REVIEW ARTICLE

Issues in sustainable supply chain's futuristic technologies: a bibliometric and research trend analysis

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Abstract

This paper presents a systematic review and bibliometric analysis in sustainable supply chain's futuristic technologies. The analysis involves 1596 articles published in the Scopus database from 1990 to 2020. The analysis examines the research outcomes by observing trends in journals, authorship, and keywords. The outcomes are visualized using VOSviewer to show the graphical network of co-authorship and the author's keywords. The results show that this research area has been a growing trend since 2016 and by 2020. The *Journal of Cleaner Production* was a leading journal in this area between 2016 and 2020, followed by *Sustainability* (Switzerland). The content analysis led to a classification of the articles into four main categories and sub-categories. The strategic diagram is used to reveal the emerging research themes analysis during the last 5 years (2016–2020) and to present future research. The data trending or emerging shows that technologies such as the technology by using combustion energy, renewable energy, and electric vehicles have been developing substantially. The research hotspots of the sustainable supply chain include, i.e., life cycle assessment (LCA), green investment, and carbon tax. Finally, the analysis also shows the research gaps that point a direction for future research.

Keywords Future technologies · Sustainable supply chain · Bibliometric analysis

Introduction

Over the last decades, climate change has been a serious concern among leaders of countries, companies, universities, and organizations in various sectors. Global climate change can only be tackled if everyone takes action in protecting and maintaining the environment and its ecosystems. Carbon dioxide (CO_2) emissions result from the burning process of fossil fuels. The higher the carbon content in the fossil fuels and the more inefficient the combustion process, the greater the quantities of CO_2. This is not only from transportation activities but also logistics and supply chain (LSC) activities. Best practices are accomplished when organizations prioritize the environment by minimizing carbon emissions. Green and sustainable supply chain management can help companies achieve this and compete in the market (Amirbagheri et al. 2019). The global trend is now to optimize production and ordering size quantities by all parties in the supply chain system, which is often referred to as a joint economic lot-sizing problem (JELP).

Most of the supply chain models assume that the vendor and buyer have not considered carbon emissions. This research is motivated by the fact that the vendor and buyer can produce the emission into the air. Recently, researchers have investigated inventory management with the consideration of the environmental and carbon emission cost. A domestic and international supply chains consider the environmental impacts (Wahab et al., 2011), a single-level lot sizing (EOQ) under emission constraints and different carbon emission policies (Benjaafar et al., 2013) and a two-level supply chain model incorporating carbon emission tax and penalties to reduce emission amount (Jaber et al. 2013). Some of the studies consider the energy (Bazan et al. 2015a), the reverse logistic and

Responsible Editor: Philippe Garrigues

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emissions from the manufacturing, re-manufacturing, and transportation activities (Bazan et al. 2015b; 2017); carbon penalty and incentive on vendor–buyer inventory model (Wangsa 2017); the carbon emissions and the defective items (Tiwari et al., 2018a); stochastic demand, defective items, and carbon emissions cost (Jauhari 2018); defective items, errors in inspection, and service level constraint (Saga et al. 2019); studied a two-echelon inventory system by considering the GHG emissions, energy usage, and inefficient production (Marchi et al. 2019); a three-echelon inventory model considering emissions from the transportation, warehousing, and disposal activities (Daryanto et al. 2019); and the emissions impact of the production, transportation, and warehousing activities (Wangsa et al. 2020).

Futuristic technologies in Industry 4.0 era can prompt innovative thinking, increase competitive advantage, and the sustainability of an industrial system (Stock and Seliger 2016; Müller et al. 2018). The literature on Industry 4.0 technologies in the period surveyed shows that typical technologies include additive manufacturing, big data and analytics, blockchain, cloud, internet of things (IoT), artificial intelligence (AI), autonomous robots, augmented reality (AR), electric vehicles, radio frequency identification (RFID), and unmanned aerial vehicle or drone (Dalenogare et al. 2018; Bai and Sarkis 2017; Schulte and Ny 2018; Wan et al. 2015; Strandhagen et al. 2017; Murray and Chu 2015). Studies have also analyzed the use of big data analytics in the supply chain management (Tiwari et al. 2018b) and green technology strategy to reduce carbon emission (Lou et al. 2015; Helmrich et al. 2015; Datta 2017; Huang et al. 2020; Karim and Nakade 2020).

There are systematic literature review and bibliometric analysis on green supply chain and Industry 4.0 in the database, but these are done in silos; for example, the systematic review of Industry 4.0 areas (Cobo et al. 2018), analysis of supply chain management from social network perspective (Ye 2019), the classification of Industry 4.0 technologies and the impact on sustainability (Bai et al. 2020), green supply chain (Amirbagheri et al. 2019), green and sustainable logistics (Ren et al. 2020), the classification of sustainable manufacturing (Bhatt et al. 2020), service supply chain (Nagariya et al. 2020), and lean supply chain management (Garcia-Buendia et al. 2021). Some comprehensive analysis involves a Scopus database on the green supply chain (Fahimnia et al., 2015), while others added on with a Web of Science database (Maditati et al. 2018; Gong et al. 2019). In terms of transportation, research outcomes have been clustered based on the carbon emissions of different modes of transportation (Tian et al. 2018), as well as based on the Life Cycle Cost Assessment of electric vehicles (Ayodele and Mustapa 2020). Although the abovementioned literature review provides

a bibliometric analysis on green and sustainable supply chain, a comprehensive bibliometric analysis considering Industry 4.0 technologies remains absent.

The purpose of this paper is to provide a comprehensive bibliometric review on futuristic technologies and sustainable supply chain by using a VOSviewer involving a database of a 30-year period from 1990 to 2020. This paper uses VOSviewer software to graphically display bibliometric map results. VOSviewer software functionality is specially designed to easily interpret large maps (Van Eck and Waltma 2010). This software collects data and creates maps based on bibliometric co-authorship, citations, co-citation, and keywords co-occurrence (Merigó, et al. 2018 and Wang et al. 2018c). The analysis reports the trends based on the number of articles, citations, authors, and keywords. The bibliometric tool undertook the content analysis (e.g., research method, research environment, Industry 4.0 technologies, and policies and regulations) and identified the major clusters of research. Likewise, a science mapping analysis based on keywords co-occurrence was carried out to evaluate and identify the main research themes addressed in this area and their evolution over time. The results provide insights into the current research interests and potential directions for future research.

The rest of the paper is organized as follows: the "Research design" section explains the methodology of the bibliometric analysis including how the data was collected and reviewed. The "Bibliometric analysis and visualization" section describes the bibliometric analysis and presents the network analysis using VOSviewer. Moreover, the "Content analysis" section presents a content analysis of sustainable supply chain and futuristic technology. The "Science mapping analysis" section presents the analysis of the science mapping of emerging research topics based on keywords from the strategic diagram. Current research gaps and future research are also discussed. The "Conclusion and directions for future research" section summarizes the results and discusses opportunities for future research.

Research design

A literature review is one of the most important elements of any research work as it maps and assesses relevant literature to identify the possible research gaps that would be helpful in further strengthening the body of knowledge (Tranfield et al. 2003). In this research, a six-step literature review to identify influential research, identify the latest research areas, and provide insights into current research interests and future research directions in those areas. In the sixth stage, we conducted a confirmation stage to fit the results of emerging and declining trends in sustainable logistics and supply chain research areas with open questionnaires and to

be confirmed by experts. Two experts in the field of the sustainable supply chain who have 10–22 years of experience were interviewed on this research. The research methodology adopted in this paper is shown in Fig. 1. The analysis was conducted on retrieved literature from the Scopus database on 16 August 2020. We focus on the Scopus database, as Scopus is the largest database of peer-reviewed research literature in the field of science, technology, medicine, social science, and the arts and humanities. It comprises 20,000 peer-reviewed journals including those published by Elsevier, Emerald, Informs, Taylor and Francis, Springer, and Inderscience (Fahimnia et al. 2015).

Stage 1: Defining the search (rules)

First, we define four topics or rules for data collection, namely *logistics and supply chain*; *green, sustainability, and environment*; *technologies*; and *inventory control*. For each topic, there are several keywords used as shown in Table 1.

Stage 2: Initial search

Using these keywords for each topic, we inputted the combination of keywords (Rule 1 AND Rule 2 AND Rule 3 AND Rule 4) in the search column and "Article title, Abstract, Keywords" search in the Scopus database. We searched with document type "All" (include articles, conference papers, books, chapters of book, review, letter, note, etc.), years of publication "All years" and access type "All" (include open access). The initial search attempts resulted in 4849 articles from 1965 to 2020. We tried to ensure that all aspects of technologies on sustainable inventory and green supply chain management were fully captured.
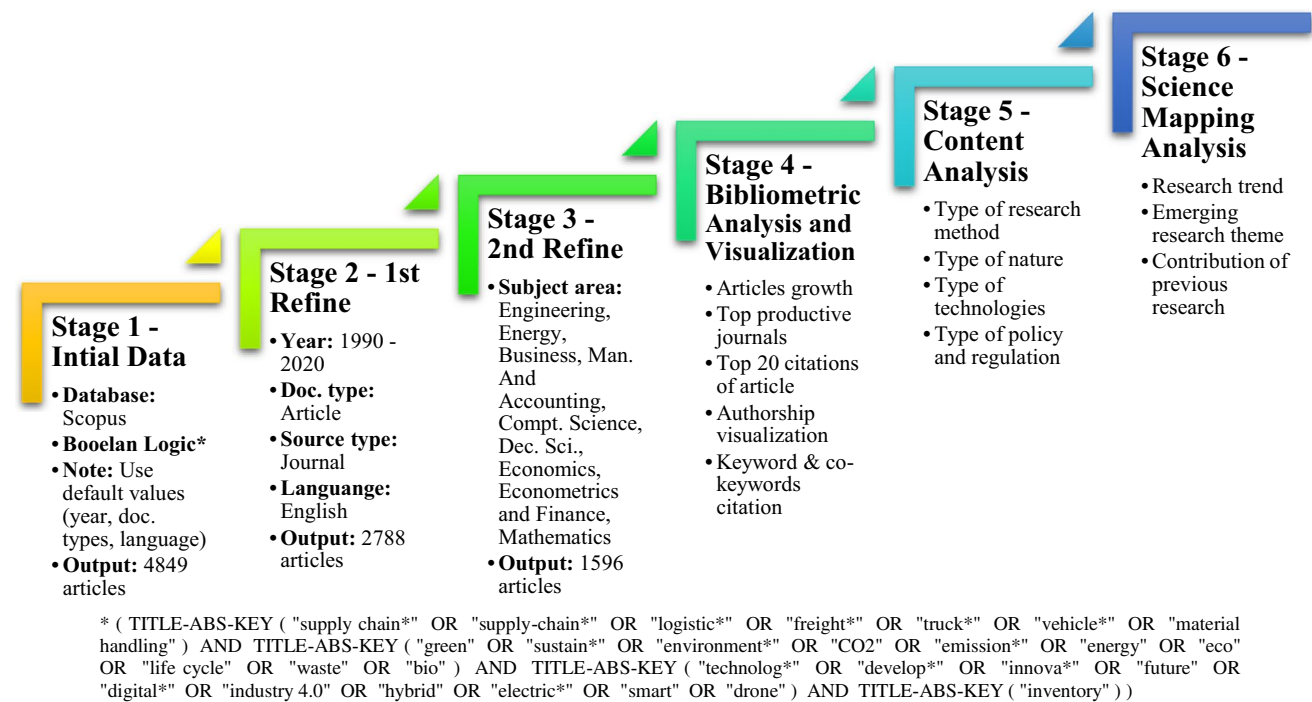

* (TITLE-ABS-KEY ("supply chain*" OR "supply-chain*" OR "logistic*" OR "freight*" OR "truck*" OR "vehicle*" OR "material handling") AND TITLE-ABS-KEY ("green" OR "sustain*" OR "environment*" OR "CO2" OR "emission*" OR "energy" OR "eco" OR "life cycle" OR "waste" OR "bio") AND TITLE-ABS-KEY ("technolog*" OR "develop*" OR "innova*" OR "future" OR "digital*" OR "industry 4.0" OR "hybrid" OR "electric*" OR "smart" OR "drone") AND TITLE-ABS-KEY ("inventory"))

Fig. 1 Stages of bibliometric analysis on technologies for sustainable logistics and supply chain research

Table 1 Rule, topic, and keywords

Rule	Topic	Keywords
1	Logistics and supply chain	"supply chain*" OR "supply-chain*" OR "logistic*" OR "freight*" OR "truck*" OR "vehicle*" OR "material handling"
2	Green, sustainability, and environment	"green" OR "sustain*" OR "environment*" OR "CO2" OR "emission*" OR "energy" OR "eco" OR "life cycle" OR "waste" OR "bio"
3	Technologies	"technolog*" OR "develop*" OR "innova*" OR "future" OR "digital*" OR "industry 4.0" OR "hybrid" OR "electric*" OR "smart" OR "drone"
4	Inventory control	"inventory"

Stage 3: Second search

Out of 4849 articles from the initial screening, many papers appeared in multiple categories, so we refined with document type "article" (excluding conference papers, books, chapters of book, review, letter, note, etc.), years of publication "1990–2020" and source type "journal" and language "English." This sifted the articles and left a total of 2788 articles.

Stage 4: Third search (last refinement)

In the last refinement, we limited the search to the subject area "Engineering, Energy, Business, Management and Accounting, Computer Science, Decision Science, Economics, Econometrics and Finance, Mathematics" and we found a total of 1596 articles. Table 2 shows the summary stages 1 to 4.

Bibliometric analysis and visualization

Article growth and trend analysis

The growth in the number of articles in the annual publication on sustainable inventory and green supply chain from 1990 to 2020 is illustrated in Fig. 2, which shows an exponential trend. The total number of articles published annually reached a peak of 189 in 2019. Even though the data was downloaded from the Scopus database in August 2020, the figure shows an increase in the next 4 months with a slope $y = 2.0804e^{0.1525x}$. By the end of 2020, it is projected that there will be 235 articles. It indicates that the interest in this research is growing and developing rapidly.

Top 30 productive journals

Table 3 shows the 30 journals that have published the largest numbers of papers from 1990 to 2020. We divided them into five periods, with the first period stretching from 1990 to 2000 and the last period from 2016 to 2020. The top five

Table 2 The search results by step

Step	Combination	Refine	Number of papers
1st	Rule 1 AND Rule 2 AND Rule 3 AND Rule 4	Year: 1965–present Doc. type: all Source type: all Language: all	4849
2nd	Rule 1 AND Rule 2 AND Rule 3 AND Rule 4	Year: 1990–2021 Doc. type: article Source type: journal Language: English	2788
Final	Rule 1 AND Rule 2 AND Rule 3 AND Rule 4	Subject area: Engineering, Energy, Business, Man. And Accounting, Compt. Science, Dec. Sci., Economics, Econometrics, and Finance, Mathematics	1596

Fig. 2 Annual publication growth and trend related to technologies on sustainable inventory and green supply chain management
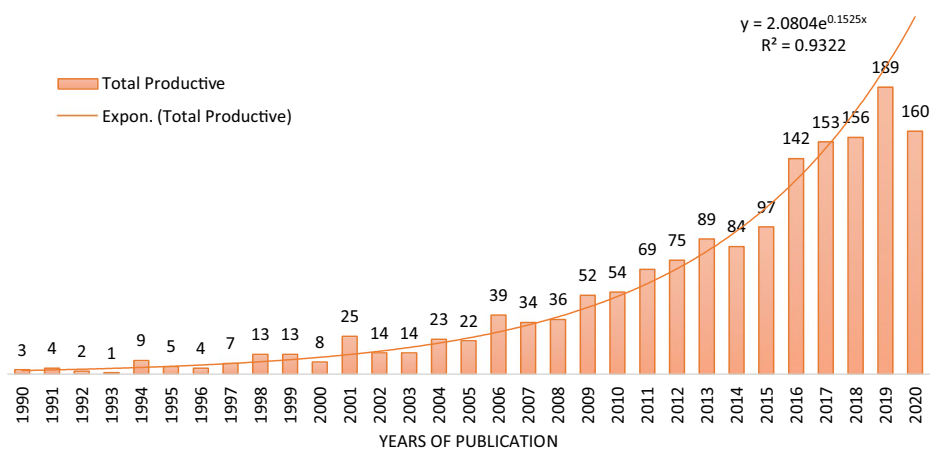
Table 3 The top 30 leading journals since 1990 to 2020

Rank	Journal name	90–00	01–05	06–10	11–15	16–20	TP
1	*Journal of Cleaner Production*	0	1	3	15	99	118
2	*International Journal of Production Economics*	4	6	16	24	28	78
3	*Transportation Research Part D: Transport and Environment*	5	3	3	17	27	55
4	*International Journal of Production Research*	2	5	8	12	22	49
5	*Sustainability (Switzerland)*	0	0	0	6	41	47
6	*Computers and Industrial Engineering*	7	1	10	7	21	46
7	*European Journal of Operational Research*	1	8	14	7	14	44
8	*Applied Energy*	0	2	0	13	18	33
9	*Energy Policy*	0	0	3	16	9	28
10	*International Journal of Supply Chain Management*	0	0	0	4	17	21
11	*Resources, Conservation and Recycling*	1	1	2	4	12	20
12	*Energy*	0	0	1	6	10	17
13	*Production Planning and Control*	4	4	5	2	1	16
14	*International Journal of Advanced Manufacturing Technology*	0	1	3	9	2	15
15	*International Journal of Logistics Systems and Management*	0	1	4	2	7	14
16	*Applied Mathematical Modeling*	0	0	0	7	7	14
17	*Interfaces*	0	1	6	4	2	13
18	*Supply Chain Management: An International Journal*	2	3	5	2	1	13
19	*Energies*	0	0	0	2	10	12
20	*Manufacturing and Service Operations Management*	0	4	2	2	3	11
21	*Annals of Operations Research*	0	0	1	1	9	11
22	*Management Science*	2	2	3	3	0	10
23	*Expert Systems with Applications*	0	0	3	4	3	10
24	*Industrial Management and Data Systems*	1	1	4	1	3	10
25	*Omega*	0	0	1	2	7	10
26	*Journal of Operations Management*	3	1	3	1	2	10
27	*Transportation Research Part E: Logistics and Transportation Review*	0	0	2	5	3	10
28	*Computers and Operations Research*	0	1	1	3	4	9
29	*Journal of Manufacturing Technology Management*	0	0	7	1	1	9
30	*International Journal of Physical Distribution and Logistics Management*	0	3	1	3	2	9
	Total	**32**	**49**	**111**	**185**	**385**	**762**

Ranking based on the total productive of the journal. *TP*, total productive per journal

leading journals identified are *The Journal of Cleaner Production* (118), *International Journal of Production Economics* (78), *Transportation Research Part D: Transport and Environment* (55), *International Journal of Production Research* (49), and *Sustainability* (Switzerland) (47), which together accounted for 45.54% of the total selected publications. Interestingly, the second-ranked journal, *Sustainability* (Switzerland), has published 41 papers during the last 5 years, which indicates the journal's growing interests.

Top 20 most cited articles

Table 4 shows the twenty most frequently cited articles from 2010 to 2020. The number one cited publication was Benjaafar et al. (2013), which studies the effect of carbon emission policy, such as carbon emission tax, inflexible cap, the cap-and-trade on a single-level lot-sizing model (EOQ model), with 569 citations in seven years or 81.29 citations per year (C/Y). The second most cited publication was Pradhan and Lee (2010), which presents a landslide survey analysis in Malaysia, with 466 citations and a C/Y score is 46.60 (466 citations in 10 years). The assessment involves neural networks of 398 landslide locations, whose 80% of the data was taken before 2004 and the remaining 20% taken post-2004. The third most cited article was Dekker et al. (2012), which presents a review of the contribution operations research to green logistics, focusing on design, planning, and control in a supply chain for transportation, inventory, and facility decisions, with 443 citations in eight years (55.38 C/Y scores),

Table 4 The top 20 citations of the article since 2010 to 2020

Rank	Authors' name	Year	The objective of the article	Journal name	TC	C/Y
1	Benjaafar et al	2013	Analysis and modeling of the relationship between simple inventory decision variables and carbon emissions in sustainable supply chains	*IEEE Trans. Autom. Sci. Eng*	569	81.29
2	Pradhan and Lee	2010	Assessment of Malaysia's susceptibility to landslides based on bivariate logistic regression models using frequency ratios and GIS and remote sensing data	*Environ. Model. Softw*	466	46.60
3	Dekker et al	2012	Reviewed of several papers which are studies related to greenhouse gas emissions, noise and accidents in logistics operations on aspects of economic, environmental, and social	*Eur J Oper Res*	443	55.38
4	Graham-Rowe et al	2012	A qualitative analysis was performed to capture consumer reactions, attitudes, affective, and behaviors towards electric vehicles that reflect the future consumers and reveal barriers to motivation for electric vehicle adoption	*Transp. Res. Part A Policy Pract*	289	36.13
5	Kennedy et al	2010	Development of a methodology for determining greenhouse gas emissions from cities. This method clarifies important details such as explicit identification of power line losses, inclusion of emissions from air and sea transport, and consistent determination of waste emissions	*Energy Policy*	244	24.40
6	You and Wang	2011	Developed an optimal design for the biomass-to-liquid (BTL) supply chain, taking into account total annual costs and greenhouse gas emissions throughout the life cycle	*Ind. Eng. Chem. Res*	244	27.11
7	Psaraftis and Kontovas	2013	Provided a taxonomy and survey of speed models in maritime transportation that ship speed is a key determinant to both shipping economics and environmental	*Transp. Res. Part C Emerg. Technol*	235	33.57
8	Jaber et al	2013	Development of a two-stage supply chain mathematical model that takes into emissions trading. The aim of the developed model is to minimize the total cost by determined the optimal production rate taking into account emission limits, penalties for exceeding emission limits and the capital invested to increase emissions limit	*Int J Prod Res*	226	32.29
9	Bouchery et al	2012	Proposed a multi-objective formulation of the EOQ model called the Sustainable Order Quantity (SOQ) model. The model considers a multi-echelon extension of the SOQ model	*Eur J Oper Res*	199	24.88
10	Kenné et al	2012	Developed a stochastic dynamic model to optimize the performance of a forward-reverse logistics network. The model considered a relationship between the market for releasing second-hand products and the market for "new" products	*Int J Prod Econ*	177	22.13
11	Rakopoulos et al	2011	Performed experimental tests in the laboratory of bus / truck turbo diesel engines to investigate the mechanism of nitrogen oxide (NO) formation, smoke, and combustion noise emissions during hot start of various alternative fuel mixtures	*Appl. Energy*	164	18.22
12	Yang et al	2015	Assessing the CO_2 footprint on a particular percentage of the concrete mixture and determining the impact of additional cement-based materials on reducing CO_2 emissions during concrete production. CO_2 emissions from concrete manufacturing were assessed using the ISO14040 series lifecycle method	*J. Clean. Prod*	157	31.40

Table 4 (continued)

Rank	Authors' name	Year	The objective of the article	Journal name	TC	C/Y
13	Wang and Li	2012	Development a mathematical model that maximizing profit by optimilize the retailer's prices for perishable food products	*Omega*	153	19.13
14	El Saadany and Jaber	2010	Developed mathematical models involving remanufacture and waste disposal to determine the optimal acceptable quality level and price of used items collected for recovery and minimize the cost of the entire system	*Comput Ind Eng*	152	15.20
15	Zhong et al	2017	Demonstrated big data analysis of RFID-enabled logistics from RFID readers, tags, and intelligent environments created with wireless communication networks in production shop floor	*Int J Prod Res*	148	49.33
16	Notarnicola et al	2017	Performed a comprehensive assessment of the environmental impact of food consumption based on the Life Cycle Assessment (LCA) approach of product shopping carts at EU level food consumption. The study focused on indicators that measure the environmental impact of consumption of goods and services by the average European citizen	*J. Clean. Prod*	145	48.33
17	Sana	2010	Proposed a production–inventory model in an imperfect production process. The production cost in their model is a function of production rate and product reliability parameters. The integrated profit function with the effects of inflation and the time value of money is maximized by the Euler–Lagrange method	*Eur J Oper Res*	144	14.40
18	Dubarry et al	2011	Design of experiments on the aging behavior of a "nominal sample cell" (NSC) that circulates at a rate of 2 C. This study uses electrochemical characterization and Incremental Capacity Analysis to derive temporally resolved information on how cells deteriorate under the cycle aging conditions	*J Power Sources*	130	14.44
19	Clavreul et al	2014	Development of a new holistic framework that allow for the modeling of highly heterogeneous material flows with large variations in physical parameters and chemical properties	*Environ. Model. Softw*	127	21.17
20	Azevedo et al	2012	Investigated the deployment of green, lean upstream SCM practices and how these practices affect a company's sustainable development by impacting its economic, social, and environmental performance	*IEEE Trans Eng Manage*	126	15.75

Ranking based on the total citation per article. *TC*, total citations per article; *C/Y*, total citations/year

Co-authorship visualization analysis

After examining the general results concerning the article growth and trend, top productive journals, and top 20 most cited articles, the next analysis is on the co-authorship, co-occurrence of keywords, countries, and citation based on organizations (journals). VOSviewer software illustrates the visualization of these outputs.

To be mapped in Fig. 3, the network of authors is determined with a threshold of minimum of three documents per author. The 1596 articles were contributed by 4135 authors and co-authors, which represents the collaboration cluster. Out of the five productive researchers, namely Jaber, M.Y.,

Wee, H.M., Zanoni, S., Zhang, Y., Li, Y., and Wang, X, as shown in Fig. 3, the leading author is Jaber M.Y. from Ryerson University, Canada. From the data in Table 4, although the article by Jaber et al. (2013) was not the most cited, Jaber M.Y. was the most prolific with 24 articles published, and he is also connected with Zanoni, S., Zavanella, L.E., El Saadany, A.M.A., Marchi, B., Khan, M., and Bazan, E. The second productive author is Wee, H.M. from Chung Yuan Christian University (CYCU), Taiwan, with 15 articles published, whose research studies were linked to Wangsa, I.D., Yang, P.C., Chung, C.J., Tiwari, S., Jaggi, C.K., and Sarkar, B. Other researchers were linked to one of these main researchers. As such, it could be said that Jaber, M.Y.,
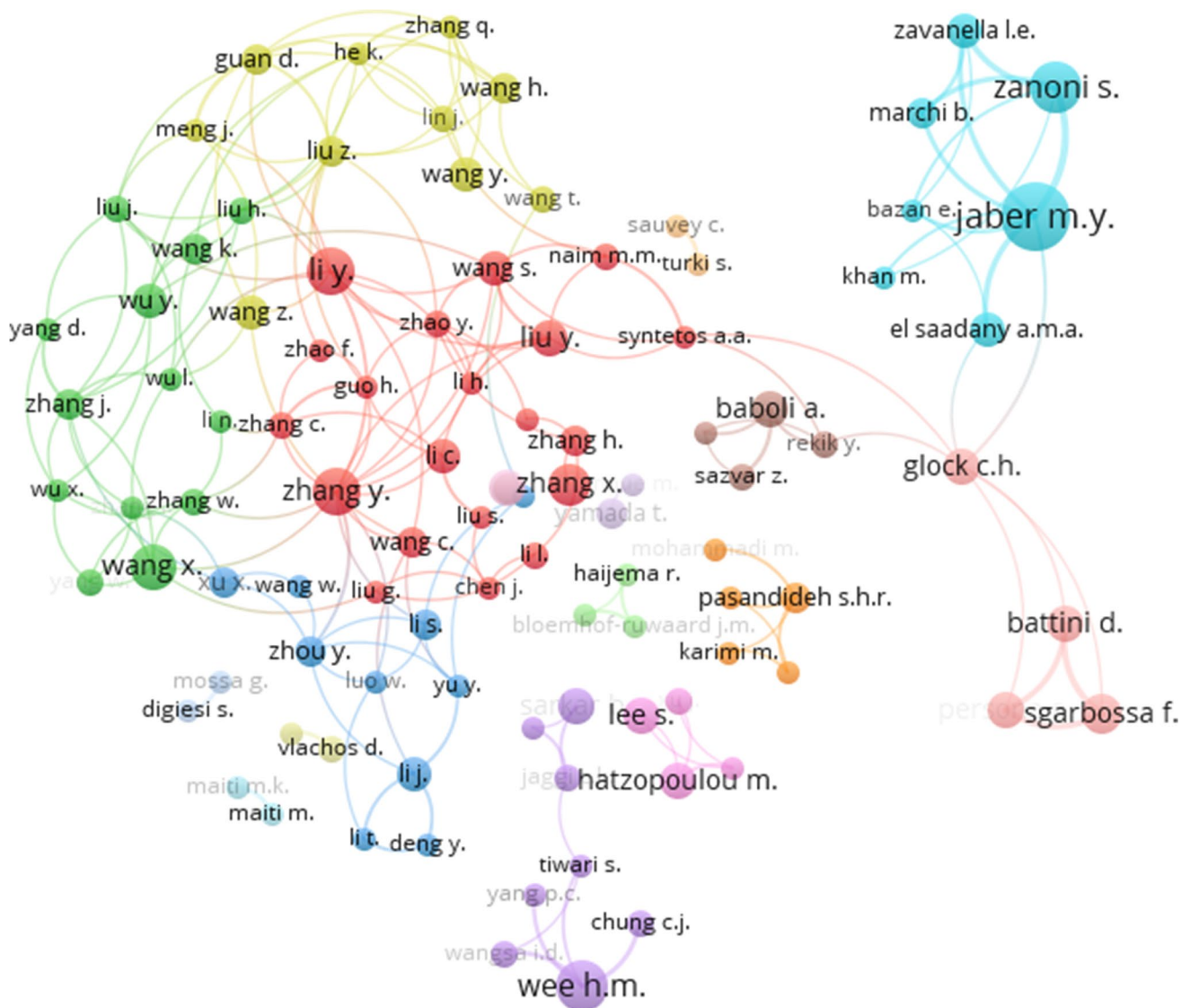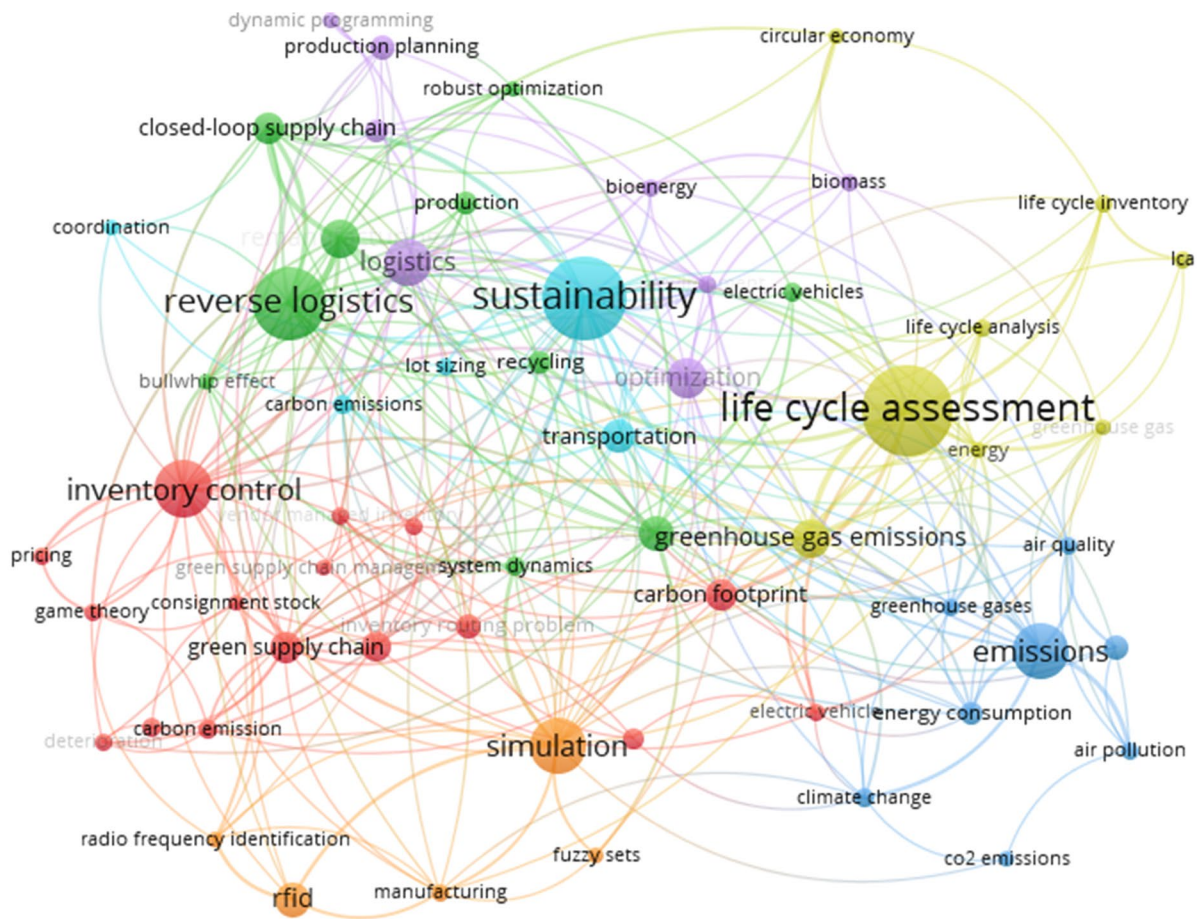
Fig. 3 Authors network visualization was based on total document

Wee, H.M., Zanoni, S., Zhang, Y., Li, Y., and Wang, X. are the leading authors in this area.
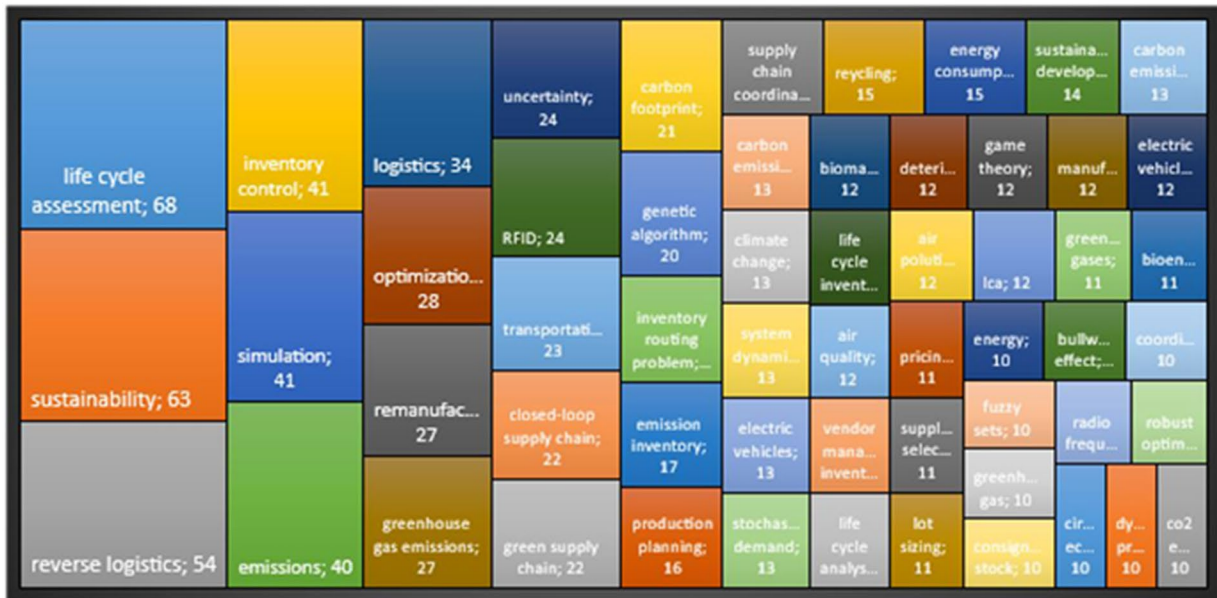
Author's keywords visualization analysis

Keywords represent the characteristic or specific field of study documents are associated with in an information system. In the data, the keywords are divided into two types: the author and the index. The author keywords are created by authors in the journal system and the index keywords are generated by the Scopus database system. The most frequent author's keywords in the selected articles and presented in clusters of circles are visualized in Fig. 4a. The network of keywords in this research has a threshold of a minimum of 10 occurrences. The data shows that the 1596 articles have 4449 different keywords. The size of the circles represents the network of keywords based on the total occurrences. The size of the circle in each cluster depicts the numbers of articles captured by the main keywords and the cluster is depicted in yellow, blue, green, red, and orange. Figure 4b presents a visual report of keywords that appear 10 times or more. The top five author's keywords are "life cycle assessment" which appeared 68 times, "sustainability" 63 times, "reverse logistics" 54 times, "inventory control" 41 times, and "simulation" 41 times. Figure 4b reports the results of Fig. 4a. These clusters are commonly found in articles on green logistics, sustainable supply chain, and technologies on inventory management.

a)

b)

Fig. 4 Authors' keywords were based on total occurrence: **a** authors' keyword network visualization; **b** authors keywords map

Content analysis

The content analysis aims to confirm different classifications covered by Scopus, which generates five main classes: (1) type of research method; (2) type of nature (conditions); (3) type of technologies; and (4) type of policies and regulations.

Types of research method

Generally, the research method was classified into modeling, case study research, conceptual framework, empirical study, and literature review. Figure 5a shows the classification of the articles based on the research method categories and its shares. The figure shows that the modeling makes up 54.45% of the total articles (869 out of 1596), case studies 18.86% (301 out of 1596), conceptual framework 17.79%, empirical study 6.89%, and literature review 2.01%.

According to Kazemi et al. (2019), the modeling method can be highlighted into several subject solution methodologies. In this paper, the methodologies were analyzed and classified into the type of methods applied: (1) analytical

or mathematical model; (2) simulation and metaheuristic approach. Figure 5b shows that the predominant model is the mathematical model, used in 593 articles (68.24%). Simulation and metaheuristic approach appeared only in 276 articles (31.76%). The classification of the analytical (mathematical) model into eight classes is shown in Fig. 5c. Out of all articles, 593 articles that used mathematical models include a wide variety of sub-categories, such as non-linear programming, linear programming, mixed-integer programming, fuzzy, dynamic programming, integer programming, Markov chain, and other optimizations. However, there are also several authors using simulation and metaheuristic approaches. In contrast to mathematical programming, this approach is simulated by models programmed using computer software to derive the problem solutions, which is a near-optimum compared to a mathematical optimization approach. This approach is also often used to solve problems dealing with uncertainty (Kazemi et al. 2019). The papers in the current review can be classified into 12 sub-categories: discrete-event simulation, genetic algorithm, agent-based simulation, simulated annealing, particle swarm optimization, artificial neural network, tabu search, machine learning,

Fig. 5 **a** Classification of research method; **b** modeling; **c** analytical (mathematical) model; and **d** simulation & metaheuristic approach

differential evolution algorithm, harmony search, memetic algorithm, and others simulation, as shown in Fig. 5d.

In this part of the study, based on the classification results above obtained, from 869 modeling articles, we investigated further our results and classified become into (i) objective function, (ii) decision variable, and (iii) system characteristic. Figure 6 shows that the minimum cost is the dominant of the objective goal from articles 78.88%. Out of all articles, the objective of maximum profit and minimize emission are around 15.36% and 5.76% respectively. The variable of lot size (order quantity) is the highest keyword used by authors in the articles, there are 240 keywords. The second till ten variables are used by authors, i.e., price of product,
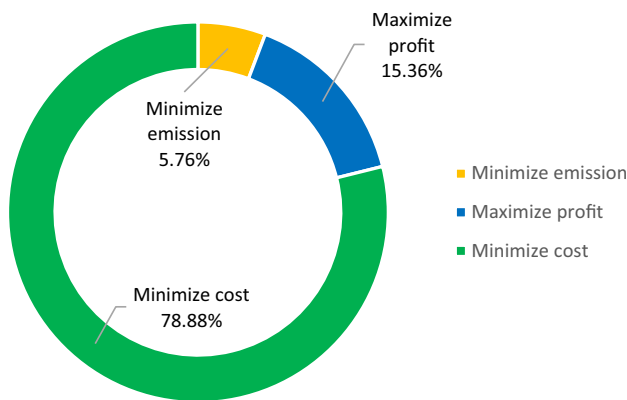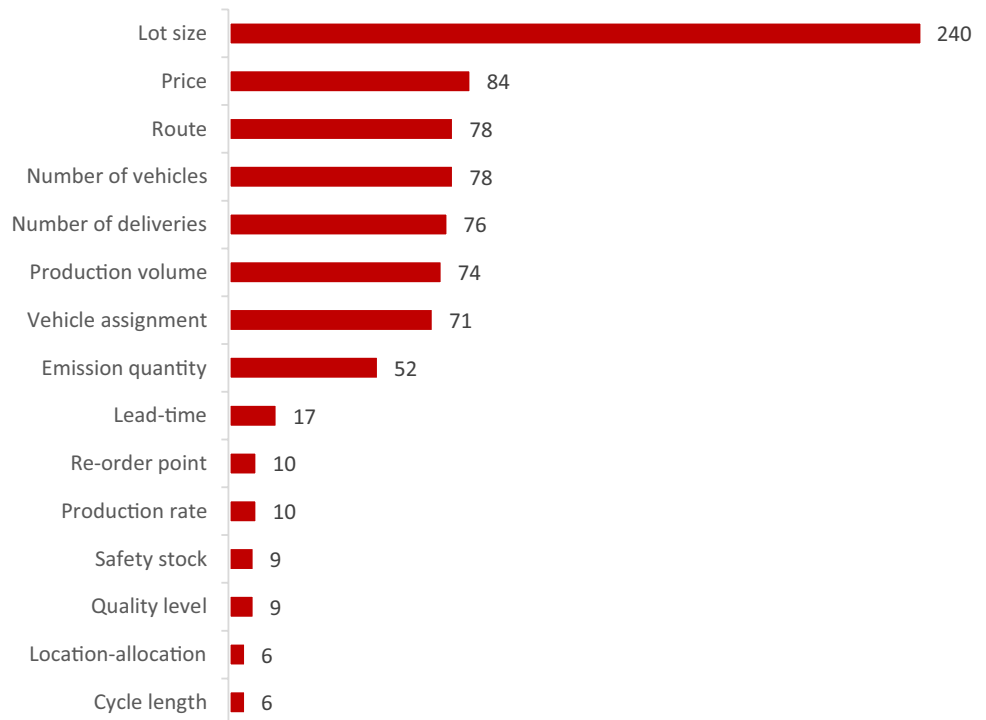
route (vehicle routing cases), number of vehicles, number of deliveries, production volume, vehicle assignment, emission quantity, lead time, and re-order point as presented in Fig. 7. Figure 8 shows the specific parameter characteristic of the system developed by authors in the articles. The characteristics such as sustainability, reverse logistics, fuzzy, VMI contract, shortage, lead time, imperfect quality, deteriorating items, and consignment contracts are used by authors in the articles.

Types of nature (conditions)

The next process is to classify 1596 articles based on the environmental phenomena in the research shown in Fig. 9, which yielded four categories, namely deterministic, probabilistic, stochastic (uncertainty), and not defined. Based on the classification, stochastic (uncertainty) is predominant as it is found in 587 articles (36.78%), followed by probabilistic and deterministic found in 298 articles (18.67%) and 174 articles (10.90%) respectively.

Types of Industry 4.0 technologies

At this stage, we classified the research topics based on the technologies used. The combustion energy such as fossil fuels, coal, and fuel-related energy sources was used in 395 articles, which makes it the most discussed. The second most discussed type of energy (appeared in 121 articles) is

Fig. 6 Classification of objective function based on modeling articles

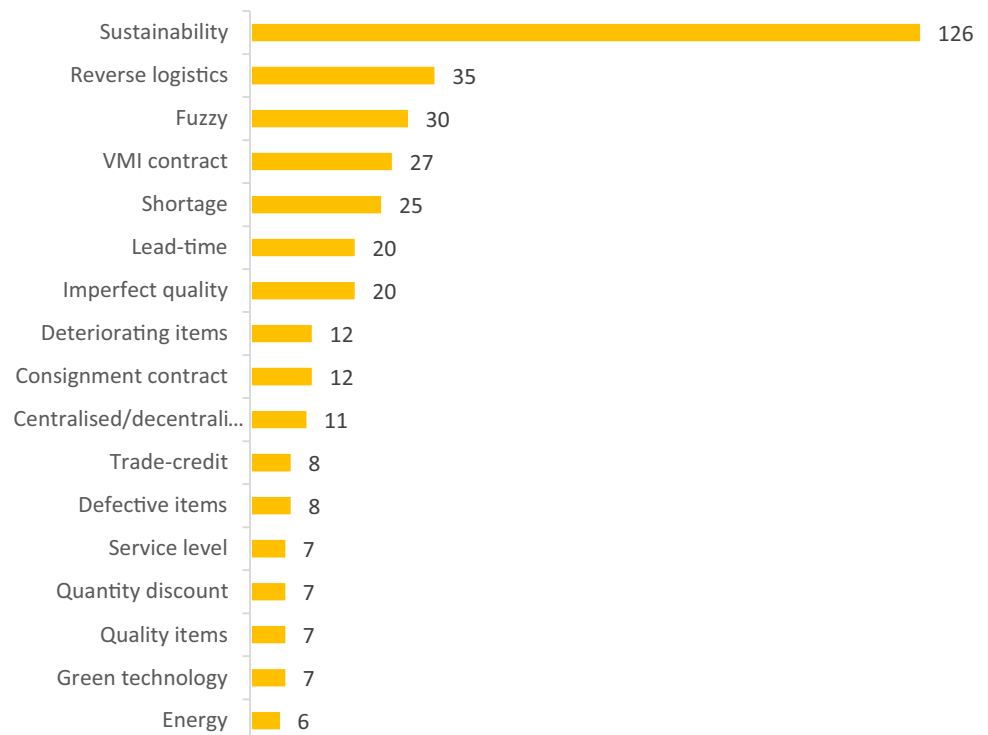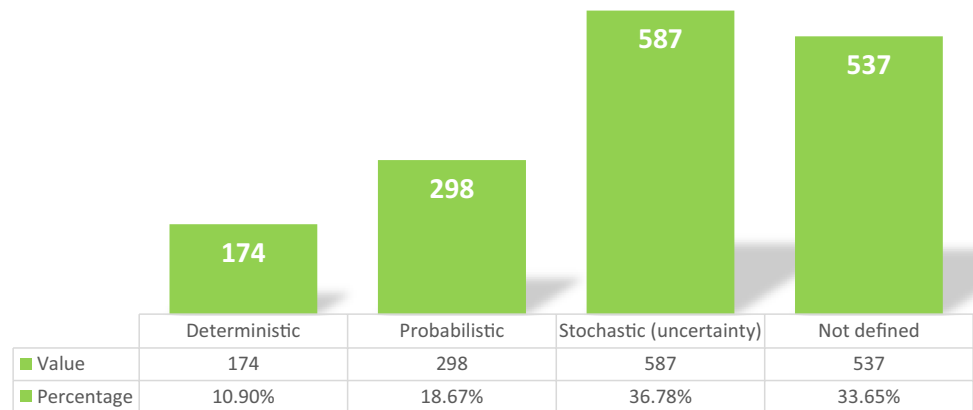**Fig. 7** Classification of decision variable based on modeling articles

Fig. 8 Classification of the characteristic of a system based on modeling articles

Category	Value
Sustainability	126
Reverse logistics	35
Fuzzy	30
VMI contract	27
Shortage	25
Lead-time	20
Imperfect quality	20
Deteriorating items	12
Consignment contract	12
Centralised/decentrali...	11
Trade-credit	8
Defective items	8
Service level	7
Quantity discount	7
Quality items	7
Green technology	7
Energy	6

Fig. 9 Classification of nature (conditions)

	Deterministic	Probabilistic	Stochastic (uncertainty)	Not defined
Value	174	298	587	537
Percentage	10.90%	18.67%	36.78%	33.65%

the renewable ones such as wind energy, biofuels, and solar energy.

Industry 4.0 technologies can be grouped into physical and digital technologies (Bai et al., 2020). In recent years, many physical and digital technologies were proposed to be incorporated into the logistics systems. Physical technologies can be defined as technologies related to hardware that can be operated by the operator. Physical technologies in this research consist of the case study, conceptual framework, and modeling. Several studies on physical technologies in manufacturing and logistics can be seen as additive manufacturing or 3D printing technology (Gibson et al. 2014; Ghadge et al. 2018; Ransikarbum et al. 2020; Boer et al. 2020), electric vehicles (EVs) technology (Taefi et al. 2016; Duarte et al. 2016; Schulte and Ny 2018), cargo bikes

(Perboli et al. 2016), autonomous vehicles (Stogios et al. 2019; Gelareh et al. 2013), and unmanned aerial vehicles (drone) technology (Murray and Chu 2015; Morrar et al. 2017). However, these technologies can only be integrated into a certain business and its operation. Meanwhile, digital technologies are related to software and mainly refer to information and communication technologies. These technologies are mostly in applications, such as intelligent transportation system (Basbas and Bouhouras 2008), big data analysis (Strandhagen et al. 2017; Tiwari et al. 2018b), radio frequency identification (Cui et al. 2017; Oya et al. 2018; Guchhait et al. 2019; Usama and Ramish 2020; and Ullah and Sarkar 2020), IoT (Melo et al. 2019), blockchain technology (Cole et al. 2019; Dutta et al. 2020; and Manupati et al. 2020), and cloud computing platform (Subramanian

et al. 2014). Figure 10 presents the category of keywords are related to Industry 4.0 technologies, such as electric vehicles (87 articles), RFID (55 articles), IoT (22 articles), autonomous vehicle (11 articles), 3D printing (7 articles), unmanned aerial vehicle or drone (6 articles), and hybrid technology (3 articles). The following are some definitions of these technologies that is currently developing as shown in Table 5.

Types of policies and regulations

At this stage, we grouped the 1596 selected articles with regard to policies and regulations. According to Tian et al. (2018), keywords used by the authors to identify the policies and regulations include "energy policy"; "transportation policy"; "sustainability policy"; "environmental policy"; and "economic policy". Figure 11 shows the classification of policies and regulations based on the author's keywords. A detailed description of the categories is as follows:

Energy policy

The energy policy was dominated by keywords related to fuels and renewable energies, such as natural gas, wind energy, solar energy, and biofuel. As shown in Fig. 11a, there are 103 out of 1596 articles (6.45%) mentioning energy policy keywords. Articles that discuss both energy and supply chain are Wangsa et al. (2018), Nouiri et al. (2020), Jauhari et al. (2020), and Marchi et al. (2019, 2020).

Transportation policy

There are proposals on the use of certain modes of transportation and logistics aiming at improving sustainability. On land, freight consolidation, last mile,

and trucking appeared in 60.31% of the total articles; marine transportation in 28.31% of the total articles; train transportation in 8.31% of the total articles; air transportation in 1.85% of the total articles; and pipeline transportation in 1.23% of the total articles. The percentages are presented in Fig. 11b. Freight transportation, warehousing, and reverse logistics are three major outsourced logistics activities (Ameknassi et al. 2016). To reduce global warming in the transportation sector, an outsourcing strategy can be applied and compared to common logistics operations (Facanha and Horvath, 2005).

Sustainability policy

There are seven strategies/regulations in the sustainability policy category as shown in Fig. 11c. Keywords include "carbon tax"; "carbon cap"; "carbon cap-and-trade"; "carbon penalty"; "carbon penalty and incentive"; "green investment"; and "life cycle assessment". The life cycle assessment (LCA) strategy was found in 53.69% of the total articles. Regulations such as carbon tax, carbon cap, and carbon cap-and-trade have been effective in reducing the carbon emissions in inventory models (Benjafaar et al. 2013). Benjafaar et al. (2013) defined several of these strategies, such as "carbon tax." The carbon tax strategy is a strategy for companies or related entities that pay taxes on the amount of emissions generated in the carbon market system (carbon trading). In addition, an obligation to reduce/limit carbon emissions can be imposed on each market participant, which is known as the "carbon cap" strategy. In general, a carbon cap is applied in the form of allowances at the beginning of the period. At the end of the period, market participants must report their actual emissions to a spe-

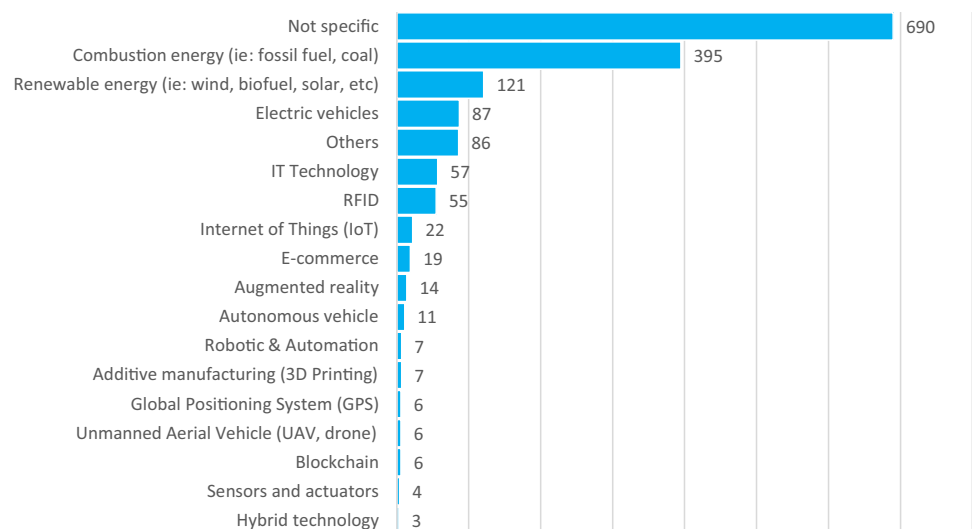**Fig. 10** Type of Industry 4.0 technologies

Technology	Count
Not specific	690
Combustion energy (ie: fossil fuel, coal)	395
Renewable energy (ie: wind, biofuel, solar, etc)	121
Electric vehicles	87
Others	86
IT Technology	57
RFID	55
Internet of Things (IoT)	22
E-commerce	19
Augmented reality	14
Autonomous vehicle	11
Robotic & Automation	7
Additive manufacturing (3D Printing)	7
Global Positioning System (GPS)	6
Unmanned Aerial Vehicle (UAV, drone)	6
Blockchain	6
Sensors and actuators	4
Hybrid technology	3

Table 5 Definition of the emerging of technologies

| Technology	Definition	Source
3D printing (additive manufacturing)	A technology that creates 3D (three-dimensional) solid objects with additive or layered materials.	Gibson et al. (2014)
Artificial intelligent	A field of computer science that focuses on the development of intelligent machines that function and react like humans.	ElMaraghy and Ravi (1992)
Augmented reality	Reality-based interactive displays using computer capabilities.	Wan et al. (2015)
Autonomous robots (robotics)	Robots are used to imitate and support human activities. This robot is often used for things beyond human capabilities.	Wan et al. (2015)
Autonomous vehicle (self-driving car)	The autonomous vehicle is a vehicle that is controlled by a computer system. Autonomous vehicles can reduce traffic congestion, air pollution and fuel consumption, as well as reduce accidents and improve driving safety.	Bezai et al. (2020) and Stogios et al. (2019)
Big data and analytics	Refers to strategies for analyzing large amounts or volumes of data. Traditional data processing analysis cannot reveal the insights and meaning of this vast amount of data.	Strandhagen et al. (2017)
Blockchain technology	A distributed database system that manages transaction data and is secured with a new cryptography and managed by a consensus mechanism.	Cole et al. (2019)
Cloud computing system	Refers to information technology (IT) services provided and accessed by cloud computing providers.	Wan et al. (2015)
Cobotic system	Robots designed to physically interact with humans.	Moulières-Seban et al. (2017)
Cybersecurity	Security and prevention methods are used to prevent the theft of data and information.	Lu (2017)
Electric vehicles	A vehicle that is fully driven on electric power, so it requires a battery to store the source of electrical energy.	Schulte and Ny (2018)
Global positioning system (GPS)	An application is connected to the satellite and is used to transmit precise signals related to data of location, speed, and time.	Strandhagen et al. (2017)
Internet of things (IoT)	Various sets of hardware working together through internet connectivity to improve industrial processes.	Lu (2017)
Mobile technology	Wireless communication technology.	Lu (2017)
Radio frequency identification (RFID)	Wireless communication technology connected between an object (tag) and a tracker (reader) to determine the position and identify the object automatically and accurately.	Strandhagen et al. (2017)
Sensors and actuators	Hardware that responds to physical stimuli (such as heat, sound, pressure, magnetism, or certain movements) and transmits data in the form of measurement results.	Teucke et al. (2018)
Unmanned aerial vehicle (drone)	Unmanned aerial (pilots) and often known as a drone.	Murray and Chu (2015)
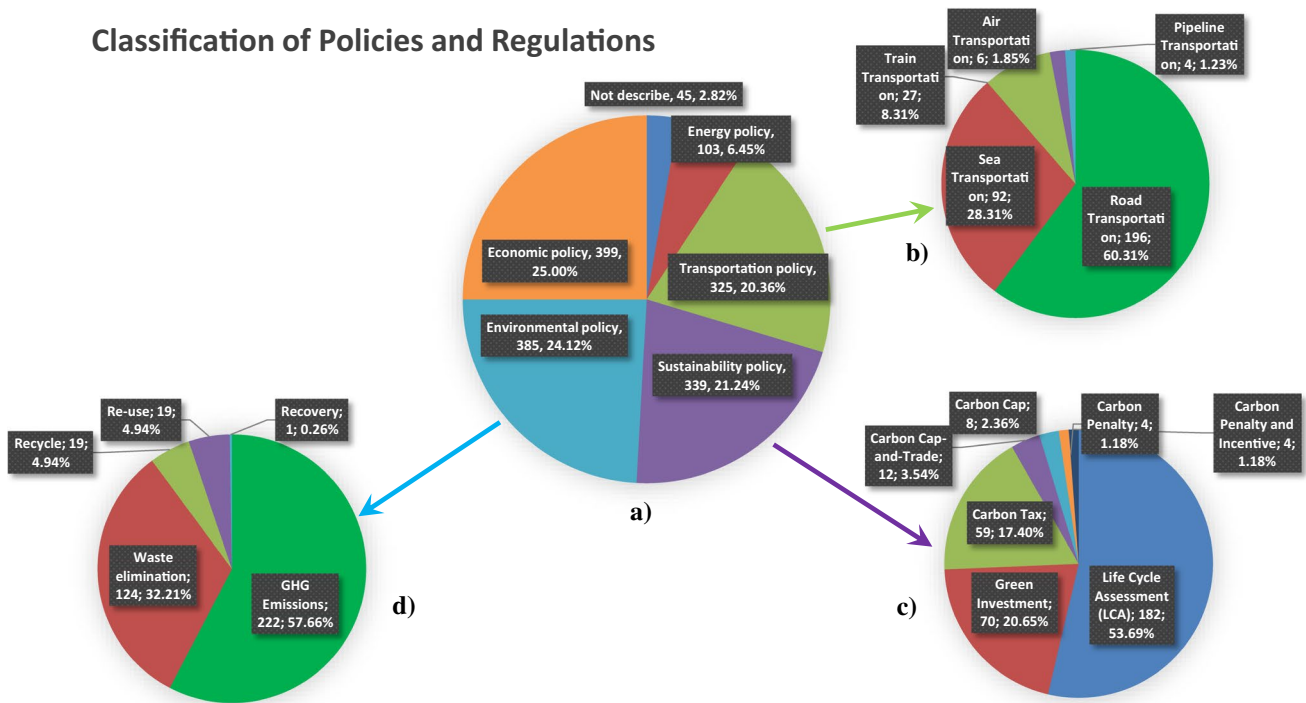
Fig. 11 **a** Type of policies and regulations; **b** transportation policy; **c** sustainability policy; and **d** environmental policy

cific authority. Participants who exceed their upper limit can purchase additional quotas from participants whose quota is not used. These data show whether the emission is too high or not. The data will also be used as a basis for establishing emission limit values in the next period (Hindarto, et al., 2018). This strategy is called the "carbon-cap-and-trade," a strategy that aims to limit carbon emissions to market participants. Thus, the "green investment" strategy can be interpreted as a strategy in which companies issue investments as a carbon compensation to reduce carbon emissions (Benjafaar et al., 2013). The investments made are, for example, forestry, development of renewable energy and others. Some of the applications of green technologies in reducing carbon emissions can be seen in Lou et al. (2015), Helmrich et al. (2015), Datta (2017), Huang et al. (2020), and Karim and Nakade (2020). Furthermore, the term "life cycle assessment (LCA)" developed in Europe and America around the 1960s and 1970s. LCA is widely used in the environmental assessment of a product (Russell et al., 2005). According to Vimpolšek et al. (2019), LCA is an analytical instrument for systematic evaluation of objectives for all product, service, or subject in the environment related to its sustainability. Larnaudie et al. (2020) explained that LCA is a method to analyze the level of sustainability in matrix form. They evaluated from an environmental and economic perspective using LCA

and techno-economic analysis (TCA). European Union has imposed penalties for vehicles that do not meet the minimum requirement (Piecyk et al., 2007). Carbon penalty and incentive strategies like this can reduce the carbon emission from the industry and transport sectors (Jaber et al., 2013; Wangsa, 2017) and so can green technology (Lou et al., 2015; Helmrich et al., 2015; Datta, 2017; Huang et al., 2020; and Karim and Nakade, 2020).

Environmental policy

Topics in this category include 3R (reuse, recovery, and recycle), greenhouse gasses (GHG) emissions, and waste elimination. Figure 11d shows discussions of this topic is dominated by GHG emissions (222 articles or 57.66%) in relation to supply chain and logistics management. Country-wise, research has been conducted to examine the practices in China (Li et al. 2016; Gao et al., 2020); the USA (Yang et al., 2016; Abolhasani and Frey, 2013); India (Baidya and Borken-Kleefeld, 2009); Brazil (Maes et al., 2019); Iran (Shahbazi et al., 2016), and Spain (Pérez-Martínez, 2012).

Economic policy

There are two policies: focusing on minimizing costs (Sardar and Sarkar, 2020; Sarkar and Giri, 2020; Lashgari et al., 2019) and maximizing profits (Cai et al.,

2019; Shaikh and Mishra, 2019) as shown in Fig. 11a. Economic policy was covered in 399 articles (25% of total articles). Almost 47.87% was conducted by using mathematical modeling. The rest consists of simulation modeling, case studies, conceptual frameworks, empirical studies, and literature reviews with the percentage of 22.56%, 14.04%, 8.27%, 4.26%, and 3.00%, respectively (Fig. 11).

Science mapping analysis

As described above, the main objective of this research is to design the science mapping of the area of sustainable supply chain and technologies. Science mapping or bibliometric mapping is a spatial representation of the relationship between disciplines, subject areas, subject areas, and documents or authors (Small 1999). To visualize the scientific mapping, we first identify the research themes using keyword co-occurrence analysis (Callon et al. 1983). Identified research topics are categorized based on their centrality and density ranking on the strategic diagram (Callon et al. 1991). Centrality measures the degree of interaction of a network with other networks. On the other hand, density measures the internal force of the network. With both measures, a research field can be visualized as a series of research topics that are mapped on a two-dimensional strategic diagram and divided into four quadrants (Cobo et al. 2011):

a) The themes in the upper-right quadrant (quadrant 1: Q1) are well developed and important to the structure of the research field. They are known as the specialty *motor themes* due to their strong centrality and high density.

b) Themes in the upper-left quadrant (quadrant 2: Q2) have well-developed internal links but unimportant external links and are therefore of marginal importance to the field. These topics are very *specialized and peripheral*.

c) Lower-left lower quadrant (quadrant 3: Q3) subjects are poorly developed and marginal. The themes in this quadrant are of low density and low centrality and represent mainly *emerging or declining themes*.

d) The topics in the lower-right quadrant (quadrant 4: Q4) are important to a research field but are not being developed. This quadrant contains general and general basic topics.

Research trend by themes

In total, 1596 publications in the period 1990–2020, this analysis shows the research trends for the subject area. Generally, the subject area is divided into two themes in this
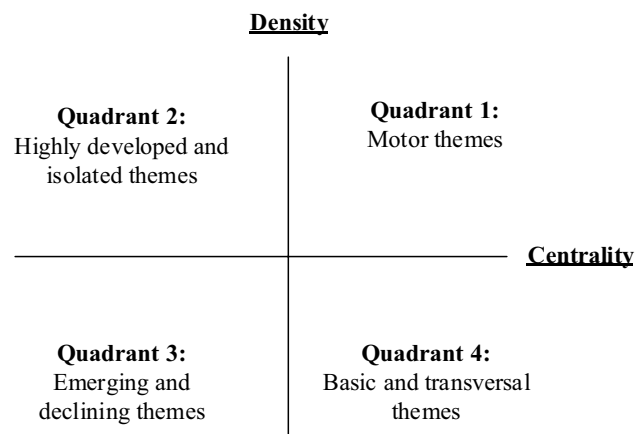
Fig. 12 The strategic diagram

study, namely the theme of the technology and the sustainable supply chain. Figures, 12, 13 and 14 show the growth trends of the top five keywords in the period 1990–2020 for each theme. These figures indicate the continuous increase in the number of publications per theme.

In Fig. 13, the milestone for the first period considers the first all-time high in terms of annual publications after a growth phase in 2009. The second period refers to the most recent maximum number of publications after a growth period of four consecutive years in 2014 and the third period to the historical maximum that the journal has reached in the year of 2016. The top 5 keywords on the theme of the sustainable supply chain are the combustion energy keywords such as fossil fuels, coal, and renewable energy (e.g., wind, biofuel, solar), electric vehicles, information technology, and RFID, respectively.

Moreover, Fig. 14 shows the annual distribution of publication based on keywords of the sustainable and environmental area. As can be seen in this figure, LCA is the most common keyword for this theme and is followed distantly by other keywords. In addition to green investment, carbon tax, carbon-cap-and-trade, and carbon cap are among the most common keywords find in studies employing the sustainable and environmental theme.

Emerging research themes

The second analysis focused on the design of the strategic diagram. Figure 15 shows a strategic diagram to analyze the most highlighted issues in this area throughout the period 1990–2020. Research topics in the strategy diagram are represented as spheres, and performance measures such as total link strength (TLS), occurrence (OCC), average publication year, logarithmic value of TLS (Log TLS), and logarithmic value of OCC (Log OCC). The themes detected in each period are analyzed considering these

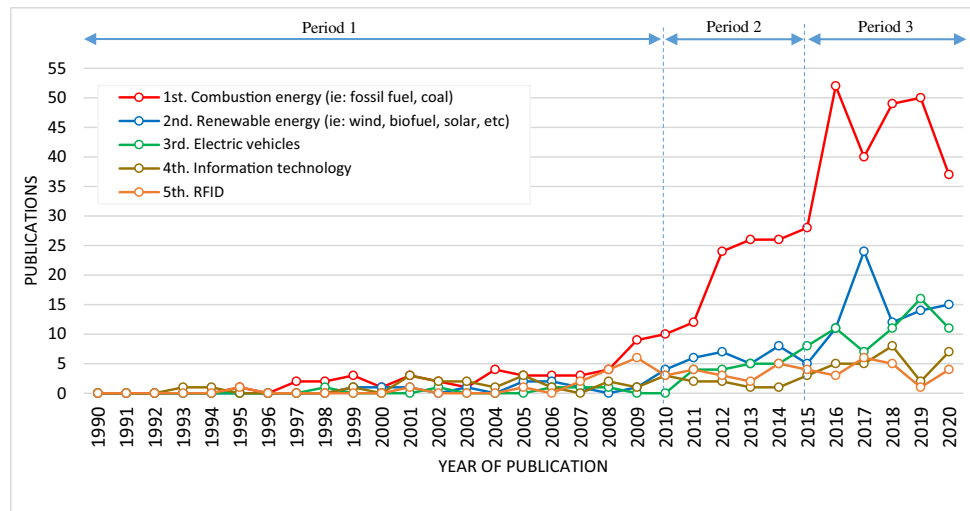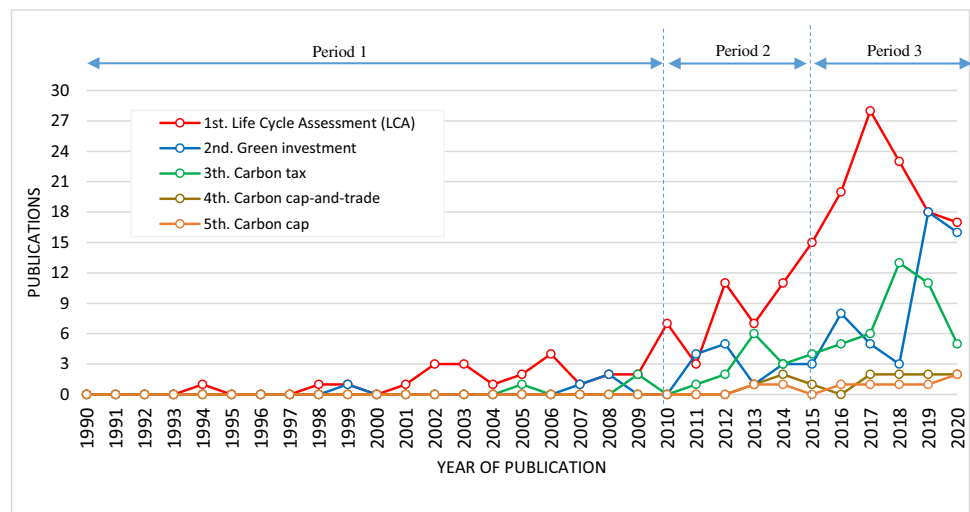**Fig. 13** Research trend by the top five on the technology theme

Fig. 14 Research trend by the top five on sustainability and environmental theme

measures. Based on all the keywords shown in Fig. 15 with the Log TLS and Log OCC values for each keyword, the average Log TLS and Log OCC values obtained are 1.385 and 1.399, respectively, where those values are density and centrality.

Based on the results of the strategy diagram, this analysis focuses on the third quadrant (lower-left quadrant). To determine the keywords that are in the third quadrant, the TLS value of each keyword is lower than the average TLS and as well as the OCC value. The keywords in the third quadrant are divided into three sub-periods, namely Q3 declining (less than 2012), Q3 semi-emerging (2012–2015), and Q3 emerging theme (over 2015) as shown in Table 6. This table shows a total of 21 keywords in quadrant 3 and the results show that the emerging topics have 8 keywords or 38.10%, semi-emerging topics is 10 keywords or 47.62%, and declining topics is 3 keywords (14.29%).

Furthermore, Table 7 shows the performance indicators (average of publication year, Log TLS, and Log OCC) for

each keyword. From the results of 8 emerging keywords, then grouped into three themes. This table shows 8 keywords that are divided into 3 thematic areas, among which are: SUSTAINABILITY-STRATEGY, TRANSPORTATION-TECHNOLOGY, and MODEL-OPTIMIZATION. Determining the classification of keywords in each theme is based on a thematic approach of interrelated keywords.

The theme SUSTAINABILITY-STRATEGY delves into carbon footprint, china, emission inventory, and sustainable development. The theme TRANSPORTATION-TECHNOLOGY deals with electric vehicles and energy consumption. Finally, the MODEL-OPTIMIZATION theme is mainly devoted to knowledge game theory and inventory routing problem.

The emerging themes were sent in advance and confirmed by well-known experts in the field who were willing to discuss in detail. We asked the experts four questions to validate the results of the study. The first question in the study is about identifying the emerging and declining trends in
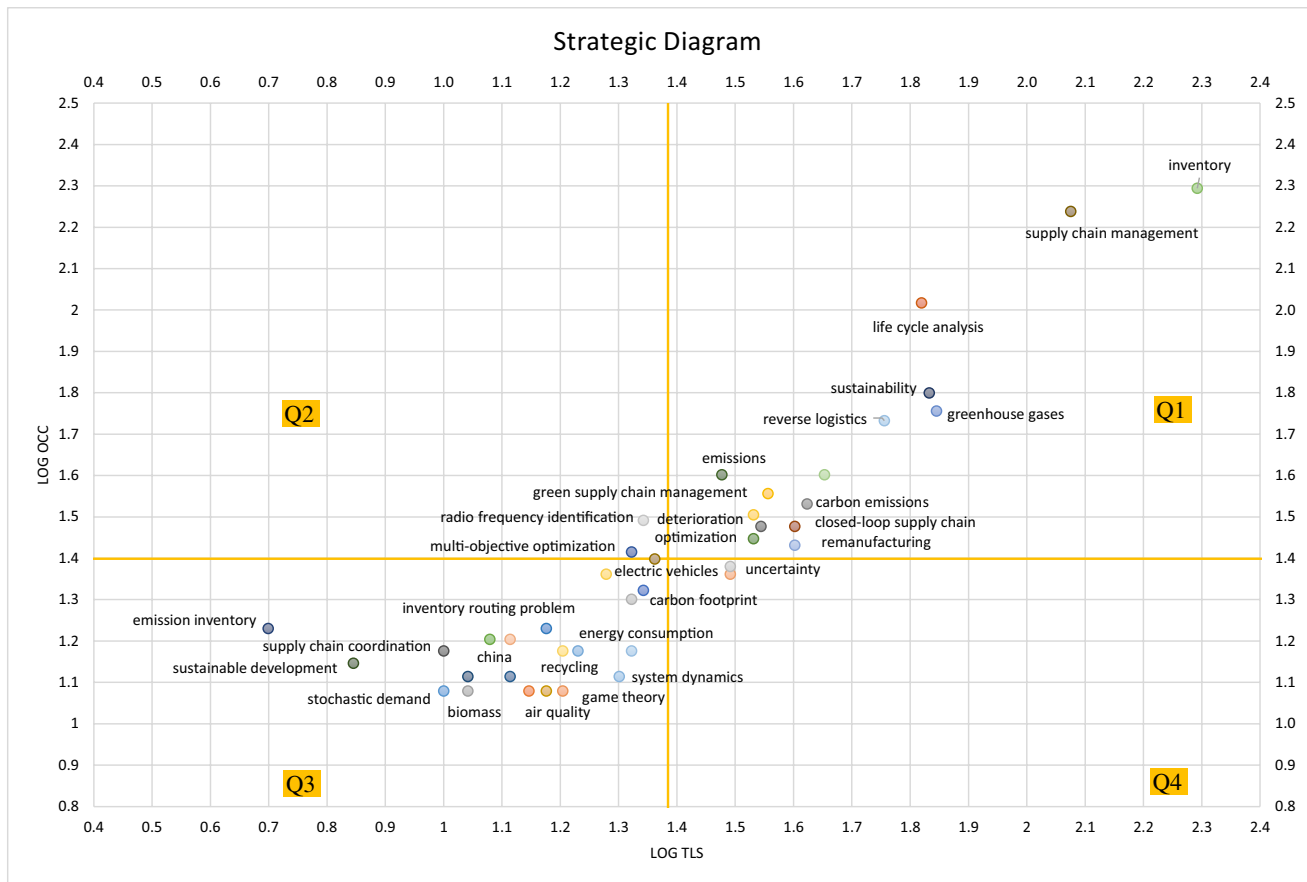
Fig. 15 Strategic diagram for the research theme (1990–2020)

sustainable logistics and supply chain research areas. The second question is related to keywords such as carbon footprint, China, emission inventory, and sustainable development, which is sufficient to fit into the theme of sustainability strategy. The third is about keywords that fit well with transportation and technology themes, such as electric vehicles and energy consumption. The last question pertains to keywords such as game theory and inventory routing issues that are sufficient to fit into the topic of modeling and optimization. The answers of the experts were as follows:

Expert 1

1. Yes, it is a good way to structure and investigate emerging and declining trends in Logistics and Supply Chain Management (LSCM).
2. No. The keywords are too broad. It is better to be more specific. For example, China Mining or China Automotive etc. and try to focus on specific industry. The same goes for sustainable development. For example, deforestation or air pollution is much focus and easier to get data etc.

3. Authors can also include sustainable urban transportation, mobility, renewable resources, green vehicles, powered transport, and others.
4. Try to include more such as industry 4.0, machine learning, data mining, adaptive algorithm and other Artificial Intelligent (AI) related terms. Authors can also include COVID-19 disruption if possible.

Expert 2

1. *Yes, it is adequate but there could be other terms to consider such as green supply chain, global warming, green manufacturing, global warming, carbon trading.*
2. *Yes, it is adequate but China is not the only biggest polluter but there are others as well such as India etc. Other keywords to consider—green energy, green building.*
3. *Electric vehicles must be expanded to include commercial land vehicle. There is a trend to use electric aircraft, drone, and electric unmanned ships for transportation.*

Table 6 The keywords at Q3 (emerging, semi-emerging, and declining)

Keyword No	Keyword	TLS	OCC	Avg. pub. year	Log TLS	Log OCC	Q3 emerging (> 2015)	Q3 semi-emerging (2012–2015)	Q3 declining (< 2012)
1	Air pollution	10	12	2012.000	1.000	1.079			Q3 declining
2	Air quality	14	12	2014.583	1.146	1.079		Q3 semi-emerging	
3	Biomass	11	12	2014.750	1.041	1.079		Q3 semi-emerging	
4	Carbon footprint	22	21	2015.238	1.342	1.322	Q3 Emerging		
5	China	12	16	2016.000	1.079	1.204	Q3 emerging		
6	Climate change	13	13	2012.769	1.114	1.114		Q3 semi-emerging	
7	Electric vehicles	23	25	2015.680	1.362	1.398	Q3 emerging		
8	Emission inventory	5	17	2015.529	0.699	1.230	Q3 emerging		
9	Energy consumption	17	15	2017.067	1.230	1.176	Q3 emerging		
10	Game theory	16	12	2017.750	1.204	1.079	Q3 emerging		
11	Genetic algorithm	21	20	2012.750	1.322	1.301		Q3 semi-emerging	
12	Inventory routing problem	15	17	2017.941	1.176	1.230	Q3 emerging		
13	Manufacturing	15	12	2010.250	1.176	1.079			Q3 declining
14	Production	21	15	2014.000	1.322	1.176		Q3 semi-emerging	
15	Production planning	13	16	2011.125	1.114	1.204			Q3 declining
16	Recycling	16	15	2015.000	1.204	1.176		Q3 semi-emerging	
17	Stochastic demand	11	13	2014.462	1.041	1.114		Q3 semi-emerging	
18	Supply chain coordination	10	15	2014.333	1.000	1.176		Q3 semi-emerging	
19	Sustainable development	7	14	2016.357	0.845	1.146	Q3 emerging		
20	System dynamics	20	13	2014.462	1.301	1.114		Q3 semi-emerging	
21	Vendor-managed inventory	19	23	2012.478	1.279	1.362		Q3 semi-emerging	

TLS, total length strength; *OCC*, occurrences

Table 7 The emerging topic

Keyword No	Keyword	Avg. publication year	Log TLS	Log OCC	Quadrant
A. SUSTAINABILITY-STRATEGY					
1	Carbon footprint	2015.238	1.342	1.322	Q3 emerging
2	China	2016.000	1.079	1.204	Q3 emerging
3	Emission inventory	2015.529	0.699	1.230	Q3 emerging
4	Sustainable development	2016.357	0.845	1.146	Q3 emerging
B. TRANSPORTATION-TECHNOLOGY					
1	Electric vehicles	2015.680	1.362	1.398	Q3 emerging
2	Energy consumption	2017.067	1.230	1.176	Q3 emerging
C. MODEL-OPTIMIZATION					
1	Game theory	2017.750	1.204	1.079	Q3 emerging
2	Inventory routing problem	2017.941	1.176	1.230	Q3 emerging

Table 8 Selected articles of emerging topic on sustainable supply chain and technology

No	Author (year)	Research objectives	Method	Technology	Sustainability aspect
1	Rout et al. (2020)	Implementation of various regulatory policies (mainly CO_2 tax, CO_2 Cap-and-offset, cap-and-trade) to reduce emissions. This reduces the impact of CO_2 emissions by reducing emissions	Fuzzy	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax, and carbon cap-and-trade
2	Wangsa et al. (2020)	Finding minimum total cost by optimizing the decision variables (order quantity, emissions, safety factor, lead time, and number of shipments)	Non-linear programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon cap-and-trade
3	Zhen et al. (2020)	Proposing a non-linear mixed integer programming model, using fleets along routes (including the introduction of environmentally friendly technologies), travel speeds of all routes, timetables, between routes of each origin-destination and berth allocations to minimize the total cost	Mixed-integer programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Green investment
4	Lu et al. (2020)	Method analysis identified the optimal equilibrium solution that maximizes the overall profits of manufacturers and retailers	Non-linear programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax, green investment
5	Manupati et al. (2020)	Developed a blockchain approach based on distributed ledger. Monitor supply chain performance and synchronize and optimize emissions and operating costs to achieve better supply chain results. As part of our carbon tax policy, a blockchain approach is proposed to various production allocation issues within the multi-echelon supply chain (MESC)	Mixed-integer programming	Blockchain technology	Carbon emission tax
6	Karim et al. (2020)	Optimized the production and green investment, and retailers decide on the best sourcing to maximize the profit in a single period	Non-linear programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon tax, green investment

Table 8 (continued)

No	Author (year)	Research objectives	Method	Technology	Sustainability aspect
7	Huang et al. (2020)	The proposed model guides companies determine the optimal production, delivery, and green investment with the goal of minimizing costs under various CO_2 emission regulations	Non-linear programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax, green investment
8	Tang et al. (2020)	Developed a three-tier dynamic game model to optimize the wholesale prices, carbon tax rates, and the percentage of sustainable investment shared by the government	Dynamic game optimization	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax
9	Yaghin and Sarlak (2019)	Considering a social purchase value, total profit (TP), delivery time, air pollution, water pollution, and energy consumption associated with boundaries are considered together in a multi-product system. A new fuzzy multi-objective optimization is modeled to capture inherent fuzziness in important data	Fuzzy	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax, green investment
10	Shen et al. (2019)	Determined the optimal production, delivery, ordering, and investment policies for buyers and sellers that maximize total profit per unit time, taking into account carbon tax policies	Non-linear programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax, green investment
11	Li et al. (2019)	The paper optimizes green cold chain inventory routing models that minimize overall costs	Simulated annealing	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon cap-and-trade
12	Hariga et al. (2019)	Introducing a single vendor, single buyer supply chain under a VMCI contract to reduce carbon emissions and total cost	Non-linear programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax
13	Rani et al. (2019)	Developed an eco-friendly supply chain model for defective items by considering recycling, reverse logistics, and remanufacturing while minimizing total cost	Fuzzy	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax

Table 8 (continued)

No	Author (year)	Research objectives	Method	Technology	Sustainability aspect
14	Bai et al. (2019)	Investigated the effects of carbon emission policies (carbon cap-and-trade regulation and investment in green technologies are used) to reduce emissions and improve total profit on a supply chain with one manufacturer and two competing retailers for deteriorating products under VMI	Non-linear programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon cap-and-trade, green investment
15	Taheri-Moghadam et al. (2019)	Minimize the total cost of the entire network (production, transportation, warehousing/outsourcing, and investment), taking into account economic, environmental, social impact, and levels of customer service	Discrete-event simulation	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax, green investment
16	Sarkar et al. (2018)	Maximize the total profit by incorporating multi-trade-credit policy, rework, shortages, and environmental impact simultaneously	Non-linear programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax
17	Fan et al. (2018)	Extended the traditional EOQ (economic order quantity) model to consider decisions on production inventory, carbon trading, and emission reduction investments in decentralized and centralized policies, reducing total supply chain costs and carbon emissions	Non-linear programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon cap-and-trade
18	Wang et al. (2018a, b, c)	Developed a mixed integer non-linear programing model to maximize the profitability of a supply chain network consisting of raw material vendors, manufacturers, and distribution centers	Non-linear programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon cap
19	Wang et al. (2018a, b, c)	Constructed a low-carbon inventory routing problem (LCIRP) optimization model of refined oil distribution network with the minimum total costs as the objective function	Genetic algorithm	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax

Table 8 (continued)

No	Author (year)	Research objectives	Method	Technology	Sustainability aspect
20	Jung and Jeong (2018)	Investigated the effect of information sharing of inventory through the virtual warehouse by using a system dynamics-based simulation model	Discrete-event simulation	Information technology	Carbon emission tax, green investment
21	Dai et al. (2018)	Formulated a mixed-integer nonlinear programming model to minimize the total costs by using hybrid genetic algorithm (HGA) and hybrid harmony search (HHS)	Genetic algorithm and harmony search	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax
22	Huang et al. (2018)	Considering economical losses and environmental issues, the model is developed to optimize pricing, inventory, and preservation decisions that maximize the individual profit under a decentralized supply chain	Non-linear programming	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax
23	Zhang et al. (2017)	Finding a compromise between economic development and environmental protection, involving local governments and firms which want to maximize its social interests and economic interests	Fuzzy	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon emission tax
24	Batarfi et al. (2017)	Investigated the impact of various return guidelines on the behavior of SC systems before and after adopting the dual-channel taking into account the refurbishment, collection and disposal processes	Non-linear programming	E-commerce	Carbon emission tax
25	Qiu et al. (2017)	Incorporating carbon emissions into production inventory and routing decisions	Branch-and-bound optimization	Conventional transportation using several parameters such as fossil fuels, fuel consumption (combustion energy)	Carbon cap-and-trade

4. *Yes, it is sufficient but newer development such as big data, data analytics* etc.*need to be considered.*

Contribution of previous research

Finally, this subsection presents a list of theoretical studies using sustainable supply chain and technology issues (Table 8). This list contains the characteristics and parameters which are most related to this field and suggests finding the theoretical gap in this research area. However, this list draws from a recent theoretical paper in the field which aims to conceptualize the field. In this analysis, we obtained 25 related studies for further analysis by making the parameters' comparison. Table 8 lists the names of the authors, the title of the article, research method, and the variables used in each study.

Conclusion and directions for future research

This paper presents a bibliometric analysis of publications from 1990 until 2020 and insights into futuristic technologies issues in green supply chain management. The analysis shows that the leading journal is the *Journal of Cleaner Production* (JCP). The journal of *Sustainability* (Switzerland) has an increasing number of relevant articles, as shown in their publication in the last 5 years. This systematic review identifies technology that has an impact on the sustainability of the supply chain systems, both practically and theoretically. This study period is divided into three sub-periods (1990–2011, 2012–2015, and more than 2015) depending on the publications and the subject or thematic area.

The main contributions of this study are the identification of the research themes developed by the strategic diagram. According to the strategic diagram, three emerging themes are identified (i) sustainable supply chains and competitive strategy, (ii) technology adoption in transportation, and (iv) modeling and optimization. These themes are linked to futuristic technologies and a sustainable supply chain. Futuristic technologies in the supply chain systems include technology by using combustion energy and renewable energy, electric vehicles technology, and RFID. Sustainable supply chain theme includes, i.e., LCA, green investment, and carbon tax. The experts confirmed the emerging themes in the strategic diagram as a good representation of the topic. At present, the research topicality mainly includes the following topics: energy policy, transportation policy, sustainability policy, environmental policy, and economic policy.

The limitations of this review are attributed to the exclusion of the other document sources such as PubMed or Web of Science and limited classification schemes.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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