1504/PIE.2010.036045.

Golicic, S. L., and C. D. Smith. 2013. "A Meta-Analysis of Environmentally Sustainable Supply Chain Management Practices and Firm Performance." *Journal of Supply Chain Management* 49 (2): 78–95. doi:10.1111/jscm.12006.

Gonzálvez-Gallego, N., F.-J. Molina-Castillo, P. Soto-Acosta, J. Varajao, and A. Trigo. 2015. "Using Integrated Information Systems in Supply Chain Management." *Enterprise Information Systems* 9 (2): 210–232. doi:10.1080/17517575.2013.879209.

Govindan, K., S. Rajendran, J. Sarkis, and Murugesan. 2013. "Multi Criteria Decision Making Approaches for Green Supplier Evaluation and Selection: A Literature Review." *Journal of Cleaner Production*. doi:10.1016/j.jclepro.2013.06.046.

Guenther, E., and V. G. Farkavcová. 2010. "Decision Making for Transportation Systems as a Support for Sustainable Stewardship: Freight Transport Process Evaluation using the ETIENNE-Tool." *Management Research Review* 33 (4): 317–339. doi:10.1108/01409171011030444.

Gupta, S., and O. D. Palsule-Desai. 2011. "Sustainable Supply Chain Management: Review and Research Opportunities." *IIMB Management Review* 23 (4): 234–245. doi:10.1016/j.iimb.2011.09.002. Dec.

Guyon, O., N. Absi, D. Feillet, and T. Garaix. 2012. "A Modeling Approach for Locating Logistics Platforms for Fast Parcels Delivery in Urban Areas." *Procedia - Social and Behavioral Sciences* 39: 360–368. doi:10.1016/j.sbspro.2012.03.114.

Harmon, R. R., and N. Moolenkamp. 2012. "Sustainable IT Services: Developing a Strategy Framework." *International Journal of Innovation & Technology Management* 9 (2): 1250014–1250023. doi:10.1142/S0219877012500149.

Hasle, G. 1999. "Transportation Management in Distributed Enterprises." *Human Systems Management* 18 (3–4): 203–212.

Hassini, E., C. Surti, and C. Searcy. 2012. "A Literature Review and a Case Study of Sustainable Supply Chains with a Focus on Metrics." *International Journal of Production Economics* 140: 69–82. doi:10.1016/j.ijpe.2012.01.042.

Iacob, M. E., M. J. Van Sinderen, M. Steenwijk, and P. Verkroost. 2013. "Towards a Reference Architecture for Fuel-Based Carbon Management Systems in the Logistics Industry." *Information Systems Frontiers* 15 (5): 725–745. doi:10.1007/s10796-013-9416-y.

Iakovou, E. T. 2001. "An Interactive Multiobjective Model for the Strategic Maritime Transportation of Petroleum Products: Risk Analysis and Routing." *Safety Science* 39 (1–2): 19–29. doi:10.1016/S0925-7535(01)00022-4.

Igarashi, M., L. De Boer, and A. M. Fet. 2013. "What Is Required for Greener Supplier Selection? A Literature Review and Conceptual Model Development." *Journal of Purchasing and Supply Management* 19 (4): 247–263. doi:10.1016/j.pursup.2013.06.001.

Ilgin, M. A., and S. M. Gupta. 2010. "Environmentally Conscious Manufacturing and Product Recovery (ECMPRO): A Review of the State of the Art." *Journal of Environmental Management* 91 (3): 563–591. doi:10.1016/j.jenvman.2009.09.037.

Jain, V., S. K. Wadhwa, and S. G. Deshmukh. 2009. "Revisiting Information Systems to Support a Dynamic Supply Chain: Issues and Perspectives." *Production Planning & Control* 20 (1): 17–29. doi:10.1080/09537280802608019.

Jenkin, T. A., J. Webster, and L. McShane. 2011. "An Agenda for 'Green' Information Technology and Systems Research." *Information and Organization* 21 (1): 17–40. doi:10.1016/j.infoandorg.2010.09.003.

Koh, S. C. L., A. Genovese, A. Adolf, P. B. Acquaye, N. Rana, J. Kuylenstierna, and D. Gibbs. 2013. "Decarbonising Product Supply Chains: Design and Development of an Integrated Evidence-Based Decision Support System - the Supply Chain Environmental Analysis Tool (Scenat)." *International Journal of Production Research* 51: 7. doi:10.1080/00207543.2012.705042.

Kurnia, S., R. M. D. Mahbubur, and M. Gloet. 2012. "Understanding The Roles of IS/IT in Sustainable Supply Chain Management." In *Proceedings of Pacific Asia Conference on Information Systems*, Paper 50. PACIS '12. Atlanta: Association for Information Systems (AIS).

Lai, R. S. Q., L.-L. Hsu, and J. C. H. Chen. 2012. "Green SCM Systems: A Case Study in the Textile Industry." *Human Systems Management* 31 (2): 111–121. doi:10.3233/HSM-2012-0765.

Lam, C. Y., and W. H. Ip. 2012. "An Improved Spanning Tree Approach for the Reliability Analysis of Supply Chain Collaborative Network." *Enterprise Information Systems* 6 (4): 405–418. doi:10.1080/17517575.2012.673236.

Lee, J. 2003. "E-Manufacturing-Fundamental, Tools, and Transformation." *Robotics and Computer-Integrated Manufacturing* 19 (6): 501–507. doi:10.1016/S0736-5845(03)00060-7.

Lehmann, R. J., R. Reiche, and G. Schiefer. 2012. "Future Internet and the Agrifood Sector: State-of-the-Art in Literature and Research." *Computers and Electronics in Agriculture* 89 (Nov.): 158–174. doi:10.1016/j.compag.2012.09.005.

Ling, L. 2012. "Effects of Enterprise Technology on Supply Chain Collaboration: Analysis of China-Linked Supply Chain." *Enterprise Information Systems* 6 (1): 55–77. doi:10.1080/17517575.2011.639904.

Loeser, F. 2013. "Green IT and Green IS: Definition of Constructs and Overview of Current Practices." In *Proceedings of the Americas Conference on Information Systems*, Presentation 4. AMCIS '13. Atlanta: Association for Information Systems (AIS).

Mani, V., R. Agrawal, and V. Sharma. 2014. "Supplier Selection Using Social Sustainability: AHP Based Approach in India." *International Strategic Management Review* 2 (2): 98–112. doi:10.1016/j.ism.2014.10.003.

Marett, K., R. F. Otondo, and G. Stephen Taylor. 2013. "Assessing the Effects of Benefits and Institutional Influences on the Continued Use of Environmentally Munificent Bypass Systems in Long-Haul Trucking." *MIS Quarterly* 37 (4): 1301–1312.

Martínez-Jurado, P. J., and J. Moyano-Fuentes. 2013. "Lean Management, Supply Chain Management and Sustainability: A Literature Review." *Journal of Cleaner Production*. doi:10.1016/j.jclepro.2013.09.042.

Martínez-Sala, A. S., E. Egea-López, F. García-Sánchez, and J. García-Haro. 2009. "Tracking of Returnable Packaging and Transport Units with Active RFID in the Grocery Supply Chain." *Computers in Industry* 60 (3): 161–171. doi:10.1016/j.compind.2008.12.003.

Mayring, P. 2003. *Qualitative Inhaltsanalyse: Grundlagen und Techniken*. 8th ed. [Qualitative Content Analysis: Basics and Techniques]. Weinheim: Beltz.

Măzăreanu, V.-P. 2013. "Considerations on Risk in Supply Chain Management Information Systems Implementation." *Amfiteatru Economic* 15 (33): 128–139.

McKinnon, A. C. 2010. "Product-Level Carbon Auditing of Supply Chains: Environmental Imperative or Wasteful Distraction?." *International Journal of Physical Distribution & Logistics Management* 40 (1/2): 42–60. doi:10.1108/09600031011018037.

Meacham, J., L. Toms, K. W. Green, and V. S. Bhadauria. 2013. "Impact of Information Sharing and Green Information Systems." *Management Research Review* 36 (5): 478–494. http://dx.doi.org/10.1108/01409171311327244.

Meixell, M. J., and M. Norbis. 2008. "A Review of the Transportation Mode Choice and Carrier Selection Literature." *International Journal of Logistics Management* 19 (2): 183–211. doi:10.1108/09574090810895951.

Melville, N. P. 2010. "Information Systems Innovation for Environmental Sustainability." *MIS Quarterly* 34 (1): 1–21.

Miemczyk, J., T. E. Johnsen, and M. Macquet. 2012. "Sustainable Purchasing and Supply Management: A Structured Literature Review of Definitions and Measures at the Dyad, Chain and Network Levels." *Supply Chain Management* 17 (5): 478–496. doi:10.1108/13598541211258564.

Min, H., and I. Kim. 2012. "Green Supply Chain Research: Past, Present, and Future." *Logistics Research* 4 (1–2): 39–47. doi:10.1007/s12159-012-0071-3.

Mollenkopf, D., H. Stolze, W. L. Tate, and M. Ueltschy. 2010. "Green, Lean, and Global Supply Chains." *International Journal of Physical Distribution & Logistics Management* 40 (1/2): 14–41. doi:10.1108/09600031011018028.

Muñoz, E., E. Capón-García, J. M. Laínez, A. Espuña, and L. Puigjaner. 2013. "Considering Environmental Assessment in an Ontological Framework for Enterprise Sustainability." *Journal of Cleaner Production* 47: 149–164. http://dx.doi.org/10.1016/j.jclepro.2012.11.032.

Ngai, E. W. T., S. Peng, P. Alexander, and K. K. L. Moon. 2014. "Decision Support and Intelligent Systems in the Textile and Apparel Supply Chain: An Academic Review of Research Articles." *Expert Systems with Applications* 41 (1): 81–91. doi:10.1016/j.eswa.2013.07.013.

Olugu, E. U., and K. Y. Wong. 2012. "An Expert Fuzzy Rule-based System for Closed-loop Supply Chain Performance Assessment in the Automotive Industry." *Expert Systems with Applications* 39 (1): 375–384. doi:10.1016/j.eswa.2011.07.026.

Perego, A., S. Perotti, and R. Mangiaracina. 2011. "ICT for Logistics and Freight Transportation: A Literature Review and Research Agenda." *International Journal of Physical Distribution & Logistics Management* 41 (5): 457–483. doi:10.1108/09600031111138826.

Pfahl, L., and C. Moxham. 2014. "Achieving Sustained Competitive Advantage by Integrating ECR, RFID and Visibility in Retail Supply Chains: A Conceptual Framework." *Production Planning & Control* 25 (7): 548–571. doi:10.1080/09537287.2012.729100.

Piotrowicz, W., and R. Cuthbertson. 2009. "Sustainability - A New Dimension in Information Systems Evaluation." *Journal of Enterprise Information Management* 22 (5): 492–503. doi:10.1108/17410390910993509.

Rao, N. H. 2007. "A Framework for Implementing Information and Communication Technologies in Agricultural Development in India." *Technological Forecasting and Social Change* 74 (4): 491–518. doi:10.1016/j.techfore.2006.02.002.

Sahamie, R., D. Stindt, and C. Nuss. 2013. "Transdisciplinary Research in Sustainable Operations – An Application to Closed-Loop Supply Chains." *Business Strategy and the Environment* 22 (4): 245–268. doi:10.1002/bse.1771.

Sarac, A., N. Absi, and S. Dauzère-Pérès. 2010. "A Literature Review on the Impact of RFID Technologies on Supply Chain Management." *International Journal of Production Economics* 128 (1): 77–95. doi:10.1016/j.ijpe.2010.07.039.

Sarkis, J. 2012. "A Boundaries and Flows Perspective of Green Supply Chain Management." *Supply Chain Management* 17 (2): 202–216. doi:10.1108/13598541211212924.

Sarkis, J., Q. Zhu, and K.-H. Lai. 2011. "An Organizational Theoretic Review of Green Supply Chain Management Literature." *International Journal of Production Economics* 130 (1): 1–15. doi:10.1016/j.ijpe.2010.11.010.

Schatten, A. 2009. ""Green" Supply Chains: Using Information Integration for Sustainable Development." In *International Conference on Complex, Intelligent and Software Intensive Systems*, 2009. CISIS '09, 1124–1127. doi:10.1109/CISIS.2009.31.

Schiller, B. 2012. "Transport's Cleaner Future." *Financial Management* 14719185: 26–30.

Seuring, S. 2013. "A Review of Modeling Approaches for Sustainable Supply Chain Management." *Decision Support Systems* 54 (4): 1513–1520. doi:10.1016/j.dss.2012.05.053.

Seuring, S., and S. Gold. 2012. "Conducting Content-analysis Based Literature Reviews in Supply Chain Management." *Supply Chain Management* 17 (5): 544–555. doi:10.1108/13598541211258609.

Seuring, S., and M. Müller. 2008. "From a Literature Review to a Conceptual Framework for SSCM." *Journal of Cleaner Production* 16 (15): 1699–1710. doi:10.1016/j.jclepro.2008.04.020.

Shi, X., L. X. Li, L. Yang, Z. Li, and J. Y. Choi. 2012. "Information Flow in Reverse Logistics: An Industrial Information Integration Study." *Information Technology & Management* 13 (4): 217–232. doi:10.1007/s10799-012-0116-y.

Sigala, M. 2014. "Customer Involvement in Sustainable Supply Chain Management: A Research Framework and Implications in Tourism." *Cornell Hospitality Quarterly* 55 (1): 76–88. doi:10.1177/1938965513504030.

Sourirajan, K., P. Centonze, M. E. Helander, K. Katircioglu, M. Ben-Hamida, and C. Boucher. 2009. "Carbon Management in Assembly Manufacturing Logistics." *IBM Journal of Research and Development* 53 (3): 433–448. doi:10.1147/JRD.2009.5429021.

Srivastava, S. K. 2007. "Green Supply-Chain Management: A State-of-the-Art Literature Review." *International Journal of Management Reviews* 9 (1): 53–80. doi:10.1111/j.1468-2370.2007.00202.x.

Stindt, D., and R. Sahamie. 2014. "Review of Research on Closed Loop Supply Chain Management in the Process Industry." *Flexible Services and Manufacturing Journal* 26 (1–2): 268–293. doi:10.1007/s10696-012-9137-4.

Suh, K., T. Smith, and M. Linhoff. 2012. "Leveraging Socially Networked Mobile ICT Platforms for the Last-Mile Delivery Problem." *Environmental Science & Technology* 46 (17): 9481–9490. doi:10.1021/es301302k.

Taghaboni-Dutta, F., A. J. C. Trappey, and C. V. Trappey. 2010. "An XML Based Supply Chain Integration Hub for Green Product Lifecycle Management." *Advances in Aligning Knowledge Systems, Improving Business Logistics, Driving Innovation and Adapting Customer Centric Services* 37 (11): 7319–7328. doi:10.1016/j.eswa.2010.04.025.

Tang, C. S., and S. Zhou. 2012. "Research Advances in Environmentally and Socially Sustainable Operations." *European Journal of Operational Research* 223 (3): 585–594. doi:10.1016/j.ejor.2012.07.030.

Taticchi, P., F. Tonelli, and R. Pasqualino. 2013. "Performance Measurement of Sustainable Supply Chains: A Literature Review and a Research Agenda." *International Journal of Productivity and Performance Management* 62 (8): 782–804. doi:10.1108/IJPPM-03-2013-0037.

Teuteberg, F., and D. Wittstruck. 2010. "A Systematic Review of Sustainable Supply Chain Management Research." In *Proceedings Der Multikonferenz Wirtschaftsinformatik 2010*, edited by K. Schumann and F. Breitner, 1001–1015. Göttingen: Universitätsverlag Göttingen.

The Association for Computing Machinery. 2015. "ACM Computing Surveys: Information for Authors." The Association for Computing Machinery. Accessed April 10. http://surveys.acm.org/author_info.html.

Thoroe, L., A. Melski, and M. Schumann. 2009. "RFID in Reverse Logistics – Research Framework and Roadmap." In *Proceedings Wirtschaftsinformatik 2009*, paper 77. Atlanta: Association for Information Systems (AIS).

Thurston, M., and M. J. Eckelman. 2011. “Assessing Greenhouse Gas Emissions from University Purchases.” *International Journal of Sustainability in Higher Education* 12 (3): 225–235. doi:10.1108/14676371111148018.

Toh, K. T. K., P. Nagel, and R. Oakden. 2009. “A Business and ICT Architecture for a Logistics City.” *International Journal of Production Economics* 122: 216–228. doi:10.1016/j.ijpe.2009.05.021.

Trappey, A. J. C., C. V. Trappey, and C.-R. Wu. 2010. “Genetic Algorithm Dynamic Performance Evaluation for RFID Reverse Logistic Management.” *Expert Systems with Applications* 37 (11): 7329–7335. doi:10.1016/j.eswa.2010.04.026.

Trienekens, J. H., P. M. Wognum, J. M. Beulens, and J. G. A. J. van der Vorst. 2012. “Transparency in Complex Dynamic Food Supply Chains.” *Advanced Engineering Informatics* 26 (1): 55–65. doi:10.1016/j.aei.2011.07.007.

Tushi, B., D. Sedera, and J. Recker. 2014. “Green IT Segment Analysis: An Academic Literature Review.” In *Proceedings of Twentieth Americas Conference on Information Systems*, 2566–2580. AMCIS ’14. Atlanta: Association for Information Systems (AIS).

Vannieuwenhuyse, B., L. Gelders, and L. Pintelon. 2003. “An Online Decision Support System for Transportation Mode Choice.” *Logistics Information Management* 16 (2): 125–133. doi:10.1108/09576050310467269.

Verma, S., and R. Chaudhuri. 2009. “Creating Customer Satisfaction and Profitable Value Chain With E-Commerce In Rural India: A Case Based Approach.” *International Journal of Business Insights & Transformation* 2 (1): 51–63.

Walker, H., and S. Brammer. 2012. “The Relationship between Sustainable Procurement and E-Procurement in the Public Sector.” *International Journal of Production Economics* 140: 256–268. doi:10.1016/j.ijpe.2012.01.008.

Winter, M., and A. M. Knemeyer. 2013. “Exploring the Integration of Sustainability and Supply Chain Management: Current State and Opportunities for Future Inquiry.” *International Journal of Physical Distribution & Logistics Management* 43 (1): 18–38. doi:10.1108/09600031311293237.

Wognum, P. M., J. H. Harry Bremmers, J. G. A. J. Trienekens, van der Vorst, and J. M. Bloemhof. 2011. “Systems for Sustainability and Transparency of Food Supply Chains – Current Status and Challenges.” *RFID and Sustainable Value Chains* 25 (1): 65–76. doi:10.1016/j.aei.2010.06.001.

World Commission on Environment and Development. 1987. *Our Common Future*. Oxford: Oxford University Press.

Zeng, Y., L. Wang, X. Deng, X. Cao, and N. Khundker. 2012. “Secure Collaboration in Global Design and Supply Chain Environment: Problem Analysis and Literature Review.” *Computers in Industry* 63 (6): 545–556. doi:10.1016/j.compind.2012.05.001.

Zhang, Q., T. Huang, Y. Zhu, and M. Qiu. 2013. “A Case Study of Sensor Data Collection and Analysis in Smart City: Provenance in Smart Food Supply Chain.” *International Journal of Distributed Sensor Networks* 382132. doi:10.1155/2013/382132.

Zhang, X., D. P. van Donk, and T. van der Vaart. 2011. “Does ICT Influence Supply Chain Management and Performance?.” *International Journal of Operations & Production Management* 31 (11): 1215–1247. doi:10.1108/01443571111178501.

Zografos, K. G., N. Sedlacek, and J. Bozuwa. 2012. “A Comparative Assessment of Freight Transport and Logistics Policies in Europe.” *Procedia - Social and Behavioral Sciences* 48: 2523–2532. doi:10.1016/j.sbspro.2012.06.1223.

Appendix 1

Table A1. Existing, relevant literature reviews.

Authors	Year	Sustainability focus	# of papers*	Period	Research focus	Data gathering method
(a) Intersection of sustainability and SCM						
1. Carter and Rogers	2008	E&S	165R	N/A	Framework development and conceptual theory building	NFM, AEA
2. Seuring and Müller	2008	E&S	191	1994–2007	Broad review and conceptual framework	KWS, ASE
3. Mollenkopf et al.	2010	ENV	135R	(1990)–2009	Combined implementation of green SCM and the lean approach	KWS, ARD, ASE + LRJ, ASE
4. Gold, Seuring, and Beske	2010a	E&S	70	1994–2007	Focus on case study articles	KWS, ASE
5. Gold, Seuring, and Beske	2010b	E&S	70	1994–2007	SSCM's role for creating interorganisational resources based on case study papers	KWS, ASE, AEA
6. Ilgin and Gupta	2010	ENV	540	1999–N/A	Focus on manufacturing and product recovery	NFM
7. Teuteberg and Wittstruck	2010	E&S	142	N/A	Broad review including IT elements and research agenda	KWS, LRJ, ASE
8. Carter and Easton	2011	E&S	80	1991–2010	Systematic review to identify research gaps	KWS, LRJ, ASE
9. Dey, LaGuardia, and Srinivasan	2011	E&S	99R	N/A	Sustainability in logistics operations	NFM
10. Gupta and Palsule-Desai	2011	ENV	49R	N/A	Broad review from value chain perspective and research agenda	NFM
11. Sarkis, Zhu, and Lai	2011	ENV	176R	N/A	Organisational theories in green SCM	NFM
12. Al-Odeh and Smallwood	2012	E&S	46R	N/A	Definition of SSCM and review along SSCM activities	NFM
13. Ashby, Leat, and Hudson-Smith	2012	E&S	134	1983–2011	Broad review at intersection of SCM and sustainability	LRJ, ASE
14. Dekker, Bloemhof, and Mallidis	2012	ENV	75R	N/A	Focus on operations research in logistics	NFM
15. Gimenez and Tachizawa	2012	E&S	41	N/A	Governance mechanisms for extending sustainability to suppliers	KWS, ASE
16. Giunipero, Hooker, and Denslow	2012	E&S	94R	N/A	Definition of supply chain sustainability; drivers and barriers for implementation	NFM, AEA
17. Hassini, Surti, and Searcy	2012	E&S	87	N/A	Metrics for sustainability in supply chains in decision science	KWS, ASE
18. Miemczyk, Johnson, and Macquet	2012	E&S	73	N/A	Interorganisational analysis of sustainable purchasing and supply management	KWS, LRJ, ASE
19. Min and Kim	2012	ENV	519	1995–2010	Broad review of green SCM	KWS, ASE
20. Sarkis	2012	ENV	136R	N/A	Specific discussion of boundaries and flow perspective	NFM
						KWS, ASE
21. Tang and Zhou	2012	E&S	74R	N/A	Focus on operations	NFM
22. Ahi and Searcy	2013	E&S	180	Until 2012	Comparison of definitions of sustainability and green SCM	KWS, ASE
23. Golicic and Smith	2013	ENV	31	1990–2011	Connection between green SCM and firm performance	KWS, ASE
24. Govindan et al.	2013	ENV	33	1997–2011	Focus on multicriteria decision-making approaches	KWS, LRJ, ASE
25. Igarashi, de Boer, and Fet	2013	ENV	60	1991–2011	Focus on green supplier selection	KWS, LRJ, ASE

(*Continued*)

Table A1. (Continued).

Authors	Year	Sustainability focus	# of papers*	Period	Research focus	Data gathering method
26. Martínez-Jurado and Moyano-Fuentes	2013	E&S	58	1990–2013	Focus on intersection with lean management	KWS, ASE
27. Sahamie, Stindt, and Nuss	2013	E&S	178	N/A	Specific application to closed-loop supply chains and transdisciplinary research	KWS, ASE
28. Seuring	2013	E&S	36	1990–2010	Modelling approaches for SSCM (i.e. quantitative models)	KWS, ASE
29. Taticchi, Tonelli, and Pasqualino	2013	E&S	205	1970–2012	Focus on performance management	KWS
30. Winter and Knemeyer	2013	E&S	456	1995–2010	Integration of sustainability and SCM	LRJ, ASE
31. Beske, Land, and Seuring	2014	E&S	52	2002–2011	In connection with dynamic capabilities; focus on food industry	KWS, ASE
32. Brandenburg et al.	2014	E&S	134	1994–2012	Focus on quantitative models	KWS, LRJ, ASE
33. Chen, Olhager, and Tang	2014	E&S	81	1990–2011	Focus on manufacturing facility location problem	KWS, ASE
34. Stindt and Sahamie	2014	ENV	167	N/A	Focus on closed-loop supply chains in process industry	KWS, ASE
(b) Intersection of IT and SCM						
1. Jain, Wadhwa, and Deshmukh	2009	N/A	34R	N/A	IT systems for dynamic supply chains	NFM
2. Arzu Akyuz and Erman	2010	N/A	24	N/A	Performance management for supply chains including some IT aspects	LRJ
3. Perego, Perotti, and Mangiaracina	2011	N/A	44	1994–2009	IT and communication technology for logistics and freight transportation	KWS, LRJ, ASE
4. Sarac, Absi and Dauzere-Peres	2010	N/A	143R	N/A	Current state of applying RFID in SCM	NFM
5. Zhang, van Donk, and Dirk	2011	N/A	40	1995–2010	Survey studies on the influence of IT on SCM and supply chain performance	KWS, LRJ, ASE
6. Zeng et al.	2012	N/A	136R	N/A	Secure collaboration in supply chains	Environment-based design
7. Costa et al.	2013	N/A	101R	N/A	Focus on RFID traceability in agri-food supply chains	NFM
8. Măzăreanu	2013	N/A	52R	N/A	Risk during implementation of information systems	NFM
9. Ngai et al.	2014	N/A	77	1994–2009	Decision support/intelligent systems; focus on textile and apparel supply chains	KWS, LRJ, ASE
10. Esposito and Evangelista	2014	N/A	41	1990–2012	Specific discussion of virtual enterprises	KWS, ASE, AEA
11. Pfahl and Moxham	2014	N/A	103	N/A	Focus on integration of ECR, RFID and visibility	KWS, ASE
(c) Intersection of sustainability and IT						
1. Elliot and Binney	2008	ENV	39	N/A	General review with a split according to corporate capabilities	NFM
2. Melville	2010	ENV	35	2000–2007	Focus on information systems innovation	LRJ, ASE
3. Dao, Langella, and Carbo	2011	E&S	98R	N/A	Integration of IT with human resources management and supply chain management based on a resource-based view of the firm	NFM
4. Jenkin, Webster, McShain	2011	ENV	38	N/A–2009	General review with multilevel research framework	KWS, ASE

(*Continued*)

Table A1. (Continued).

Authors	Year	Sustainability focus	# of papers*	Period	Research focus	Data gathering method
5. Brooks, Wang, and Sarker	2012	ENV	22**	N/A	Green IT, including practitioner magazines	KWS, LRJ, ASE
6. Harmon and Moolenkamp	2012	E&S	64R	N/A	Direct and indirect sustainability effects of IT services including a strategy framework	NFM
7. Loeser	2013	ENV	78	2008–2012	Construct definition and practice overview for Green IT measures and Green IS initiatives	KWS, LRJ, ASE
8. Tushi, Sedera, and Recker	2014	ENV	98	2007–2013	Green IT including a taxonomy of the area	KWS, ASE
(d) Intersection of sustainability, SCM and IT						
1. Thoroe, Melski, and Schumann	2009	N/A	38R	N/A	Focus on RFID and reverse logistics	NFM
2. Kurnia, Mahbubur, and Glohet	2012	E&S	43	N/A	Discussion of role of IT in sustainable SCM	KWS, ASE
3. Frehe and Teuteberg	2014	ENV	51	2000–N/A	Focus on green logistics with slight elements of SCM	KWS, LRJ, ASE

Notes:
Topics: SSCM, intersection of sustainability and SCM; IT&SCM, intersection of IT and SCM; IT&S, intersection of IT and sustainability.
Sustainability focuses: ENV, environmental; E&S, environmental and social; N/A, no focus on either environmental or social sustainability.
Data gathering methods: KWS, keyword search; LRJ, research limited to certain journals; NFM, no stated formal material collection; ASE, author-based subject and paper exclusion; AEA, additional empirical analyses; ARD, automatic relevance detection (by search engine).
* 'R's indicate numbers of references instead of numbers of papers included in literature review.
** Academic papers only.

Table A2. Overview of classification of papers.

Paper	Methodology	Supply chain focus	IT focus	Sustain ability	Immediacy of IT
Abukhader 2008	T	O	STM	E	I
Abukhader and Jönson 2004	T	O	STM	E	I
Ali and Kumar 2011	S	FF	STM, EM	S	I
Ayoub et al. 2006	T	FF	STM	E&S	D
Barrett and Strunjaš-Yoshikawa 2007	T	P	STM	E	D
Benz et al. 2012	T	FF	STM, EM	E	D
Björk et al. 2011	T	P	EM	E	D
Borsato 2014	CS	O	EM	E	D
Bosona et al. 2013	T	FF	STM	E	I
Bullinger, Von Steinaecker, and Weller 1999	T	O	STM, EM	E	D
Carlson, Forsberg, and Pålsson. 2001	T	O	STM, EM	E	D
Chen, Tai, and Hung 2012	T	P	STM	E	D
Clausen, Geiger, and Behmer 2012	CS	O	STM, EG	E	D, I
Dao, Langella, and Carbo 2011	T	O	STM	E&S	I
Davies, Mason, and Lalwani 2007	CS	FF	STM	E	I
Dhanda and Hill 2005	CS	RF	STM	E	I
Dotoli et al. 2006	M	O	STM	E	I
Edwards, Lyons, and Kehoe 2004	T	RF	STM, EM	E	I
Fozza and Recagno 2012	S	O	STM, EG	E&S	D, I
García-Rodríguez, Castilla-Gutiérrez, and Bustos-Flores 2013	S	RF	STM	E	I
Guenther and Farkavcová 2010	T	FF	STM	E	D
Guyon et al. 2012	T	FF	STM	E&S	D
Hasle 1999	T	FF	STM	E	I
Iacob et al. 2013	T	FF	EM	E	D
Iakovou 2001	M	FF	STM	E	I
Koh et al. 2013	T	O	STM	E&S	D
Lai, Hsu, and Chen 2012	CS	P	STM	E	I
Lee 2003	T	O	STM, EM	E	I
Lehmann, Reiche, and Schiefer 2012	R	O	STM, EM	E&S	I
Marett, Otondo, and Stephen Taylor 2013	S	FF	EM, EG	E	D, I
Martínez-Sala et al. 2009	T	P	STM, EM	E	I
McKinnon 2010	T	P	STM, EM	E	D
Meacham et al. 2013	S	O	STM, EM	E	D
Meixell and Norbis 2008	R	FF	STM	E	D, I
Melville 2010	R	O	STM, EM	E	D, I
Muñoz et al. 2013	T	O	STM, EM	E	D
Olugu and Wong 2012	T	RF	EM	E	D
Piotrowicz and Cuthbertson 2009	T	O	STM	E&S	D
Rao 2007	CS	FF	STM, EM, EG	E&S	D, I
Schiller 2012	T	FF	STM	E	I
Shi et al. 2012	T	RF	STM, EM	E	I
Sigala 2014	T	O	STM	E&S	D
Sourirajan et al. 2009	M	FF	STM	E	D
Suh, Smith, and Linhoff 2012	M	FF	EM	E	I
Taghaboni-Dutta, Trappey, and Trappey 2010	T	P	STM	E	I
Thurston and Eckelman 2011	CS	O	STM	E	D
Toh, Nagel, and Oakden 2009	T	O	EG	E&S	D, I
Trappey, Trappey, and Wu 2010	T	RF	EM	E	I
Trienekens et al. 2012	T	O	EM	E&S	D
Vannieuwenhuyse, Gelders, and Pintelon 2003	T	FF	STM	E	D
Verma and Chaudhuri 2009	CS	FF	STM, EM	E&S	I
Walker and Brammer 2012	S	O	STM	E&S	D
Wognum et al. 2011	T	O	EM	E&S	I
Zhang et al. 2013	T	O	EM	E&S	D
Zografos, Sedlacek, and Bozuwa 2012	R	FF	EM, EG	E&S	I

Notes: CS, case study; S, survey/empirical model; M, mathematical model; R, (literature) review; T, theoretical/conceptual model; FF, forward flow; RF, reverse flow; P, product; O, overarching; STM, systems for strategic and tactical management; EM, systems for execution and monitoring; EG, supporting (policy) environment and general framework; E, environmental; S, social; E&S, environmental & social; D, direct effects; I, indirect effects.

Appendix 2

Table A3. Grouping of keywords (elements/objects) for the IT and SCM domain.

Level 2	Level 3	Level 4
Level 1: Management related		
Management elements and structures	Coordination and alignment	
	Customisation and postponement	Customisation, postponement
	Decision-making approach/ decision	Big data, decision-making approach, decisions, selection
	General management	
	Investments	
	Monitoring and control	Assessments, control, evaluation, measurement, monitoring, other, scorecard
	Organisation and governance	Governance, organisational structure, other, outsourcing, policies and rules, teams
	Other	
	Planning and forecasting	Collaborative planning forecasting and replenishment (CPFR), forecast, measures
	Routing and scheduling	Consolidation, other, routing, scheduling, street routing problem (SRP)
	Strategy	Business strategy, differentiation, other
Processes	Coordination and alignment	
	Design and engineering	Design, engineering, other
	Development and implementation	Development, implementation, other
	Discovery and exploration	
	Exchange	Communication, connectivity, flow, general exchange, interchange, other, sharing, transfer
	General process/workflow	
	Learning	
	Maintenance	
	Marketing	
	Operations	
	Production and manufacturing	3D printing, approach, manufacturing, other, production, remanufacturing
	Purchasing and procurement	General commerce, procurement, purchasing, sourcing
	Sales and distribution	Distribution, other, retailing, sales
	Transportation and logistics	Logistics, other, transportation, vendor managed inventory
Business concepts	Asset	
	Automation	
	Barriers	
	Business model	
	Challenges/dependencies	Challenges, other, pressures
	Channels	
	Commitment/bond	
	Competitive advantage	
	Complexity	
	Creation/extension	
	Culture	
	Exploitation	
	General business	
	Influencing factors/volatility	
	Integration	
	Issues and risks	Issues, other, risk, uncertainties
	Needs	
	Orientation	
	Renewal	Change, dynamics, innovation, transformation
	Supply/value chain	Cluster, haulage, life cycle, other, returns/recycling, SCOR model, supply chain, value chain
	Top management	

(*Continued*)

Table A3. (Continued).

Level 2	Level 3	Level 4
Indicators and controls	General performance	
	Impact	
	Indicators/metrics in general	
	Productivity and efficiency	Efficiency, lead times, productivity
	Profit, revenue and costs	
	Quality and satisfaction	
	Responsiveness	
	Value and benefits	Benefits, value
Level 1: Resource/service related		
Resources, systems and services	General (IT) technology	Computing, devices, information and communication technology, other, programming specifics, service-oriented architecture (SOA), software as a service, technologies
	General resources	
	Identifiers	Electronic product code
	Infrastructure and networks	Event management, general networks, Internet of Things (IoT), Internet/Web, IT infrastructure, other, RFID network, sensor networks, tags, virtual networks
	Services and solutions	Agents, middleware, other, protocols, services, solutions, virtualisation
	Systems and applications	Adaptive systems, applications, decision support systems, DSRC, enterprise resource planning (ERP), general systems, information systems, intelligent transportation systems (ITS), lifecycle system, management systems, other, planning systems, platforms, SCM systems, software systems, support systems
	Tools	
Properties and aspects	Agility and flexibility	Agility, flexibility, other
	Applications	
	Competences and capabilities	Capabilities, competences, development, knowledge, skills
	Configuration	
	Functionalities and requirements	Architecture, capacity, general requirement, hierarchies, interoperability, other, security, specifications
	Transparency and visibility	Identification, interfaces, labelling, tracking/tracing, transparency, visibility
Other		
Level 1: Scientific concept related		
Science-based theories, methods and problems	Analysis	
	Framework and practices	
	General research	
	Mathematical approach	Cluster analysis, differential evolution, factor analysis, general algorithm, genetic algorithm, heuristics, logistic regression, mixed integer linear programming (MILP), neural networks, optimisation/minimisation, other, Petri nets, real options, regression analysis, simulation, structural equation modelling
	Methodology	
	Model/modelling	
	Problems	Bias, bullwhip effect, error, inaccuracy, location problem, productivity paradox
	Specific theory	Artificial intelligence, contingency theory, data science, design science, diffusion theory, game theory, institutional theory, organisation theory, other, processing theory, relational view, resource based view, services science, set theory, swarm intelligence, synchronisation, transaction cost theory
	Study types	Case study, content analysis, empirical research, focus groups, industry study, interviews/surveys, meta-analysis, review, survey study
	Theory development/testing	

(*Continued*)

Table A3. (Continued).

Level 2	Level 3	Level 4
Economic concepts	Economic/trade zones	
	General static concept	Acceptance, allocation, antecedents, complementarity, contracts, demand, dependence, determinants, economics, economy, environments, information, orientation, other, ownership, perspective and orientation, power, products, rent, rights, scale, standards, trade, trust, view
	Market dynamic behaviour/mechanism	Adoption and usage, assimilation, auctions, behaviour, competition/rivalry, cycles, diffusion, disruptions, dynamics/evolution, intervention, movement, other
	Political economy	
Economic entities	Alliances	
	Consumers	
	Enterprises/companies	
	Foundations	
	Government/states	
	Joint ventures	
	Markets, marketplaces and hubs	
	Organisations	
	Providers/manufacturers/vendors	
	Small- and medium-sized enterprises (SMEs)	
	Stakeholders	
Future agenda and directions	Agenda/directions	
	Future research	
Other	Other	