Sustainable Supply Chain Analytics: Grand Challenges and Future Opportunities

Completed Research Paper

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Abstract

Over the last few years, the pressure for decreasing environmental and social footprints has motivated supply chain organizations to significantly progress sustainability initiatives. Since supply chains have implemented sustainability strategies, the volume of economic, environmental and social data has rapidly increased. Dealing with this data, business analytics has already shown its capability for improving supply chain monetary performance. However, there is limited knowledge about how business analytics can be best leveraged to grow social, environmental and financial performance simultaneously. Therefore, in reviewing the literature around sustainable supply chain, this research seeks to further illuminate the role business analytics plays in addressing this issue. A literature survey methodology is outlined, scrutinizing key papers published between 2012 and 2016 in the research fields of Information/Computing Science, Business and Supply Chain Management. From examination of 311 journal papers, 39 were selected as meeting defined criteria for further categorization into three distinct research groups including: (a) sustainable supply chain configuration; (b) sustainable supply chain implementation; (c) sustainable supply chain evaluation. The issues involved within each grouping are identified and the business analytics processes (i.e. prescriptive, predictive, prescriptive analytics) to specifically address them are discussed. This wide-ranging review of sustainable supply chain analytics can assist both scholars and practitioners to better appreciate the current grand challenges and future research opportunities posed by this area.

Keywords: Sustainable Supply Chain Analytics, Business Analytics, Environmental and Social Sustainability, Literature Survey

Introduction

Sustainable development in terms of financial, environmental and social measures has become an important competitive factor in the modern business community. Not only markets, but also governments, industry bodies and individual stakeholders put pressure on organizations to demonstrate their commitment to sustainability. Companies help ensure sustainability by integrating critical inter-organizational processes into a supply chain (SC). Furthermore, the deliberate alignment of critical SC processes to sustainability goals (i.e. reducing ecological and social footprints while increasing economic performance) has created the concept of "sustainable supply chain (SSC)" - the effectiveness of which is dependent upon operational and strategic decision-making capabilities (De Oliveira et al. 2012).

Since information communication technology (ICT) and web technology have empowered data analysis, a new hybrid form, termed business analytics (BA) has emerged. BA is now a key tool enabling corporations to better drive sustainability-based outcomes. Encompassing tools, techniques, and procedures, it helps aggregate business data into the information necessary for describing, predicting, and analysing a phenomenon (Acito and Khatri 2014). A more detailed definition is provided by a study from Sun et al. (2016) who suggest that BA can be presented as follows:

> Business analytics = business analysis (e.g., qualitative analysis, statistical analysis, and mathematical modelling) + computer science and information technology (e.g., data warehousing, data mining, data modelling, data visualization tools) + Domain knowledge (e.g., SC, SCC, healthcare, e-commerce, etc.).

There are multiple components to BA: *decision capability*, *analytical capability* and *information capability* (Herden 2017). *Decision capability* implies tools that deliver required information for decision making, such as reports and dashboards. *Analytical capability* points towards a set of processes for analysing data using various techniques, ranging from traditional ad hoc queries to more advanced mathematical programming. Finally, *information capability* signifies state-of-the-art technologies that describe, organize, integrate and share data assets. BA is no longer an innovation requiring top management ratification, but that is necessary to create competitive advantage via increasing information transparency and decision efficiency (Hazen et al. 2016). As BA and sustainability are strategic priorities for SC, their alignment implies new modus which, for the purposes of this paper, we will refer to as sustainable supply chain analytics (SSCA).

It has been suggested by many researchers that BA can empower SC by creating new capabilities to improve its strategic performance (De Oliveira et al. 2012). However, in contrast, there are relatively few studies that investigate ways SSCA can be leveraged to enhance the sustainability performance of SC (Hazen et al. 2016). Therefore, this paper aims to more closely examine the relationship between BA and SSC, and potential opportunities for further research, by examining the following questions:

- RQ1: What are the key areas of current research in SSC?
- RQ2: What are the relevant issues related to the key SSC research areas?
- RQ3: How can the analytic capability of BA address issues associated with SSC?
- RQ4: What are the current challenges and future opportunities for SSCA research?

In order to address these questions, this paper seeks to provide a big picture view of SSCA by linking and cross-referencing two emerging fields of research:

1. SSC- categorized as SSC configuration, SSC implementation, and SSC evaluation;
2. BA- composed of descriptive, predictive and prescriptive process areas. (However, for purpose of this study only the analytic capability spanning these three areas has been reviewed).

Although there is considerable extant literature for both SSC (Brandenburg et al. 2014) and BA (Sun et al. 2016), a structured cross-disciplinary review has not been conducted. This research contributes to the body of knowledge by providing important insights for researchers and practitioners seeking to identify the challenges and opportunities implied by SSCA.

The structure of the paper is as follows. First, the research methodology of the study (literature survey) is elaborated. Second, the obtained results for SSC and BA are introduced, implications are discussed and potential future research directions for SSCA are presented. Third and finally, some concluding remarks and limitations of the research are outlined.

Research Methodology

Inspired from the literature review method introduced by Kitchenham (2004), this study undertakes a literature survey approach that summarises the domain of SSC. For this to happen, the research has been carried out through three phases: (1) journal list development; (2) dataset extraction; (3) data synthesize. These steps have been developed to assist readers in comprehending the logical order of the research processes. Figure 1 depicts the conceptual scheme of the methodology.

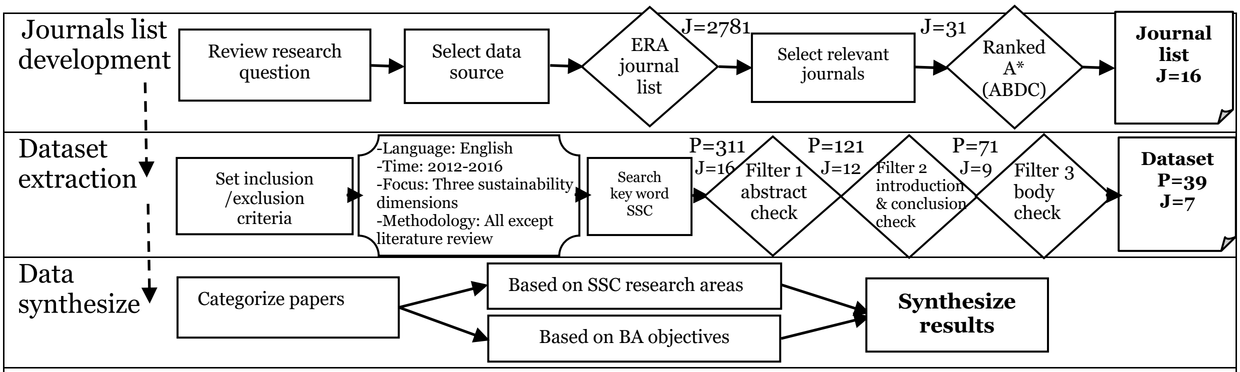

Figure 1. Research process diagram

Phase 1- Journal list development

In commencing the search process, the study objectives were reviewed in depth to determine the data source. In this regard, an initial list of journals (J=31) was selected from the relevant categories of research including Information and Computing Science, Business and Management, Transportation and Freight Services, Applied Mathematics and Manufacturing Engineering, which were encompassed in a journal list named "Excellence in Research for Australia" (ERA). ERA evaluates research produced in Australian universities against national and international benchmarks. Ensuring the quality of selected journals, the journals' rankings were examined according to journal quality list developed by Australian Business Deans Conceal (ABDC). While the ones ranked less than A* (i.e. top quality) were excluded from the initial list, 16 highest-quality journals composed the journal list of the study (See Table 1).

Phase 2- Dataset extraction

The process of paper extraction has been started by setting reasonable inclusion and exclusion criteria to collect relevant papers from the journal list. These criteria were defined as: (1) articles should be published in the English language; (2) articles should be published within the five-year time span between 2012 and 2016 to best represent the current state of the research domain. The justification for choosing this time span is that the researches around the impact of BA on SC performance (De Oliveira et al. 2012) became most prominent from 2012 onwards; (3) articles should simultaneously address economic, environmental and social dimensions of sustainability; (4) papers focused upon a literature review methodology should be excluded from the dataset. Using "sustainable supply chain" as the key phrase, relevant papers were searched within selected journals. 311 studies from 16 journals underwent further analysis via three filtration stages to ensure meeting the significance criteria. In the first filtration, the abstract of each paper was reviewed. Subsequently, 190 papers were excluded (i.e. where sustainability was defined as being solely environmental or social), 25 papers met all criteria and 96 papers required a more detailed examination (sustainability definition was not clearly articulated within the abstract) (J=12 per Figure 1). In the second filtration, the introduction and conclusion sections of the 96 studies were examined to understand whether sustainability in terms of economic, environmental and social dimensions were explicitly addressed. Subsequently, 62 articles were removed from consideration, 10 were accepted and 28 studies identified where the sustainability framework was not directly referenced in the research (J=9 per Figure 1). In the third filtration, the 28 remaining articles were subjected to detailed whole-text examination. Consequently, a further 4 papers were accepted into the dataset while 24 were excluded as not satisfying criteria 3. Table 1 presents the journals hosting 39 articles meeting the defined criteria for inclusion in the study dataset.

Table 1. Journal and article list				
No.	**Title**	**Academic Database**	**Initial number of papers**	**Final number of papers**
1	International Journal of Production Economics	Science Direct	173	24
2	Transportation Research Part E: Logistics and Transportation Review	Science Direct	29	5
3	European Journal of Operational Research	Science Direct	48	4
4	OMEGA	Science Direct	22	3
5	Journal of Operations Management	Science Direct	5	1
6	Decision Science	Wiley online library	5	1
7	Regional Studies	Taylor & Francis	3	1
8	Decision Support Systems	Science Direct	3	0
9	Transportation Research Part B: Methodological	Science Direct	5	0
10	Management Science	INFORMS Journals	7	0
11	Journal of the Association for Information Science and Technology	Wiley online library	3	0
12	European Journal of Information Systems	Springer	2	0
13	IEEE Transactions on Fuzzy Systems	IEEE Xplore Digital Library	2	0
14	Operations Research	INFORMS Journals	2	0
15	Information Systems Journal	Wiley online library	1	0
16	Journal of Information Technology	Springer	1	0
Total number of papers			**311**	**39**

Phase 3- Data synthesis

In the final phase, all articles went through in-depth study. For each paper, two primary outcomes were recorded: (1) research areas of SSC and involved issues; (2) the application of BA in response to identified issues within each area.

For categorizing the SSC process, a plethora of structural frameworks and conceptions has been suggested in literature. The SSC functions framework developed by Hassini et al. (2012) has the research areas divided into planning and assessment. Later, Reefke and Sundaram (2016) critiqued this framework because of its narrow focus, developing a more extended frame of reference by adding two new dimensions – namely, SSC coordination and collaboration. Our current research uses this latter schema to investigate issues within multiple areas of SSC. However, as both Balakrishnan and Geunes (2004) and Moharana et al. (2012) remark, coordination and collaboration activities have similar focus (i.e. coordinating of SC members and managing information exchange between them) - these two dimensions can be integrated into a single category of SSC implementation. Next, the problems associated with each area were mapped. Likewise, the BA processes and techniques used in the literature were grouped based upon their task-orientation towards addressing these issues (Evans and Lindner 2012). Synthesis results are discussed following.

Findings

To address the nominated research questions, first the SSC investigation areas and their issues are presented. Thereafter, techniques incorporated within each BA analytic process for dealing with the identified issues are elaborated.

Sustainable Supply Chain Research Areas

The papers under review in this study concentrate on three core topics: (a) SSC configuration; (b) SSC implementation; and (c) SSC evaluation. Issues within each area are also identified. A summary of research areas, relevant issues and associated supporting references are shown in Table 2.

Table 2. SSC research areas and relevant issues

Research area	Related issue	Description	Reference
SSC configuration	SSC network design	Determining the location and capacity of a new facility in SSC	Varsei and Polyakovskiy (2016), Gonela et al. (2015)
		Determining the location and capacity of a new facility in closed-loop SSC	Zhalechian et al. (2016), Fahimnia and Jabbarzadeh (2016), Pishvaee et al. (2014), Devika et al. (2014)
	SSC network planning	Planning a sustainable production system	Gebrezgabher et al. (2014), Wang et al. (2015a)
		Planning a sustainable distribution system	Besiou et al. (2012), Ramos et al. (2014, Boukherroub et al. (2015)
		Scheduling inventory in sustainable supply chain	Bouchery et al. (2012), Khan et al. (2016)
SSC implementation	Sustainability management in supply chain	Analysing the drivers and barriers to SSC adoption	Chowdhury and Quaddus (2016), Gmelin and Seuring (2014), Luthra et al. (2016), Silvestre (2015), Gopalakrishnan et al. (2012)
		Exploring the SSC management and development actions	Klooster and Mercado-Celis (2015), Giannakis and Papadopoulos (2016)
	Relationship management for SSC implementation	Analysing success factor for supplier management in SSC	Goebel et al. (2012), Grimm et al. (2014)
		Exploring the strategies for buyer-supplier relationship management in SSC	Wilhelm et al. (2016b), Wilhelm et al. (2016a), Ageron et al. (2012), Touboulic et al. (2014), Luzzini et al. (2015)
SSC evaluation	Sustainable supplier selection	Evaluating sustainable performance of suppliers	Baskaran et al. (2012), Scott et al. (2013), Sarkis and Dhavale (2015)
	SSC practice performance evaluation	Evaluating the practices and performance of sustainable service supply chain	Tseng et al. (2016)
		Evaluating the practices and performance of sustainable manufacturing supply chain	Lam (2015), Bergenwall et al. (2012), Kusi-Sarpong et al. (2016), Wang et al. (2015b), Zailani et al. (2012) Yusuf et al. (2013), Gimenez et al. (2012)
		Evaluating the practices and performance of sustainable food supply chain	Sgarbossa and Russo (2016)

SSC Configuration

The foundation of SSC execution, this area concerns itself with developing an optimal configuration for SC in respect to sustainability priorities. Two central concerns for SSC configuration arise:

(a) SSC network design: This issue refers to the physical reconfiguration of the SC network whenever the desired strategic outcomes of firms change. In this way, the decision maker intends to manage resources, processes, and relationships to maximize the created value of the network in accordance with sustainability policies. Sustainable design decisions would also affect the strategy, context, and structure of organizations. While a few researchers concentrated on harmonizing the elements of forward SSC network structure (Gonela et al. 2015; Varsei and Polyakovskiy 2016), most focused on optimizing the components of a sustainable closed-loop SC structure (Devika et al. 2014; Fahimnia and Jabbarzadeh 2016; Pishvaee et al. 2014; Zhalechian et al. 2016). Closed-loop or circular supply chain is an aggregated form of forward and reverse SC, balancing the flow of information and material through an integrative approach.

(b) SSC network planning: This issue refers to planning and management of procurement, logistics, manufacturing and post-use activities of SC by the explicit involvement of environmental, social and economic responsibilities. SSC network planning decisions occur at production planning, distribution planning, and inventory management levels. In production planning, the researchers stressed the selecting of sustainable production technologies (Gebrezgabher et al. 2014; Wang et al. 2015a). Sustainable resource allocation and sustainable logistics planning issues were investigated in distribution planning (Besiou et al. 2012; Boukherroub et al. 2015; Ramos et al. 2014). In addition, two central problems within SSC operations related to sustainable inventory control and sustainable lot sizing topics were examined (Bouchery et al. 2012; Khan et al. 2016).

SSC Implementation

The transition of SSC configuration into implementation is a complicated task; nonetheless, successful incorporation of sustainability practices into SC activities can yield considerable advantages for the organizations. Two central issues for SSC implementation arise:

(a) Sustainability management in SC: Encouraging and preventive factors impact SCs endeavours to implement sustainability initiatives. Drivers motivate and assist the organizations' engagement with sustainable practices; in contrast, barriers hinder the employment of sustainable practices across the SC. In the relevant literature, the enablers/barriers to adopting sustainable service design practices (Chowdhury and Quaddus 2016), sustainable product development practices (Gmelin and Seuring 2014), sustainable production practices (Luthra et al. 2016) and SSC management practices

(Gopalakrishnan et al. 2012; Silvestre 2015) have been identified. Moreover, organizations can create action plans to step towards sustainability development in the global SC networks (Klooster and Mercado-Celis 2015) and sustainability risks control (Giannakis and Papadopoulos 2016).

*(b) Relationship management for SSC implementation: M*easures which impact focal firms' decisions to choose sustainable suppliers have been investigated in the literature (Goebel et al. 2012; Grimm et al. 2014). To ensure that suppliers comply with SC sustainability expectations (and to maintain buyer-supplier relationships), focal firms strive towards controlling their partners by developing relationship management strategies. This issue was an interest area for researchers, such as Ageron et al. (2012), Luzzini et al. (2015), Wilhelm et al. (2016b), Wilhelm et al. (2016a), and Touboulic et al. (2014).

SSC Evaluation

Ultimately, it is the responsibility of evaluation models to monitor and maintain control over the sustainable performance of SC activities. Two critical issues for SSC evaluation emerge:

(a) Sustainable supplier selection: Extending sustainability across SC, buyer firms are interested in selecting those suppliers whose processes and products are aligned with their sustainability standards. Thus, some performance evaluation frameworks have been developed as assisting means for purchasing managers to order the required material from sustainable suppliers and to keep the collaborative networks sustainable (Baskaran et al. 2012; Daniel and Talaei-Khoei 2016; Sarkis and Dhavale 2015; Scott et al. 2013).

(b) SSC practice performance evaluation: The impact of sustainable practices on the sustainable performance of SCs needs to be assessed, so that their contribution to sustainability development will be revealed. Referring to the reviewed studies, the performance of sustainable practices incorporated in to food SC (Sgarbossa and Russo 2016), manufacturing SC (Bergenwall et al. 2012; Gimenez et al. 2012; Kusi-Sarpong et al. 2016; Lam 2015; Wang et al. 2015b; Yusuf et al. 2013; Zailani et al. 2012), and service SC (Tseng et al. 2016) has been assessed using different indicators and frameworks.

Sustainable Supply Chain Analytics

SSCA examines how BA, in terms of analytical capability, has addressed SSC issues mentioned previously. Based on the objectives of analytics processes and the functionality domain of results, BA can be categorised as: (a) descriptive analytics; (b) predictive analytics; and (c) prescriptive analytics (Herden 2017). These are presented in Table 3 and further expounded following.

Table 3. Business analytics and SSC issues

Analytics category	Techniques	Addressed issues	references
Descriptive analytics	Descriptive statistics	*SSC implementation:* -Relationship management for SSC implementation	(Ageron et al. 2012)
	Business metrics	*SSC evaluation:* -Sustainable practice performance evaluation	(Sgarbossa and Russo 2016)
Predictive analytics	Regression	*SSC implementation:* -Relationship management for SSC implementation	(Goebel et al. 2012)
	SEM		(Luzzini et al. 2015)
	FMEA	-Sustainability management in SC	(Giannakis and Papadopoulos 2016)
	Regression	*SSC evaluation:* -Sustainable practice performance evaluation	(Gimenez et al. 2012), (Zailani et al. 2012)
	Chi square test		(Yusuf et al. 2013)
Prescriptive analytics	MOP	*SSC configuration:* -SSC network design	(Varsei and Polyakovskiy 2016), (Fahimnia and Jabbarzadeh 2016), (Devika et al. 2014), (Pishvaee et al. 2014), (Zhalechian et al. 2016), (Gonela et al. 2015)
	MOP	-SSC network planning	(Ramos et al. 2014), (Bouchery et al. 2012), (Khan et al. 2016), (Gebrezgabher et al. 2014)
	SOP		(Boukherroub et al. 2015)
	Game theory		(Wang et al. 2015a)
	Simulation		(Besiou et al. 2012)
	SOP	*SSC implementation:* -Sustainability management in supply chain	(Chowdhury and Quaddus 2016)
	AHP/ANP		(Luthra et al. 2016)
	SOP	*SSC evaluation:* -Sustainable practice evaluation	(Wang et al. 2015b)
	AHP/ANP		(Lam 2015), (Tseng et al. 2016), (Kusi-Sarpong et al. 2016)
	AHP/ANP	-Sustainable supplier selection	(Scott et al. 2013)
	GRA		(Baskaran et al. 2012)
	Simulation		(Sarkis and Dhavale 2015)

Descriptive Analytics

Descriptive analytics (business reporting) elaborates current situational opportunities and problems by understanding what has happened up to now and what is happening at present (Sun et al. 2016). Descriptive statistics and business metrics were the descriptive techniques addressing SSC issues.

Descriptive statistics summarizes the sample and central tendency (e.g., mean, median) and variability measures (e.g., standard deviation, variance) of data. Since statistics of this type are both inflexible and incapable of learning about data population, this method has been criticized in the literature. Ageron et al. (2012) study was an isolated instance of using descriptive statistics to operationalize a sustainable supply management model.

Business metrics are a set of quantitative measures that allow managers to track and monitor performance of business processes in regard to key objectives. Using profitability and energy self-sufficiency indicators, Sgarbossa and Russo (2016) assessed the sustainable performance of a new recovery loop in a food SC.

Predictive Analytics

Predictive Analytics reveals the trends and the hidden patterns in datasets to forecast what will possibly happen in the future. Regression, structural equation modelling (SEM), chi-square, failure mode and effect analysis (FMEA) were the predictive techniques addressing SSC issues.

Regression identifies the relationships and causality between variables to provide a reliable estimation. Heterogeneity, experimental variations, and statistical bias are several deficiencies of this technique. In the reviewed literature, the application of various regression models (e.g., least square, linear, non-linear) have been experienced to investigate the hypothesis about the positive effect of sustainable practices on sustainable performance of manufacturing firms (Gimenez et al. 2012; Zailani et al. 2012). Furthermore, Goebel et al. (2012) employed the technique to examine the impact of ethical culture on purchasing managers' decisions about sustainable supplier selection.

SEM combines a diverse set of analysis of variance (ANOVA), regression and factor analysis techniques to analyze multiple-dependency between the measured and latent variables. However, the findings cannot be generalized since the model fits the covariance of the sample instead of sample values. Employing SEM, Luzzini et al. (2015) investigated the role of sustainability commitment in buyer-supplier relationship management.

Chi-square test statistically compares the observed data with expected data, based on a proposed hypothesis. As the variables relationship strength is disregarded in calculation, the technique functionality is solely dependent on sample size. Yusuf et al. (2013) utilized a combination of cross tabulation technique and chi-square test to study the adoption of sustainable measures in the UK oil industry and the performance outcomes.

FMEA systematically identifies the failure points of a system in early stages to implement preventive strategies. The technique receives two criticisms related to the complex worksheet and low valid results. Giannakis and Papadopoulos (2016) was one isolated case of utilizing FMEA to find the sustainability-related risks and determine the suitable response strategies.

Prescriptive Analytics

Prescriptive analytics advises the systems' behavior in confronting with future situation and indicates a course of actions that can be taken to face uncertainties. Optimization models, simulation, grey relational analysis (GRA), game theory, analytical hierarchical process (AHP) and analytical network process (ANP) were the prescriptive techniques addressing SSC issues in the literature.

AHP/ANP are typical group decision-making approaches to sort out a problem through decomposing it into a hierarchy (refers to AHP) or a network (refers to ANP). Easy to adjust with sized problems, they are not data-intensive. However, the inconsistencies and lack of interdependencies between judgments and ranking criteria limit the performance. In the reviewed papers, Luthra et al. (2016), and Boukherroub et al. (2015) employed these techniques to rank barriers of sustainable production practices and to evaluate the sustainable performance of mills, respectively. The integration of techniques with quality function deployment (QFD) provided a complementary approach to assess the sustainable practices of maritime supply chain (Lam 2015) and to select strategic suppliers for bio-energy industry (Scott et al. 2013). The consolidated framework affords AHP/ANP techniques a fortune to systematically identify evaluation criteria and decision alternatives. As the engagement of fuzzy Delphi approach reinforces the ANP capability to deal with vagueness, Tseng et al. (2016) operationalized a combination of them to assess the performance of sustainable service supply under uncertainty. Moreover, to control the number of pair-wise comparisons, Kusi-Sarpong et al. (2016) incorporate Fuzzy-DEMATEL in ANP to assess the green practices of mining industry performance.

GRA measures the distance of the comparability sequences (translated from decision alternatives) from the target sequence, even if the data sample is small, incomplete, and uncertain to determine the appropriate (not the best) action. The technique cannot deal with a large range of alternatives. Baskaran et al. (2012) used this technique to select the sustainable suppliers of textile industry.

Single- and multi-objective optimization consolidate different variables, historical data, and constraints in a mathematical form to find the best solution for the compound problems. Having said that, it is not feasible to translate all aspects of the real-world case as model. Additionally, slow coverage rate of the solution approaches leads to unstable answers. For instance, Boukherroub et al. (2015) solved a wood resource allocation problem by developing two linear single-objective optimization (SOP) models. Chowdhury and Quaddus (2016) utilized QFD-SOP approach to identify the barriers to achieve a sustainable service SC and find suitable mitigation strategies. Wang et al. (2015b) utilized multi-objective optimization (MOP) to find the best subset of sustainable practices in the manufacturing firms, based on their sustainable performance. The broad application of different MOP optimization models (e.g., stochastic programming, fuzzy programming, etc.) was observed for solving SSC network design (Devika et al. 2014; Fahimnia and Jabbarzadeh 2016; Gonela et al. 2015; Pishvaee et al. 2014; Varsei and Polyakovskiy 2016; Zhalechian et al. 2016) and SSC network planning issues (Bouchery et al. 2012; Gebrezgabher et al. 2014; Khan et al. 2016; Ramos et al. 2014).

Game theory defines the circumstance of interactive decision-making problems as games, in which each player's outcome causes the other participants become losers. Due to the generality of game models, deriving all the situation-related hypotheses is pretty sophisticated. Wang et al. (2015a) analyzed the effect of carbon tariff on the operational decisions in a game between textile industries of developed and developing countries.

Simulation establishes a mathematical prototype to predict systems' behavior under distinct probable scenarios with a small amount of data. Difficult to interpret results, the validation of simulation model is poor. System dynamics and Mont-Carlo are two techniques applied in the study of Besiou et al. (2012) to address network planning issue (the former) and in the study of Sarkis and Dhavale (2015) in combination with Bayesian framework to address sustainable supplier selection issues (the latter). Bayesian framework empowers this technique to decrease the dependency on subjective inputs of management and to deal with missing data.

Discussion and implication

Table 4 summarizes the previous findings regarding the SSC areas and issues against BA techniques. The main body of SSCA literature relies heavily on prescriptive analytics (22 out of 30). In comparison, predictive analytics (6 out of 30) rates much less and diagnostic analytics (2 out of 30) is generally not popular. One likely reason for limited application of predictive analytics in SSC areas might relate to the vague functionality and viability of BA tools and techniques (Hazen et al. 2016). Apparently, the SSC implementation area also suffers from a lack of prescriptive and predictive analytics approaches. Interestingly, none of the prescriptive techniques addressed buyer-supplier relationship management issues, making this an intriguing topic for future research within SSCA.

From information shown in Table 5 literature gaps and potential research areas can be identified:

Opportunities within SSC configuration: While SSC design models attempted to address strategic decisions (e.g., facility location, capacity planning), incorporation of operational planning decisions have been largely disregarded (e.g., inventory management). Arguably, the limited ability of analytical techniques to confront multi-level decision-making has caused this deficiency. In addition, as the sustainability objective of the business does not always remain consistent over time, the dynamic nature of SSC reconfiguration should be considered in the models (Melnyk et al. 2014). Future researchers may likely to contemplate developing dynamic design models capable of rapid response to change. For this purpose, a real-time simulation-based architecture can be designed to optimize the network structure at the same rate as the sustainability strategies are modified. Regarding network planning issues, a new avenue for research exists investigating the effects of sustainable practices on the disruption toleration capacity of SC at planning level (Fahimnia and Jabbarzadeh 2016). An accumulation of advanced predictive and prescriptive analytics (e.g., artificial neural network (ANN), stochastic programming) might be helpful in this case.

Table 4. Intersection of SSC and BA

SSC research area	SSC issue	Analytics process → / Analytics technique → / References ↓	Non-Analytics	Descriptive Analytics: Descriptive statistics	Descriptive Analytics: Business metrics	Predictive Analytics: Regression	Predictive Analytics: FMEA	Predictive Analytics: SEM	Predictive Analytics: Chi-square test	Prescriptive Analytics: Multi-objective optimization	Prescriptive Analytics: Single objective optimization	Prescriptive Analytics: Game theory	Prescriptive Analytics: AHP/ANP	Prescriptive Analytics: Grey relation	Prescriptive Analytics: Simulation
SSC Configuration	SSC network design	(Varsei and Polyakovskiy 2016)								■					
		(Fahimnia and Jabbarzadeh 2016)								■					
		(Devika et al. 2014)								■					
		(Zhalechian et al. 2016)								■					
		(Gonela et al. 2015)								■					
		(Pishvaee et al. 2014)								■					
	SSC network planning	(Ramos et al. 2014)								■					
		(Gebrezgabher et al. 2014)								■					
		(Bouchery et al. 2012)								■					
		(Khan et al. 2016)								■					
		(Boukherroub et al. 2015)									■				
		(Wang et al. 2015a)										■			
		(Besiou et al. 2012)													■
SSC Implementation	Sustainability management in supply chain	(Chowdhury and Quaddus 2016)									■				
		(Luthra et al. 2016)											■		
		(Giannakis and Papadopoulos 2016)					■								
		(Klooster and Mercado-Celis 2015)	■												
		(Gmelin and Seuring 2014)	■												
		(Silvestre 2015)	■												
		(Gopalakrishnan et al. 2012)	■												
	Relationship management for SSC	(Touboulic et al. 2014)	■												
		(Grimm et al. 2014)	■												
		(Wilhelm et al. 2016a)	■												
		(Wilhelm et al. 2016b)	■												
		(Ageron et al. 2012)		■											
		Goebel et al., 2012)				■									
		(Luzzini et al. 2015)						■							
SSC Evaluation	Sustainable supplier selection	(Baskaran et al. 2012)												■	
		(Sarkis and Dhavale 2015)													■
		(Scott et al. 2013)											■		
	Sustainable practice performance evaluation	(Lam 2015)											■		
		(Tseng et al. 2016)											■		
		(Kusi-Sarpong et al. 2016)											■		
		(Wang et al. 2015b)									■				
		(Gimenez et al. 2012)				■									
		(Zailani et al. 2012)				■									
		(Yusuf et al. 2013)							■						
		(Bergenwall et al. 2012)	■												
		(Sgarbossa and Russo 2016)			■										

Opportunities in SSC implementation: Researchers have already identified several drivers for and barriers against successful implementation of SSC. However, influence degree of each factor for facilitating/delaying sustainability adoption is unknown. Future researchers are advised to estimate the impact factor of enablers/disruptions using predictive analytics like data mining. Another research opportunity can be recognized in developing strategies for relationship management across SSC, under two conflicting scenarios. In the first scenario (which is typical), a focal firm determines the sustainability implementation strategies centrally and imposes them upon the other parties. In the second, each party is responsible for making its policies and managing relations individually (Kumar and Rahman 2015). Comparing the effects of each strategy within these scenarios (plus associated problems and potential solutions within simulation) might be an area ready for future research.

Opportunities in SSC evaluation: Although supplier selection modelling is already a mature topic, some interesting fields of associated research remain untouched. For example, researchers have so far largely neglected behavioural frameworks linked to sustainable supplier selection processes. This shortcoming affects the reliability of models and generality of results. Decreasing the effect of humans' bias in decisions, it is necessary to simulate the decision makers' behaviours carefully. As a suggestion, researchers can employ ANN in combination with prescriptive techniques to help analyse complicated systems such as human behaviour. Also, while the performance of SSC is subjected to change over time, the moderating effect of time has not yet being investigated in evaluation models. Therefore, one possible future research direction could encompass exploring the impact of practices for developing sustainability over longer periods and/or predicting the maturation time of such practices (Gimenez et al. 2012; Kusi-Sarpong et al. 2016). As a time series problem, various techniques such as machine learning, dynamic Bayesian network, Markov model, queuing theory analysis, etc. may assist.

Conclusion and limitations

The current research is an attempt to present a snapshot of SSC research areas, the issues involved and the BA analytical capacity to address them. Starting from a sample set of 311 papers published over the last five years in highly regarded journals, a landscape analysis was carried out to review, reduce and summarize the 39 SSC papers best meeting significance criteria. Based on similar internal themes, the SSC discipline was categorized into configuration, implementation and evaluation domains. The issues associated with each area were identified and further synthesized against the business analytics (descriptive, prescriptive and predictive). The grand challenges revealed by this study are found in considering the dynamic nature of sustainability and analysing the behavioural perspective of operational research. These challenges may suggest a need for developing a more layered analytics approach, first predicting a future followed by executing an appropriate scenario plan for that future.

Finally, this study has a couple of limitations. First, the SSC papers identified were manually searched in A* journals involved in ERA list. Moreover, by setting a time limit on the articles (between 2012 and 2016) the boundaries of research became more limited. Therefore, it is possible that some less visible or less cited articles/journals were unintentionally overlooked. To address this issue, research using a more technology-driven keyword search of automated academic databases may reveal wider insights. Furthermore, the meaning and intentions of original authors may not have been fully understood as only published writings were examined without face-to-face explication. A more in-depth research scope may open up new perspectives regarding emergent SSCA capabilities. It is to be hoped that this research provides useful insights into SSCA body of knowledge and assists other researchers, analysts, supply chain practitioners and managers to better leverage the benefits offered by a more informed understanding.

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