Journal of Cleaner Production 328 (2021) 129544

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Green supply chain quantitative models for sustainable inventory management: A review

Pablo Becerra[a,b], Josefa Mula[a,*], Raquel Sanchis[a]

[a] Universitat Politècnica de València, Research Centre on Production Management and Engineering (CIGIP), c/ Alarcón, 1, 03801, Alcoy, Alicante, Spain
[b] Universidad de Atacama, Copayapu 485, 1530000, Copiapó, Región de Atacama, Chile

ARTICLE INFO

Handling editor: Kathleen Aviso

Keywords:
Supply chain
Sustainability
Inventory management
Quantitative models
Optimisation
Simulation

ABSTRACT

This paper provides a systematic and up-to-date review and classification of 91 studies on quantitative methods of green supply chains for sustainable inventory management. It particularly identifies the main study areas, findings and quantitative models by setting a point for future research opportunities in sustainable inventory management. It seeks to review the quantitative methods that can better contribute to deal with the environmental impact challenge. More specifically, it focuses on different supply chain designs (green supply chain, sustainable supply chain, reverse logistics, closed-loop supply chain) in a broader application context. It also identifies the most important variables and parameters in inventory modelling from a sustainable perspective. The paper also includes a comparative analysis of the different mathematical programming, simulation and statistical models, and their solution approach, with exact methods, simulation, heuristic or meta-heuristic solution algorithms, the last of which indicate the increasing attention paid by researchers in recent years. The main findings recognise mixed integer linear programming models supported by heuristic and metaheuristic algorithms as the most widely used modelling approach. Minimisation of costs and greenhouse gas emissions are the main objectives of the reviewed approaches, while social aspects are hardly addressed. The main contemplated inventory management parameters are holding costs, quantity to order, safety stock and backorders. Demand is the most frequently shared information. Finally, tactical decisions, as opposed to strategical and operational decisions, are the main ones.

1. Introduction

This paper is oriented to sustainable inventory management (SIM), which refers to making decisions about inventory, storage and material handling to reduce economical, environmental and social impacts. Including location and transport issues in supply chain modelling would lead to sustainable supply chains. Green supply chain management would, on the other hand, focus mainly on the integration of environmental considerations.

In past decades, awareness and growing concern about environmental, social and economic aspects have significantly increased. The focus on supply chain (SC) management (SCM) has, therefore, moved from a specific economic perspective to the broader adoption and development of the other sustainability, environmental and social aspects (Nikolopoulou and Ierapetritou, 2012). Sustainability can be defined as the development that meets the current generation's needs without compromising the ability of future generations to meet their own needs (Brundtland, 1989). Zarta Ávila (2018) defines the sustainability objective based on fulfilling human needs and achieving their aspirations, understood as improved quality of life. Therefore, a greater equitable redistribution of resources, higher productivity levels and a substantial change in technological terms are required. The incorporation of the sustainability concept into SCs has been widely studied by researchers (Ahi and Searcy, 2013).

Thus sustainable SCM has been defined as the creation of a coordinated SC by integrating economical, environmental and social issues with key industrial systems designed to effectively manage the flows of materials, information and capital associated with the procurement, production and distribution of goods to meet stakeholder needs, and to improve profitability, competitiveness and resilience in the short and long terms. Otherwise green SCM (GSCM) would not contemplate the integration of economic and social considerations in relation to

* Corresponding author. Universitat Politècnica de València, Research Centre on Production Management and Engineering (CIGIP), c/ Alarcón, 1, 03801, Alcoy, Alicante, Spain.
E-mail addresses: pablo.becerra@uda.cl (P. Becerra), fmula@cigip.upv.es, fmula@cigip.upv.es (J. Mula), rsanchis@cigip.upv.es (R. Sanchis).

https://doi.org/10.1016/j.jclepro.2021.129544
Received 19 June 2021; Received in revised form 17 October 2021; Accepted 28 October 2021
Available online 5 November 2021

sustainable SCM. GSCM can help companies to decrease wasted energy, reduce carbon emissions and continue with their operations by considering environmental impacts and resource efficiency (Halat and Hafezalkotob, 2019). Research on GSCM has considerably increased, which is important for developing sustainable inventory models that consider revenue growth, waste prevention and reduced energy costs in, for example, the online pharmaceutical SC (Chen et al., 2019). Direct carbon emissions, caused by both the transport and storage of goods as an indicator of the inventory system's environmental performance, are a major cause of CO_2 emissions and the single largest source of environmental hazards in the logistics chain (Arikan et al., 2014). Thus decisions on supply lead times (LTs), reorder quantities and storage equipment impact costs and emissions (Fichtinger et al., 2015). In light of all this, there is a growing need to design and apply reverse logistics systems in different sectors. A major difficulty arises from considering uncertainty in the rate of product returns and estimations of supplies. Therefore, developing more realistic models capable of handling complex industrial cases, and efficient solution techniques for dealing with big data, is necessary (Bostel et al., 2005). Moreover, the adoption of cleaner technologies allows the amount of waste to decrease and, hence, disposal costs also lower (Yadav et al., 2021). Here circular economy (CE) strategies support SCs to become more sustainable (Geisendorf and Pietrulla, 2018). CE is defined as an economic system that aims to prevent the depletion of resources, close energy and materials loops, and to facilitate sustainable development by implementing it at micro- (enterprises and consumers), meso- (economic agents integrated into symbiosis) and macro- (city, regions and governments) levels. For instance, avoiding returns of faulty products to manufacturers, considering that a manufacturer is far away, it is costly and time-consuming for purchasers to have to use reverse logistics, and repairing them in local repair stores will also have a positive environmental impact (Ahmed et al., 2021). This CE model requires cyclical and regenerative environmental innovations in the way that society legislates, produces and consumes (Prieto-Sandoval et al., 2018). Thus, CE can be considered a means to achieve business sustainability, but not all the systems that incorporate circular flows are intrinsically more sustainable. This could be because CE practices, which consist of reusing of products and providing them a new market position, focus mostly on caring for the environment and overlook the other two sustainability aspects: economic and social (Alarcón et al., 2020).

Sustainable inventory management (SIM) practices in the SC context have scarcely been analysed in the scientific literature. Hence, this research aims to review the literature on quantitative models for SIM in different application contexts along with a green SC. More specifically, this study attempts to provide answers to the following research questions (RQ):

RQ1. What are the main sustainability research areas developed for inventory management in SCM according to sustainability principles and CE?

RQ2. What are the main findings for inventory management along with SCM according to sustainability principles and CE?

RQ3. Which quantitative models and software tools are used for inventory management in SCM according to sustainability principles and CE?

Alternatively, Nikolopoulou and Ierapetritou (2012) review some relevant research works on sustainable chemical processes and SCs, and identify emerging challenges: energy efficiency and waste management; environmentally sustainable SC; sustainable water management. Kamble et al. (2020) present a framework for the practitioners involved in the agri-food SC that identifies both visibility and resources as the main driving forces for developing data analytics capability and achieving sustainable performance. The main contributions of the study of Asghari and Mirzapour Al-e-hashem (2021) are related to the green vehicle routing problem. They present a classification scheme based on three major technologies, including internal combustion engine vehicles, alternative-fuel powered vehicles and hybrid electric vehicles. The aforementioned reviews focus on specific contexts of application or decision problems. Here, the orientation of this article is focused on providing a literature review on quantitative SIM models in green SCs in order to offer structured knowledge for a better understanding of inventory management from a quantitative and sustainable perspective. Articles based on the following main criteria were selected, reviewed and classified: sustainable SCM or GSCM, SIM and quantitative models. The main contributions of this paper are to: (i) review the literature; (ii) classify the literature based on the purpose, context application, SC structure, level decision, shared information, inventory policies, inventory model variables, sustainability, CE, green approaches, modelling approaches, solution approaches and software tools; (iii) discuss trends and identify future research directions.

The remaining paper is organised as follows. Section 2 presents the review methodology. Section 3 offers the literature review that focuses on each classification criterion. Section 4 and 5 respectively offer the research conclusions and discussion.

2. Review methodology

Fig. 1 presents the review methodology based on Díaz-Madroñero et al. (2014) and Novais et al. (2019) which, as a first step, contemplates the research questions (RQ1, RQ2 and RQ3) to fulfil the research objectives.

Regarding data collection, the second step involves searching and identifying relevant studies to answer the research questions. In this case, the search which considers the terms sustainable SC, inventory management and quantitative methods was performed using the Scopus and Web of Science (WOS) databases. The search criteria script, based on the topic (TS) in the WOS core collection and source title, abstract and keywords (TITLE-ABS-KEY) in Scopus, was applied in both search engines as shown in Table 1.

After the search, those articles that met the research objectives were selected. Likewise, a series of exclusion criteria was determined: documents beyond the main research scope, i.e. papers that do not consider environmental issues, quantitative models or case studies about specific sectors unrelated to SCs, among others; duplicate articles between the WOS and Scopus databases; conference reviews. As a result, 91 articles were selected for the literature review, where the first paper in this research area was published by Pati et al. (2004) and, therefore, the topic has been mainly studied in recent years (Fig. 3). This paper presents a broader classification of those articles published until the first quarter of 2021. A summarised table with the main contributions of the reviewed articles is provided in Appendix 1. Of selected papers, a set of 15 (16.5%) was selected from the International Journal of Production Economics, six (6.6%) from the Journal of Cleaner Production, five (5.5%) from the European Journal of Operational Research and five (5.5%) from Sustainability. The other papers were published in diverse journals (54.9%), conferences (7.7%) and two book chapters (2.2%), as shown in Fig. 2. Here it is important to highlight that of the authors reviewed Kannan Govindan from the University of Southern Denmark, which stands out with 30 publications in the last 5 years in the Journal of Cleaner Production that refer to sustainability in the SC.

The distribution of publications with time (Fig. 3) revealed that the research topic has recently caught researchers' attention. Indeed in the last 10 years, most research (91.1%) has been conducted and more than half the studies (60%) have been published in the last 5 years.

According to the research methodology, the fourth step is to define research classification criteria. Accordingly, Díaz-Madroñero et al. (2014) present a review of discrete-time optimisation models for tactical production planning whose classification criteria are considered here by selecting those that met the research objective and extending the classification criteria with three new specific criteria: (i) inventory modelling; (ii) inventory policies; (iii) sustainability, CE and green modelling approaches. All the classification criteria are described as follows:

Purpose: the objective/s defined in the quantitative model.

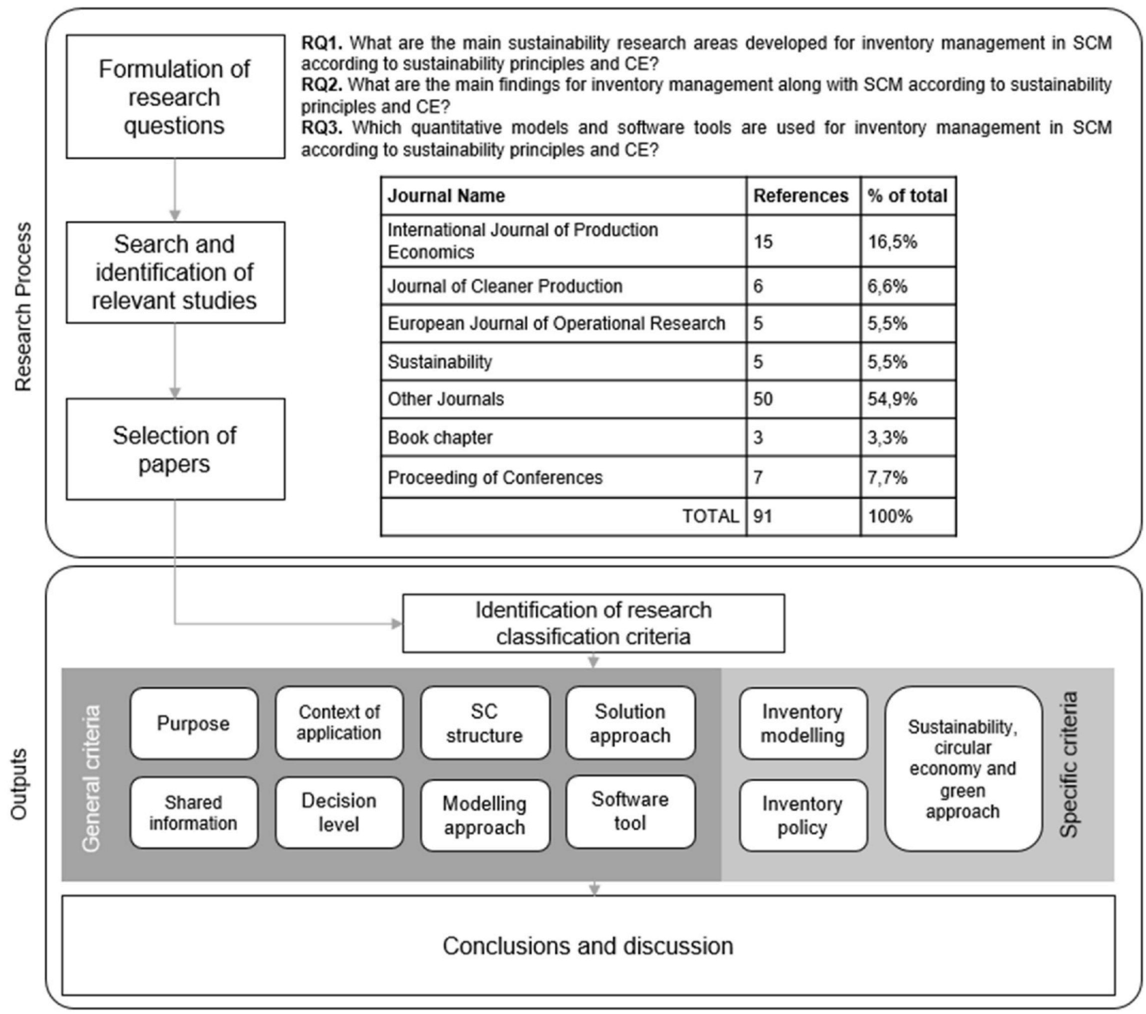

Fig. 1. Research methodology.

Table 1
Search methodology.

Database	Search criteria script	Results
WOS	TS= ("supply chain*" OR "supply network") AND TS= (sustainab* OR green OR "circular economy" OR environment* OR social*) AND TS= ("inventory management") AND TS= ("quantitative method*" OR "quantitative model*" OR "math* programming" OR "optimisation*" OR "analytic model*" OR simulation OR "artificial intelligence")	366
Scopus	(TITLE-ABS-KEY ("supply chain*" OR "supply network*") AND TITLE-ABS-KEY ("sustainab*" OR "green" OR "circular economy" OR "environment*" OR "social") AND TITLE-ABS-KEY ("inventory management") AND TITLE-ABS-KEY ("quantitative method" OR "Math* programming" OR "Optimisation" OR "Analytical Model*" OR "Simulation" OR "artificial intelligence"))	172

Application context: this presents the application that each proposal considers in terms of supporting numerical experiments or case studies in real-world production contexts.

SC structure: it defines the way that the various organisations in the SC are arranged and how they relate to one another.

Decision level: three decision levels were distinguished in terms of the decision to be made, strategical, tactical, operational, along with its corresponding time period, i.e., long term, mid-term, short term.

Shared information: it consists of the information shared between each network node that which the model determines, which enables production and transport planning in accordance with the drawn up purpose.

Inventory policies: they refer to the supplier, manufacturer or distributor policies for replenishing customers' goods.

Inventory modelling: it provides details of the inventory variables and/or parameters that are used to model the inventory.

Sustainability, CE and green modelling approaches: they offer details as to whether the study develops a green solution (environmental), a sustainable solution, or an economic, environmental and social one or in the CE context.

Modelling approach: it consists of the type of problem representation (mathematical relations in this case) and the aspects to be considered in the production system.

Solution approaches: they are the mathematical methods and solution algorithms developed to solve the proposed quantitative models, such as exact algorithms, relaxation heuristics, metaheuristics, problem-specific heuristics, among others.

Software tool: it refers to the commercial or non-commercial software tools needed to implement and solve the proposed models.

3. Literature review

Regarding the purpose of the reviewed articles, a set of objectives in the quantitative models studied was identified and classified as shown in Table 2. They are related to costs, customer service and environmental

Fig. 2. Source and type of document.

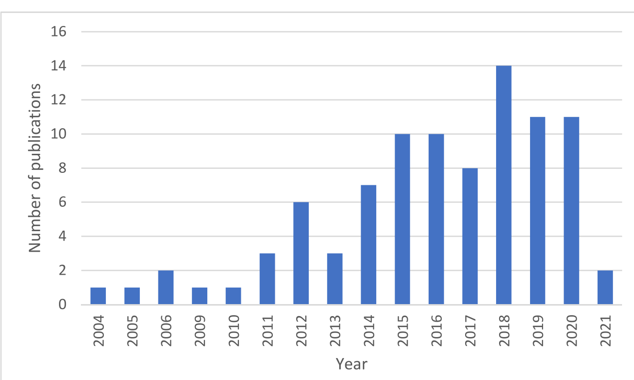

Fig. 3. Distribution of publications per year.

aspects. On costs, minimisation of costs, maximisation of benefits or profits, and maximisation of revenues are taken into account, while maximisation of the service level and minimisation of LTs are studied in customer service. Minimisation of emissions is considered an environmental aspect. Minimisation of total cost is the main purpose of the reviewed articles (78%), while maximisation of social impacts is studied less (1.1%). There is also a group of 23 studies that simultaneously considers minimisation of costs and emissions (see Table 2), and one reference (Ugarte et al., 2016) sets minimisation of emissions as its main purpose. Minimisation of costs is studied simultaneously with other purposes: minimisation of LTs; maximisation of benefits by Nativi and Lee (2012), who also include insight generation as a purpose; maximisation of the service level by Deng et al. (2014), Yılmaz Balaman and Selim (2016) and Amer et al. (2018) who include maximisation of benefits as a third purpose; finally, maximisation of revenues (Ali et al., 2020). Moreover, a group of nine papers contemplates only maximisation of benefits or profits.

With respect to the application context, as shown in Fig. 4, 40% of the papers do not consider a real-world application of the proposed model in a specific context. However, in the remaining articles, the main addressed application contexts of quantitative modelling for SIM in SC are: consumer goods (11%), energy, fuel and biofuel (9%), and other categories (17%) like waste management, spare parts, warehousing and hazardous substances.

Appendix 2 describes the case studies and numerical examples used to validate the models proposed by the reviewed articles. It is important to highlight that of the 91 analysed articles, 80 were validated by a numerical example or practical application.

With regards to the SC structure, the number of facilities and levels, and the structure of the material and information flow, contribute to chain complexity. SC structures can be classified as: dyadic, serial, convergent, divergent, conjoined and network (George and Madhusudanan Pillai, 2019). The classification was extended to include closed-loop and reverse logistics criteria. A reverse logistics system consists of a series of activities like: collection, cleaning, disassembly, testing and sorting, storage, transport, recovery operations (Bostel et al., 2005). A closed-loop SC (CLSC) consists in integrating a forward and reverse logistics system, including the use of the traditional SC structures of the forward movement of goods to consumers and the application of specialised operations for reverse SC activities (Kuo, 2011). Fig. 5 shows the distribution of publications per SC structure. Here the divergent structure is the most studied structure in the reviewed articles. Moreover, reverse logistics and CLSC represent 29.7% of all the studies, and the remainder is distributed among other structures. In particular, the aim of incorporating reverse and closed-loop logistics into the SC design is to achieve a certain level of sustainability. These designs have drawn researchers' attention because of its contributions to economic,

Table 2
Purpose of the reviewed articles.

Reference	Min C	Max SL	Max B	Min LT	Max R	IG	Max S	Min E
Pati et al. (2004)	X							
Lejeune (2006)	X							
Pati et al. (2006)	X							
Dekker et al. (2009)	X			X				
Ross et al. (2010)	X					X		
Kuo (2011)	X							
Hua et al. (2011)	X							
Zhang et al. (2011)	X							
Nativi and Lee (2012)	X		X			X		
Zhang et al. (2012)	X							
Bouchery et al. (2012)	X							
Ji et al. (2012)			X					
Kannan et al. (2012)	X							
Palak et al. (2013)	X							X
Chen and Hsieh (2013)	X							
Benjaafar et al. (2013)	X							X
Longo (2014)	X							
Arikan et al. (2014)	X							X
Zhang et al. (2014)	X							
Battini et al. (2014)	X							
Bozorgi et al. (2014)	X							X
Deng et al. (2014)	X	X						
Kuo et al. (2014)	X							
Fichtinger et al. (2015)	X							X
Andriolo et al. (2015)	X							X
Bazan et al. (2015)	X							
Chen et al. (2015)			X					
Glock et al. (2015)	X							
Jindal et al. (2015)			X					
Kumar et al. (2015)	X							
Roozbeh Nia et al. (2015)	X							X
Rezapour et al. (2015)			X					
Soysal et al. (2015)	X							
Ugarte et al. (2016)								X
Yılmaz Balaman and Selim (2016)	X	X						
Chibeles-Martins et al. (2016)			X					X
Franco et al. (2016)	X							X
Galel et al. (2016)						X		
Khan et al. (2016)	X							
Konur et al. (2016)	X							X
Saif et al. (2016)	X							X
Tang et al. (2016)	X							X
Zhalechian et. (2016)	X						X	X
Calmon and Graves (2017)					X			
Tsolakis and Srai (2017)					X			
Bazan et al. (2017)	X							X
Iassinovskaia et al. (2017)	X							
Karimi et al. (2017)			X					
Karimi et al. (2017)	X							X
Moslemi et al. (2017)	X							X
Rahimi et al. (2017)		X	X					X
Takeda Berger et al. (2018)		X		X				
Ivanov (2018)	X							
Amer et al. (2018)	X	X	X					
Khademi and Eksioglu (2018)	X							
Sun et al. (2018)	X							
Yang et al. (2018)	X							
Guo et al. (2018)	X							
Galanopoulos et al. (2018)			X					
Asadi et al. (2018)	X							X
Niknamfar et al. (2018)			X					
Kang et al. (2018)	X							
Lee et al. (2018)	X							
Rau et al. (2018)	X							X
Stenius et al. (2018)	X							
Galanopoulos et al. (2018)						X		
Halat and Hafezalkotob (2019)	X							X
Wang et al. (2019)								
Tighazoui et al. (2019)			X					
Paam et al. (2019)	X							
Chen et al. (2019)			X					
Al-Aomar et al. (2019)	X							
Castellano et al. (2019)	X							
Darvish et al. (2019)	X							X

(*continued on next page*)

Table 2 (*continued*)

Reference	Min C	Max SL	Max B	Min LT	Max R	IG	Max S	Min E
Kovacs et al. (2019)	X			X				
Li et al. (2019)	X							
Ajay et al. (2020a)	X							
Ajay et al. (2020b)	X							
Ajay et al. (2020c)	X							
Al-Haidous et al. (2020)	X							X
Mohammadnazari and Ghannadpour (2020)	X							
Ganev et al. (2020)	X							X
Žic and Žic (2020)	X							X
Wang et al. (2020)	X							
Ali et al. (2020)	X				X			
Govindan et al. (2020)	X							
Jemai et al. (2020)	X							X
Wu et al. (2021)	X							
Solina et al. (2021)	X							

Min C: Minimise cost; Max SL: Maximise satisfaction level; Max B: Maximise benefit (profit); Min LT: Minimise lead time; Max R: Maximise revenue; IG: Insight generation; Max S: Maximise social implications; Min E: Minimise emissions.

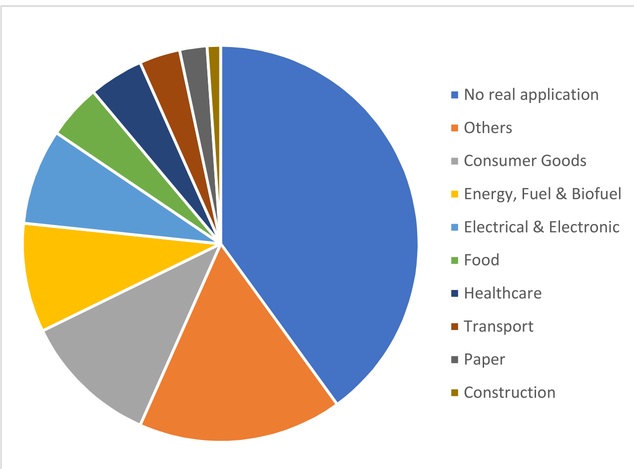

Fig. 4. Distribution of publications per application context.

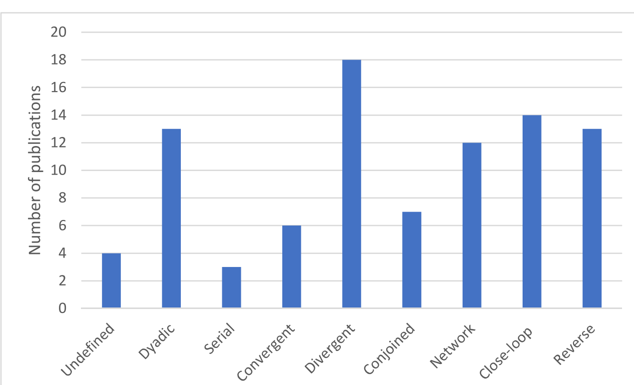

Fig. 5. Distribution of publications per SC structure.

social and sustainable competitiveness. Since the beginning of the present century, many authors have begun to glimpse the impossibility of contemplating forward and reverse logistics as independent activities (Carrasco-Gallego, 2010). A CLSC considers the manufacturer and returns processes by integrating all the SC activities that capture additional value by extending the traditional forward SC activities and additional activities of the reverse SC (Daniel et al., 2003).

Decision levels are classified mainly as strategical, tactical and operational. They are differentiated by the scope or effect of the decision to be made in time terms. For instance, the decisions made in storage and distribution locations are strategical decisions, aspects like distribution planning, transport capacities, inventories and managing safety inventories are tactical decisions, while replenishment and delivery operations are operational decisions (Huang et al., 2003). Table 3 shows the distribution of publications at the different decision levels and, in some cases, at more than one level. Of all the reviewed articles, only one covers the operational decision level (Wang et al., 2020) to learn the minimum expectation value of all the orders' total costs by assigning orders to different production lines and ships. Most studies (91%) focus on tactical level decisions, or only the tactical decision level, the

Table 3
Distribution of publication per decision level.

Decision Level	Reference
Operational	Wang et al. (2020)
Tactical	Pati et al. (2004), Dekker et al. (2009), Ross et al. (2010), Kuo (2011), Nativi and Lee (2012), Palak et al. (2013), Chen and Hsieh (2013), Longo (2014), Arikan et al. (2014), Zhang et al. (2014), Battini et al. (2014), Ugarte et al. (2016), Calmon and Graves (2017), Takeda Berger et al. (2018), Amer et al. (2018), Khademi and Eksioglu (2018), Yang et al. (2018), Ching et al. (2019), Halat and Hafezalkotob (2019), Wang et al. (2019), Paam et al. (2019), Chen et al. (2019), Ajay et al. (2020a), Ajay et al. (2020b), Ajay et al. (2020c), Al-Haidous et al. (2020), Žic and Žic (2020), Lejeune (2006), Pati et al. (2006), Hua et al. (2011), Zhang et al. (2011), Bouchery et al. (2012), Ji et al. (2012), Benjaafar et al. (2013), Bozorgi et al. (2014), Kuo et al. (2014), Andriolo et al. (2015), Bazan et al. (2015), Glock et al. (2015), Kumar et al. (2015), Roozbeh Nia et al. (2015), Soysal et al. (2015), Franco et al. (2016), Galal et al. (2016), Khan et al. (2016), Konur et al. (2016), Bazan et al. (2017), Iassinovskaia et al. (2017), Karimi et al. (2017), Konur et al. (2017), Rahimi et al. (2017), Niknamfar et al. (2018), Kang et al. (2018), Lee et al. (2018), Rau et al. (2018), Stenius et al. (2018), Al-Aomar et al. (2019), Castellano et al. (2019), Darvish et al. (2019), Kovacs et al. (2019), and Li et al. (2019)
Strategical	Zhang et al. (2012), Fichtinger et al. (2015), Tsolakis and Srai (2017), Galanopoulos et al. (2018), and Tighazoui et al. (2019)
Tactical-Strategical	Yılmaz Balaman and Selim (2016), Ivanov (2018), Guo et al. (2018), Mohammadnazari and Ghannadpour (2020), Ganev et al. (2020), Ali et al. (2020), Kannan et al. (2012), Deng et al. (2014), Chen et al. (2015), Jindal et al. (2015), Saif et al. (2016), Tang et al. (2016), Zhalechian et. (2016), Moslemi et al. (2017), and Jemai et al. (2020)
Operational-Tactical-Strategical	Bostel et al. (2005), Nikolopoulou and Ierapetritou (2012), Sun et al. (2018), Wu et al. (2021), Rezapour et al. (2015), Chibeles-Martins et al. (2016), Asadi et al. (2018), and Govindan et al. (2020)

strategical and tactical levels, the operational and strategical ones, or they consider them all decision levels. Specifically, Bostel et al. (2005) consider reverse logistics at the different hierarchical planning levels of the logistics network. The studies that only focus on tactical decisions mostly solve inventory problems (INP) and inventory-routing problems (IRP) to a similar extent, as detailed in Tables 3 and 5. Furthermore, publications that consider the strategical level of decisions include location problems (LOP) as in Ivanov (2018) who defined an optimal bioethanol facility location. Moreover, Guo et al. (2018) solved a location-inventory problem (LIP) to determine the optimal location and the number of orders per year in a CLSC. Finally, a set of articles take into account location-inventory-routing problems (LIRP), Bostel et al. (2005) and Nikolopoulou and Ierapetritou (2012) consider the three kinds of problems separately or in an integrated manner. Instead to a lesser extent, solve integrating LIRP in their cases as shown in Table 5.

Regarding the shared information, the flow of information from each network node to the node that needs that piece of information is crucial to effectively plan an integrated SC. Seven types of shared information through the SC have been defined: product structure or bill of materials (BOM), inventory level (IL), inventory capacities (INC), inventory costs (IC), LTs, backorder costs (BC) and demand (D). This shared information is related to inventory management, and that is the reason for it being selected. It is worth highlighting shared information in relation to inventory and planning. According to the reviewed articles, demand in 70 publications is the most shared information, followed by IL as the second most shared information in 31 articles. Table 4 summarises the various types of shared information per publication. Lack of timely shared information among companies, including delays and feedbacks, distorts actual demand information and causes unnecessary waste (Huang et al., 2003).

One specific criterion proposed to extend the existing taxonomy is inventory policies. Most of the reviewed articles do not define an inventory policy, rather continuous review policies are adopted in a group of 27 publications (Appendix 4). In particular, the most studied policy is the (s, Q) policy, and economic order quantity (EOQ), Q, ordered every time the inventory position drops below reorder point s. Furthermore, five authors focus their studies on the (s, S) policy order up to a given level, S, every time the inventory position drops below reorder point s. Additionally, three special cases of the (s, S) policy are studied, with the base-stock policy (S-1, S) calls for placing a replenishment order after each demand that is equal in magnitude to the size of the demand. Moreover, periodic review policies appear in two articles to implement an (R, Q) policy, and to order an optimal quantity, Q, for every R time period. Only one publication (Longo, 2014) develops a model according to an (R, S) policy, and orders up to level S every R time periods. Other authors, for instance, Žic and Žic (2020) focus on an (R, s, S) policy that consists in ordering up to a level, S, every R time periods if the inventory position is less than or equals reorder point s. Some authors centre their research on the first-in first-out (FIFO) and last-in first-out (LIFO) inventory management methods. In their studies, Ajay et al. (2020a) compare both methods and, additionally, Ching et al. (2019) evaluate the impact of this opposing issuance policies on perishable products by reducing food wastage. Moreover, Amer et al. (2018) and Takeda Berger et al. (2018) develop models based on the replenishment pull system strategy, which is a lean technique for reducing waste in any production process. A group of seven studies implement the vendor management inventory (VMI), which is an inventory management practice in which a supplier is responsible for optimising the inventory held by the manufacturer or retailer. Finally, specific inventory policies are proposed by Calmon and Graves (2017), who characterise the optimal policy structure for a problem with stochastic demand, and introduce an algorithm to calculate optimal sell-down levels and to provide a closed-form policy for the deterministic version of the problem. Finally, Al-Haidous et al. (2020) study a maritime transportation problem in which contracts last several years, and specify the quantity and time for deliveries.

Besides inventory polices, inventory modelling has been proposed as a specific classification criterion; that is, the inventory variables and/or parameters that are used to model the inventory. Fig. 8 presents the number of publications per parameter or variable used to model the inventory in each article, sorted by frequency. The most recurrent variable in the reviewed studies is holding costs. Regarding the use of this variable and inventory policy, Nativi and Lee (2012) conclude that holding costs lower because of the better reorder points according to a continuous review with real-time monitoring. In relation to the environmental impact, the sensitive analysis of the model by Halat and Hafezalkotob (2019) shows that the carbon emissions of green SCs are inversely related to the inventory holding cost. Another significant cost variable is the replenishment cost, but it has been less frequently studied, and is related to fixed administrative and handling costs of placing an order (Guo et al., 2018). Inventory level, order quantity and inventory capacity, are the most studied non-cost variables. In the model proposed by Nativi and Lee (2012) recycled-material supplier inventory on-hand is available for the manufacturer's inventory position and reorder decisions. Alternatively, Al-Haidous et al. (2020) use minimal and maximal IL of a storage tank as parameters. Lot sizing is a critical issue that directly impacts the economic efficiency of both purchasing and production activities. Battini et al. (2014) explore the economic lot sizing problem in purchasing materials when environmental concerns are considered and propose a new easy-to-use theoretical model to calculate a sustainable economic order quantity (S-EOQ). Finally, inventory capacity is a decisive factor given the importance of an additional storage area (Mohammadnazari and Ghannadpour, 2020). This parameter is often used as a model constraint related to limited storage room capacity.

From the perspective of the sustainability characteristics, the need to address the triple bottom line of economic, environmental and social considerations throughout SCs, it is necessary to improve the profitability, competitiveness and resilience of the organisation in the short and long terms (Ahi and Searcy, 2013). Accordingly, Appendix 6 classifies the reviewed articles in terms of the sustainability issue and details the sustainability research area developed for inventory management. Firstly from the reviewed articles, 20.9% focus only on the economic dimension of sustainability, 2.2% on the environmental aspect, followed by 61.5% that consider both economic and environmental aspects in an integrated manner. Finally, 15.4% of the studies consider the three aspects of sustainability: economic, environmental, social. It is important to point out to readers that although some publications only consider the economic factor, the environmental aspect is implicitly presented, and reminds us that sustainable inventory models are being studied in green SCs, as in Khademi and Eksioglu (2018) and Niknamfar et al. (2018) who incorporate environmental regulation costs, Al-Aomar and Alshraideh (2019) and Kovács and Illés (2019) who introduce sustainability through company policies that include decisions about regular green sourcing and the purchasing of materials. Some authors also propose changes in the transportation system that has an environmental impact, and Dekker et al. (2009) state that the impact of intermodal transport per ton per kilometre is lower for intermodal transport than it is for road transport, while Wang et al. (2020) conclude that sustainable port-centric SCs using large-scale vessels consume less fuel per freight unit than small vessels. Additionally, Calmon and Graves (2017), Chen and Hsieh (2013), Chen et al. (2015), Deng et al. (2014), Jindal et al. (2015), Rezapour et al. (2015) and Tighazoui et al. (2019) implicitly incorporate returned, recycled and remanufacturing products into a reverse logistics system, including environmental aspects, whereas Chen et al. (2019) develop a sustainable inventory model that considers revenue growth while preventing waste and reducing energy costs. Regarding the articles that focus only on the environmental aspect, Ugarte et al. (2016) employ a simulation model to evaluate the total amount of emissions according to a given inventory management practice measured in carbon dioxide equivalents. Furthermore, Takeda Berger et al. (2018) emphasise the use of lean practices for production according to customer demand with little or no waste.

Table 4
Shared information of the reviewed articles.

Reference	Undefined	BOM	IL	INC	IC	LT	BOC	D
Pati et al. (2004)			X	X				X
Bostel et al. (2005)	X							
Lejeune (2006)			X	X	X	X		X
Pati et al. (2006)				X	X			X
Dekker et al. (2009)			X					X
Ross et al. (2010)			X					
Kuo (2011)			X					
Hua et al. (2011)								X
Zhang et al. (2011)			X		X			
Nativi and Lee (2012)			X					X
Zhang et al. (2012)								X
Nikolopoulou and Ierapetritou (2012)								
Bouchery et al. (2012)					X			X
Ji et al. (2012)				X	X			
Kannan et al. (2012)				X				
Palak et al. (2013)					X			X
Chen and Hsieh (2013)			X					X
Benjaafar et al. (2013)			X		X		X	
Longo (2014)			X		X	X	X	X
Arikan et al. (2014)								X
Zhang et al. (2014)			X	X	X	X		
Battini et al. (2014)				X	X			X
Bozorgi et al. (2014)					X			X
Deng et al. (2014)					X			X
Kuo et al. (2014)		X						
Fichtinger et al. (2015)	X							
Andriolo et al. (2015)								X
Bazan et al. (2015)								X
Chen et al. (2015)								X
Glock et al. (2015)					X			X
Jindal et al. (2015)			X	X	X			X
Kumar et al. (2015)		X	X	X				X
Roozbeh Nia et al. (2015)					X		X	X
Rezapour et al. (2015)					X			X
Soysal et al. (2015)			X					X
Ugarte et al. (2016)			X					X
Yılmaz Balaman and Selim (2016)				X	X			X
Chibeles-Martins et al. (2016)				X				X
Franco et al. (2016)			X	X	X			
Galal et al. (2016)								X
Khan et al. (2016)				X			X	X
Konur et al. (2016)			X		X			X
Saif et al. (2016)				X	X			X
Tang et al. (2016)								X
Zhalechian et al. (2016)				X	X	X		X
Calmon and Graves (2017)		X	X		X			X
Tsolakis and Srai (2017)			X					X
Bazan et al. (2017)								X
Iassinovskaia et al. (2017)								X
Karimi et al. (2017)				X		X		X
Konur et al. (2017)								X
Moslemi et al. (2017)								X
Rahimi et al. (2017)			X	X				X
Takeda Berger et al. (2018)			X					
Ivanov (2018)								X
Amer et al. (2018)								X
Khademi and Eksioglu (2018)			X					
Sun et al. (2018)			X					X
Yang et al. (2018)			X					X
Guo et al. (2018)								X
Galanopoulos et al. (2018)								X
Asadi et al. (2018)			X		X			X
Niknamfar et al. (2018)			X					
Kang et al. (2018)								X
Lee et al. (2018)								X
Rau et al. (2018)								X
Stenius et al. (2018)			X					X
Galanopoulos et al. (2018)								X
Halat and Hafezalkotob (2019)								X
Wang et al. (2019)								
Tighazoui et al. (2019)								X
Paam et al. (2019)								X
Chen et al. (2019)								X
Al-Aomar et al. (2019)								X

(*continued on next page*)

Table 4 (*continued*)

Reference	Undefined	BOM	IL	INC	IC	LT	BOC	D
Castellano et al. (2019)								X
Darvish et al. (2019)			X					X
Kovacs et al. (2019)		X	X					
Li et al. (2019)			X					X
Ajay et al. (2020a)	X							
Ajay et al. (2020b)	X							
Ajay et al. (2020c)	X							
Al-Haidous et al. (2020)	X							
Mohammadnazari and Ghannadpour (2020)								X
Ganev et al. (2020)								X
Žic and Žic (2020)						X		X
Wang et al. (2020)								X
Ali et al. (2020)								X
Govindan et al. (2020)								X
Jemai et al. (2020)								X
Wu et al. (2021)			X	X	X	X	X	X
Solina et al. (2021)								X

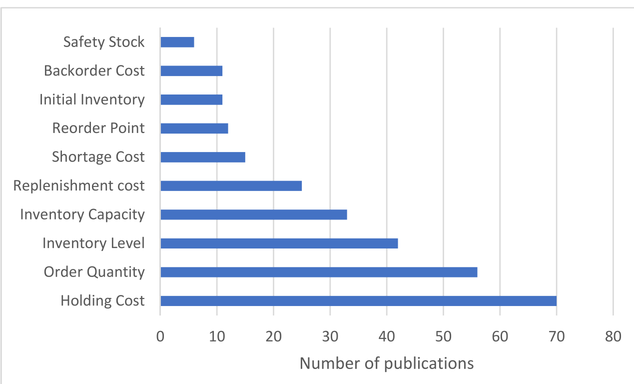

Fig. 8. Number of publications per parameter or variable.

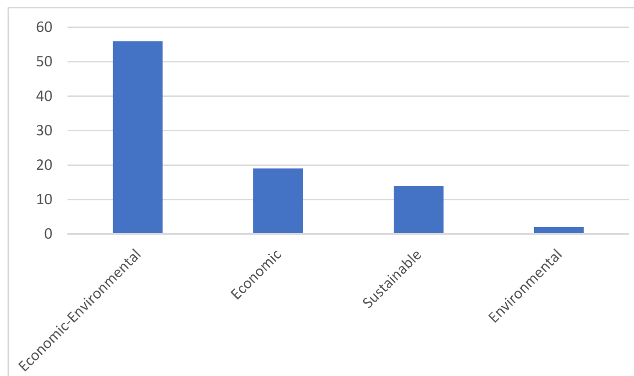

Fig. 9. Number of publications per sustainability aspect.

In frequency terms, the main sustainability aspects addressed in the publications correspond to both economic and environmental aspects. For the economic aspect, the commonest criterion is minimisation of costs, while it is more complex for the environmental aspect. Accordingly, Reike et al. (2018) propose value retention options in CE by spreading the well-known 3R (reduce, reuse, recycle) policy to 10R contents (refuse, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover, re-mine). Here the 3R policy was extended to a 6R policy, which includes remanufacturing, renewal and repair criteria. Firstly, as regards recycling policies, Pati et al. (2004) propose a method to address the environmental waste treatment problem by a systematic management strategy. Furthermore, Ji et al. (2012), Moslemi et al. (2017), Nativi and Lee (2012) and Pati et al. (2006) aim to increase the recycled product return. Secondly, the reuse of products is studied by Ross et al. (2010) and Yang et al. (2018), who agree that repositioning reusable containers is relevant for reducing management costs and environmental impacts throughout products' life cycles. The reduce policy from a production perspective has been studied, focusing mainly on reducing greenhouse gas (GHG) emissions. Moreover, Zhang et al. (2014, 2011) aim to reduce waste generation and fuel use. Specifically, Paam et al. (2019), Soysal et al. (2015) and Sun et al. (2018) focus on reducing food waste and social implications. Furthermore, in the extended 6R policy, remanufacturing is studied by Kuo (2011), Longo (2014) and Guo et al. (2018), who also incorporate reused products and propose integrating reverse logistics into a CLSC. Following the proposed criteria, renewal is associated with optimising renewable energy SCs and reducing GHG emissions (Yılmaz Balaman and Selim, 2016; Zhang et al., 2012).

Finally, the consideration of all three sustainability aspects is the second less frequent topic in this review, as shown in Fig. 9. As explained above, the most frequent economic aspect is cost minimisation, while the main common environmental aspect is waste minimisation and reducing GHG emissions. The approach followed for the social impact is more varied; for instance, Halat and Hafezalkotob (2019) consider total costs of the GSC, carbon emissions and social welfare. In order to consider the environmental and social dimensions jointly in inventory and delivery operations, Battini et al. (2014) and Khan et al. (2016) apply the "external costs" concept, while Tsolakis and Srai (2017) propose pharmaceutical industries to promote providing patients with equitable access to essential medicines. Moreover, Ganev et al. (2020), Ivanov (2018) and Zhalechian et al. (2016) agree about the convenience of using the social approach as an estimate of a work system's social impact, specifically by employing the exact coefficients that account for indirect jobs in the local economy. Amer et al. (2018) include the following indicators: service level, percentage of wasted food and average product's remaining shelf life. Galanopoulos et al. (2018) conclude that in order to make an SC sustainable, only 30% of all wheat straw produced in each district can be used for the biorefinery, while the rest is utilised as natural fertiliser and animal feed. Moreover, Ching et al. (2019) focus their studies on perishable product management because those products necessary to sustain human life, such as food and healthcare, are of prevailing importance. Specifically, Wang et al. (2019) state that food waste is becoming a global issue and it strongly impacts the three pillars of sustainability. Furthermore, Mohammadnazari and Ghannadpour (2020) propose that road safety/conditions are second in importance, after economic and environmental issues, unlike Bouchery et al. (2012) who incorporate the injury rate as a social criterion with the same relevance as economic and environmental criteria.

Another dimension of the review examines the characteristics of the quantitative models used to model SIM in SCs and their classification.

Inventory management problems are NP-hard because it is a natural extension of the inventory routing problems (IRP) classified as NP-hard (Baller et al., 2020). Four general types of model approaches are identified in the literature: analytical model, simulation, conceptual, artificial intelligence. Two subclassifications for analytical models are presented: mathematical programming (MP) models and statistical analysis models. Statistical analyses have been dealt with less frequently, and only two publications employ this modelling approach: one as a multivariable set correlation model to provide an understanding of and to gain insights into the changes of inventory policies by Ross et al. (2010) and the other studies the derivation of probability mass functions to determine the number of units on each shipment (Stenius et al., 2018). MP models are the main widely used approach in the reviewed publications (78%). As shown in Table 5, most MP-based problems are mixed-integer linear programming (MILP). MILP optimisation models include modelling the environmental impact and economic performance (Ganev et al., 2020). For example, in single objective problems, Ivanov (2018) proposes an optimisation model to identify what combination of options is the most efficient approach for supply the facility, for the optimal location of bioethanol production plants, and also for the efficient available land use. Moreover, Mohammadnazari and Ghannadpour (2020) develop a MILP model to determine the economic quantities of the material supplied by specific suppliers in the construction industry. To quantify the impact of new inventory and storage policies, Paam et al. (2019) apply an MP model to the Australian apple industry, and Halat and Hafezalkotob (2019) develop eight scenarios in a bi-level MP model by considering the structure of the green SC and government regulations. An extension of MILP is the inclusion of multi-objectives. The model by Palak et al. (2013) captures trade-offs between transportation costs and products' remaining shelf life, transportation and inventory costs on the one hand, and total costs and CO_2 emissions on the other. The model by Yılmaz Balaman and Selim (2016) is developed as a multi-objective MILP (MO-MILP) and is solved with fuzzy goal programming (FGP) that incorporates seasonality into biomass sources and fluctuations in both revenue and cost parameters caused by unstable economic conditions. Moreover, Jindal et al. (2015) present a network design and the optimisation of a multiproduct, multi-time, multi-echelon capacitated CLSC in an uncertain environment in a fuzzy MILP (F-MILP) model. Here the presented models all minimise both the total cost and environmental impact by treating them as competing objective functions. Two models are presented by Al-Aomar and Alshraideh (2019) where the first provides a deterministic single-order model with a linear programming (LP) model, and this is extended to a multiperiod comprehensive material planning model with a MILP model. The remaining less frequently treated MP models are (Table 5): mixed-integer non-linear programming (MINLP), multi-objective mixed-integer non-linear programming (MO-MINLP), LP, integer programming (IP), stochastic programming (SP), stochastic dynamic programming (SDP), fuzzy multi-objective linear programming (FMOLP), non-linear programming (NLP), stochastic mixed integer quadratic programming (SMIQP), fuzzy linear programming (FLP), fuzzy multi-objective linear programming (FMOLP) constraint programming (CP) and piecewise interval programming (PIP).

Additionally, two special analytical models in inventory management were studied: EOQ and the joint replenishment problem (JRP). Specifically, the EOQ model is defined as a general solution to an overall problem, such as finding the most economical quantity to manufacture an order (Harris, 1990). Thus, two studies develop and propose sustainable EOQ (S-EOQ/SOQ) by considering that minimising the cost may not be the only company objective, and environmental and social objectives are included in models (Battini et al., 2014; Bouchery et al., 2012). Additionally, a group of studies incorporate minimisation of emissions (Andriolo et al., 2015; Bazan et al., 2017; Bozorgi et al., 2014; Khan et al., 2016) and minimisation of emissions and waste (Bazan et al., 2015) in EOQ models. Lastly, Hua et al. (2011) consider the single-product replenishment problem with carbon trading based on the EOQ model. JRP it is a multiproduct problem that involves deciding about the optimal quantities for products ordered from the same supplier or when the output of a batch production goes to different

Table 5
MP models distributed per problem type along with references.

	Problem type				
MP model	INP	IRP	LIRP	LOP	LIP
LP	Al-Aomar et al. (2019)	Pati et al. (2004), Pati et al. (2006)			
MILP	Khademi and Eksioglu (2018), Halat and Hafezalkotob (2019), Paam et al. (2019), Ali et al. (2020), Kumar et al. (2015), Al-Aomar et al. (2019)	Galanopoulos et al. (2018), Mohammadnazari and Ghannadpour (2020), Solina et al. (2021), Lejeune (2006), Kannan et al. (2012), Benjaafar et al. (2013), Franco et al. (2016), Iassinovskaia et al. (2017), Castellano et al. (2019), Darvish et al. (2019), Li et al. (2019)	Sun et al. (2018), Ganev et al. (2020), Rezapour et al. (2015), Saif et al. (2016), Moslemi et al. (2017)	Ivanov (2018)	
MO-MILP	Palak et al. (2013)	Al-Haidous et al. (2020), Kovacs et al. (2019)	Yılmaz Balaman and Selim (2016), Zhalechian et. (2016), Govindan et al. (2020), Jemai et al. (2020)		Chibeles-Martins et al. (2016)
F-MILP					Jindal et al. (2015)
MINLP	Roozbeh Nia et al. (2015), Karimi et al. (2017)	Glock et al. (2015), Konur et al. (2017), Lee et al. (2018)	Wu et al. (2021)		Guo et al. (2018)
MO-MINLP		Rau et al. (2018)	Deng et al. (2014), Tang et al. (2016), Asadi et al. (2018)		
NLP	Niknamfar et al. (2018)				
IP	Chen et al. (2019)	Wang et al. (2020), Ji et al. (2012), Kuo et al. (2014)			
SDP	Chen and Hsieh (2013), Khademi and Eksioglu (2018), Yang et al. (2018)				
FGP			Yılmaz Balaman and Selim (2016)		
SP	Calmon and Graves (2017)				
SMIQP					Chen et al. (2015)
FMOMILP		Rahimi et al. (2017)			
FLP	Kang et al. (2018)				
FMOLP	Ali et al. (2020)				
PIP	Zhang et al. (2011)				
CP		Zhang et al. (2014), Soysal et al. (2015)			

packages. Classic JRP assumptions are similar to EOQ, and include deterministic and uniform demand, do not allow shortages, have no quantity discounts and the holding cost is linear (Khouja and Goyal, 2008). One article integrates sustainability into a coordinated multi-item inventory control model by formulating a bi-objective joint replenishment problem referred to as sustainable JRP (SJRP) (Konur and Schaefer, 2016).

The second most frequent quantitative models found in the reviewed publications correspond to simulation models. Discrete event simulation (DES) models are the most frequent approach in this field (87.5%), as are system dynamic (SD) models to a lesser extent. However, no agent-based models were identified in the reviewed articles. Appendix 3 presents the main results obtained from the simulation models. The conceptual modelling approach consists of a general network representation of the distribution process together with assumptions and is used in 71.4% of the reviewed articles. Finally in relation to artificial intelligence models, Nativi and Lee (2012) develop a multilinear regression model based on a machine-learning algorithm used to predict a dependent variable with two predictors or more, while Iassinovskaia et al. (2017) use a clustering heuristic before executing the branch-and-cut algorithm to reduce the time needed by the branch-and-cut algorithm by assigning a set of customers to each vehicle.

Additionally, this article proposes a classification of several solution approach types, such as commercial software, authors' software, open-source software, relaxation heuristics, metaheuristics, and problem-specific heuristics. Exact methods are considered to be those embedded in default solvers, such as the typical branch and bound algorithm, solved using both commercial software and open-source software and, similarly, modelling simulation models can be performed with these two software types. Fig. 10 shows the distribution of publications per employed solution approach and software too.

Commercial software is the most widely used solution approach (45%), and publications are distributed in simulation software (11 publications) and optimisation software (27 publications). For simulation models, SC models are designed and implemented more often with Arena Simulation, Anylogic and ExtendSim. Arena Simulation can integrate system characteristics by utilising the SIMAN simulation language (Ugarte et al., 2016). In relation to optimisation models, the most widespread ones are GAMS and ILOG CPLEX for solving single-objective or multi-objective MILP models. On open-source software, Lindo 32 is used by Pati et al. (2004, 2006) to model their cost optimisation model for a multivariety recycled waste reverse logistics system. Moreover in three publications, the authors develop their own software; e.g., Longo (2014) present an advanced simulation framework called inventory management with a product returns simulator (IMPRES), Žic and Žic (2020) develop a software programmed in Python to generate market demand and Kovács and Illés (2019) develop a software in the Java language to optimise sustainable green SCs based on their proposed method.

The remaining solution approaches refer to the use of heuristic and metaheuristic algorithms to solve more complex systems, problems for which no exact solution method, and not even an exact formulation, are known, and can be computationally intensive, or to calculate the bounds in the optimal solution in branch and bound solution processes (Eiselt, 2000). In the reviewed articles, a heuristic algorithm is used by Battini et al. (2014) to adopt the easy-to-use algorithm to compare total cost functions for each discontinuity point quantity and local optimal order quantity. Khademi and Eksioglu (2018) propose two classes of heuristics based on a rolling horizon two-stage stochastic programming formulation of the problem and a standard base-stock ordering policy. Calmon and Graves (2017) develop a gradient search algorithm to find the optimal sell-down levels. Yang et al. (2018) propose extending the analysis of value of information to a myopic policy of full, partial and no recovery information. The remaining algorithms correspond to:

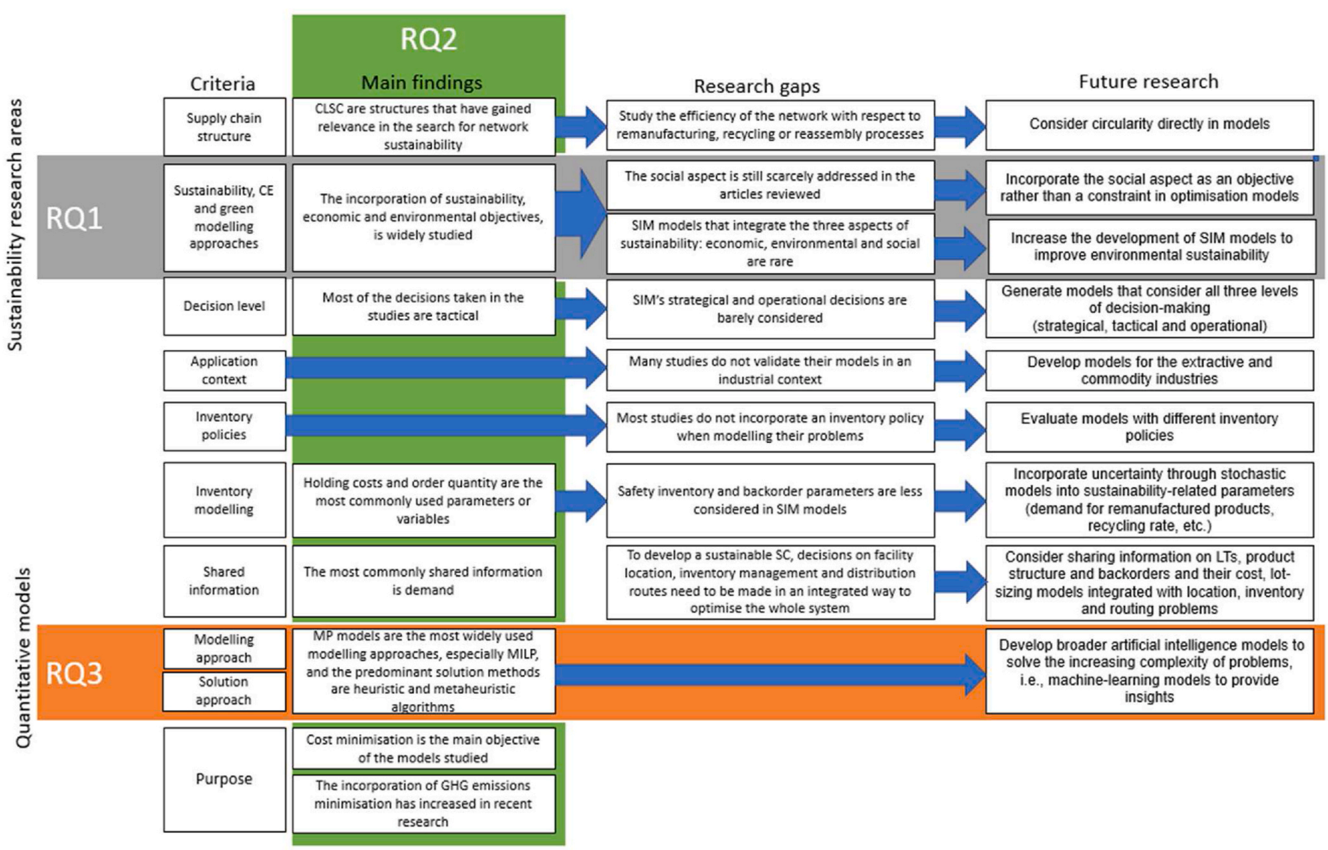

Fig. 10. Conceptual framework for future SIM research.

modified projection algorithm (Rezapour et al., 2015); non-inferior set estimation (NISE) algorithm and column generation (Franco et al., 2016); interior-point method (Niknamfar et al., 2018); search heuristic (Kovács and Illés, 2019; Stenius et al., 2018) and problem-specific heuristics. For meta-heuristics algorithms, one approach is to characterise the search strategy type, trajectory-based algorithms like the simulated annealing (SA) heuristic used by Ajay et al. (2020a) based on the theory of thermodynamics of liquids, which solidify to give a crystalline while cooling. Another and more extent approaches is population-based metaheuristics. Evolutionary algorithms are metaheuristic search methods used generally to solve difficult optimisation problems based on population genetics, where Tighazoui et al. (2019) develop an optimisation method based on an evolutionary algorithm that provides optimal values of the vector that maximises the profit function. A genetic algorithm (GA) is a global search and optimisation technique motivated by the natural selection process in a biological system. Here Chen et al. (2019), Deng et al. (2014), Konur and Schaefer (2016) and Wu et al. (2021) propose this procedure to increase the feasibility of models in solving real-world problems. Here two hybrid algorithms are studied: GA with other algorithms; for example, GA and a gradient descendent algorithm (Wu et al., 2021) and GA and an imperialist competitive algorithm (ICA) (Roozbeh Nia et al., 2015). A genetic simulated annealing algorithm (GASA) is developed by Li et al. (2019). Similarly to GA, in differential evolutionary (DE) algorithms, a randomly generated population is created by using the randomly sampled difference in object vector pairs to control the mutation process, which makes it relatively new compared to other algorithms (Ajay et al., 2020c). Although DE has an excellent global search ability, its performance is not always guaranteed because of its prematurity and weak local search ability. Therefore, two self-adaptive algorithms are studied: firstly, Guo et al. (2018) design an improved self-adaptive DE algorithm to obtain a more robust and effective approach. Then Zhalechian et al. (2016) present a self-adaptive GA to solve an MINLP problem with large-sized instances. Moreover, Ajay et al. (2020b) design particle swarm optimisation (PSO) to determine the specific product on which to concentrate and the amount of product stocks that must be maintained by different members. This algorithm is based on the social behaviour of birds. Particular cases of PSO are the binary PSO (BPSO) algorithm used by Al-Haidous et al. (2020) to perform a heuristic search in the high-dimensional binary solution space for feasible solutions, a hybrid multi-objective PSO and non-dominated sorting genetic algorithm (NSGA II) is developed by Asadi et al. (2018) and Tang et al. (2016) and a dynamic programming-based PSO with multiple social learning structures (DP-based GLNPSO) is proposed by Kang et al. (2018). The remaining metaheuristic algorithms are as follows: NSGA II (Moslemi et al., 2017; Rahimi et al., 2017); chaos-based interactive artificial bee colony (CI-ABC) (Kumar et al., 2015) and a variable neighbourhood decomposition search (Lejeune, 2006). More details on the approaches and solution tools used are provided in Appendix 5.

4. Discussion

Sustainability that focuses on inventory management in an SC context is a novel concept (Tiwari et al., 2018), and even more so if it is considered integrally in conjunction with location, transportation or routing problems. In this sense, it is important to highlight that inventory management models pursue mainly cost minimisation and level service maximisation whereas SIM models are incorporating to this trade-off environmental and social issues. The authors are referred to Table 5 for MP models in the respect.

Although there are limited published articles on SIM with which to analyse the current gaps in the literature, there is a wealth of practical research opportunities in this area. Based on this review, the following trends and future research directions in this field are identified to provide practitioners and interested researchers with a roadmap.

Regarding sustainability and CE as a purpose, very few of the reviewed articles consider the three sustainability pillars in their study objectives or purposes (see Appendix 6). The economic factor is the predominant considered aspect, although many studies integrate economic and environmental aspects into their models. Social impacts as the purpose of models are the least studied, and only Zhalechian et al. (2016) aim to maximise the positive social impacts of designing an SC network. Although sustainability aspects are incorporated into models, they tend to be modelled as constraints rather than as an objective, or through indicators employed to measure impacts rather than optimising them. Therefore, it is important for future research to incorporate social objectives into models; for example, aspects related to health and safety, the impact on the levels and quality of employment of a given local community, the incorporation of local suppliers to positively impact local economy, among others. There is no contradiction among the different sustainability pillars to generate a solution that satisfies economic, environmental and social aspects (Amer et al., 2018).

Despite being a relatively new concept, the CE paradigm is implicitly incorporated into models without actually referring to it. Nevertheless, Govindan et al. (2020) develop an MP model for circular supplier evaluation, selection and order allocation. Thus by incorporating circularity directly into models is a future research challenge. Here it is important to note that the reviewed studies of quantitative SIM models based on CLSC or reverse logistics are oriented mostly to SC design or configuration, and do not consider SC coordination aspects like the assessment of environmental efficiency (see Appendix 1), which could be a novel research future direction.

As for using more complex, integrated and realistic models, the complexity of the model can be defined according to the number of variables and elements that compose it, as well as by SC structure. Models that incorporate location, inventory and routing issues (Table 5) increase the number of variables and parameters (Fig. 8), which makes them more complex. It also makes them more realistic for decision making and more focused on achieving SC sustainability. It is necessary to incorporate all decision making levels, which is already complex. Most of the reviewed articles do not specify the decision level, and one way of classifying it is according to its impact over time. Tactical decisions are the most commonly found, and strategic ones the least (Table 3). A future research challenge is to incorporate all three decision levels.

Most studies define an application context for the presented models and even develop numerical experiments to validate these models (Fig. 4). However, 40% of these studies do not apply their proposal in an industrial context. The most widely studied industries are consumer goods, electrical and electronic appliances, and fuels (Appendix 2). There is a research gap about SIM for extractive industries, such as agricultural, mining and energy.

With regards inventory policies (see Appendix 4), more than half the articles (51.6%) do not define an inventory policy when modelling the proposed problem. This is an opportunity for future research to test models with different policies and to observe the impact they have on objectives. The VMI strategy is poorly studied in the reviewed literature. Here it is assumed that the vendor pays the ordering and holding costs on behalf of the buyer as part of the mentioned agreement, and the buyer pays no cost (Roozbeh Nia et al., 2015). The SC is coordinated by a contract that enables the decision maker to access information about not only the IL of products for the supplier and retailers, but also final customer requests (Rahimi et al., 2017).

According to SC structures for sustainability (Fig. 5), the divergent SC structure is the commonest and seeks to optimise distribution from one point, which may be a supplier or manufacturer, to a set of distributors, retailers or consumers. As for information sharing (Table 4), demand is the most shared parameter throughout the SC as it allows better coordination and production planning at each network node. There is a research gap about information sharing related to LTs, product structure, and backorders and their costs. Incorporating this piece of information in a shared way would increase network efficiency (Huang et al., 2003). For example, knowing the product structure in the management of product recovery in reverse logistics would improve the collection, disassembly and distribution of recovered products (Daniel et al., 2003). It is important to highlight how the CE paradigm is implicitly incorporated through SC structures; for instance, through reverse logistics SCs or CLSCs.

Based on lot-sizing problems, EOQ models are widely studied in relation to inventory management and to incorporate sustainability into these models. Likewise, JRP is developed whose objectives include the environmental factor with a view to minimise GHG emissions (Table 5). These MP models allow us to define the quantities to be ordered and the reorder point towards achieving efficient inventory management. A future research opportunity is to complement these models with MP models to integrate location and routing problems. This leads to more complexity, LIR problems are considered NP-hard problems and solving them by exact methods is complex (Baller et al., 2020). For this reason, heuristic and metaheuristic algorithms are proposed as solution approaches in the short term and quantic simulation and quantic algorithms for the mid term and the long term, respectively.

In a general way, future research directions are oriented to develop new mathematical programming and artificial intelligence models by integrating decisions about facility location, inventory management and distribution routes to optimise the entire supply chain considering the sustainable triple bottom line. Based on the main findings and discoveries of this literature review, a conceptual framework for future research into the development of SIM models in a GSCM context is proposed (Fig. 10). This conceptual framework provides answers to the research questions herein posed, specifically in terms of sustainability research areas (RQ1), the main findings (RQ2) and SIM quantitative models (RQ3) by also considering the classification criteria of the reviewed articles, identifying research gaps and proposing further research lines relating to the addressed research questions.

5. Conclusions

This literature review has analysed and defined the state of the art of knowledge about SIM in an SC context with a GSCM perspective. A systematic literature review of 91 studies was performed to identify, select, classify and analyse the most relevant studies and research works about quantitative models for sustainable SCs. It has revealed the sustainability research areas (RQ1) (Appendix 6), the main findings (RQ2), and existing research gaps (RQ3) in relation to the quantitative models used in SIM on SCM.

The main findings and discoveries of this literature review as to the defined criteria can be summarised as follows: (i) cost minimisation is the main purpose of the studied models; (ii) the incorporation of GHG emissions minimisation has increased in more recent research; (iii) CLSC are SC design structures that have become relevant in the search for network sustainability; (iv) most of the decisions taken in the studies correspond to tactical decisions; (v) the most commonly shared information is demand; (vi) holding costs and quantity to order are the most widely used parameters or variables; (vii) the incorporation of sustainability, economic and environmental objectives, is widely studied; (viii) MP models are the most widespread modelling approaches, especially MILP, and predominant solution methods are heuristic and metaheuristic algorithms.

The main identified research gaps are related to: (i) the social aspect is still scarcely addressed in the reviewed articles; (ii) SIM models integrating the three sustainability aspects (economical, environmental, social) are scarce; (iii) study the efficiency of the network in relation to remanufacturing, recycling or reassembly processes; (iv) many studies do not validate their models in an industrial context; (v) strategical and operational SIM decisions are hardly considered; (vi) the majority of studies do not incorporate an inventory policy when modelling their problems; (vii) safety stock and backorder parameters are less considered in SIM models; and, finally, (viii) in order to develop a sustainable SC, it is necessary that decisions about facility location, inventory management and distribution routes are made in an integrated manner to optimise the entire system.

Managerial implications of this research are oriented to provide researchers and practitioners an inventory management with a starting point and a roadmap about quantitative green SC methods for SIM. In this sense, researchers and practitioners could identify and check from an aggregated source reference SIM works according to the following aspects of interest: purpose, context application, SC structure, level decision, shared information, inventory policies, inventory model variables, sustainability, CE, green approaches, modelling approaches, solution approaches and software tools. Furthermore, the incorporation of quantitative SIM models, particularly MP models, into SC designs would lead to optimising environmental sustainability at each network node, and is applicable to different industries like extractive and commodity industries where even environmental sustainability studies are underresearched. Thus it is important for managers to identify the relations and impacts that these elements have on one another. For example, the efficiency of reverse logistics processes depends on demand levels, with reverse logistics being highly profitable for systems with high demand (Ullah et al., 2021). Besides, variable safety factors largely control the holding costs based on fluctuating market demands (Dey et al., 2021).

It should be mentioned that this research has some limitations. For example, only the scientific databases Scopus and WoS have been consulted, which, moreover, are constantly updated and the articles found correspond to those obtained at the time the research was carried out. Furthermore, despite having followed a systematic search process, it is possible that some articles may have been overlooked for this review.

Finally, further research lines are identified throughout this study to: (i) define conceptually the process and content of a SIM in a green SC; (ii) increase the development of SIM quantitative models oriented towards improving environmental sustainability in a real world green SC; (iii) incorporate the social aspect as an objective rather than a constraint into optimisation models; (iv) consider circularity directly in models; (v) generate models that consider all three decision levels, i.e. strategical, tactical, operational; (vi) develop models for extractive and commodity industries; (vii) evaluate models with different inventory policies; (viii) consider sharing information on LTs, product structure and backorders and their cost, lot-sizing models integrated with location, inventory and routing problems; (ix) develop broader artificial intelligence models to solve the increasing complexity of problems, specifically machine-learning models to provide insights; and (x) incorporate uncertainty through stochastic models into parameters related to sustainability, such as demand for remanufactured products, the recycling rate, among others. Along these lines, a forthcoming work is aimed at proposing a conceptual reference framework that will lead researchers and practitioners to accurately define and categorise the SIM problem under study and, furthermore, to map, build and validate such a conceptual framework as a basis for the subsequent development and implementation of quantitative models based on MP and artificial intelligence to incorporate the main findings and fill the research gaps identified in this study of SIM models in the context of green SC.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The research leading to these results received funding from the Grant RTI2018-101344-B-I00 funded by MCIN/AEI/10.13039/501100011033 and by "ERDF A way of making Europe". It was also funded by the National Agency for Research and Development (ANID)/

Scholarship Program/Doctorado Becas en el Extranjero/2020 - 72210174.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jclepro.2021.129544.

References

Ahi, P., Searcy, C., 2013. A comparative literature analysis of definitions for green and sustainable supply chain management. J. Clean. Prod. 52, 329–341. https://doi.org/10.1016/j.jclepro.2013.02.018.

Ahmed, W., Moazzam, M., Sarkar, B., Ur Rehman, S., 2021. Synergic effect of reworking for imperfect quality items with the integration of multi-period delay-in-payment and partial backordering in global supply chains. Engineering 7, 260–271. https://doi.org/10.1016/j.eng.2020.07.022.

Ajay, S.Y., Abid, M., Bansal, S., Tyagi, S.L., Kumar, T., 2020a. Fifo & lifo in green supply chain inventory model of hazardous substance components industry with storage using simulated annealing. Adv. Math.: Scientific Journal 9, 5127–5132. https://doi.org/10.37418/amsj.9.7.79.

Ajay, S.Y., Kapil, K.B., Shivani, Seema, A., Vanaja, R., 2020b. Fifo in green supply chain inventory model of electrical components industry with distribution centres using particle swarm optimization. Adv. Math.: Scientific Journal 9, 5115–5120. https://doi.org/10.37418/amsj.9.7.77.

Ajay, S.Y., Kumar, A., Agarwal, P., Kumar, T., Vanaja, R., 2020c. Lifo in green supply chain inventory model of auto-components industry with warehouses using differential evolution. Adv. Math.: Scientific Journal 9, 5121–5126. https://doi.org/10.37418/amsj.9.7.78.

Al-Aomar, R., Alshraideh, H., 2019. A service-oriented material management model with green options. J. Clean. Prod. 236 https://doi.org/10.1016/j.jclepro.2019.07.032.

Alarcón, F., Cortés-Pellicer, P., Pérez-Perales, D., Sanchis, R., 2020. Sustainability vs. Circular economy from a disposition decision perspective: a proposal of a methodology and an applied example in SMEs. Sustainability 12, 1–26. https://doi.org/10.3390/su122310109.

Al-Haidous, S., Govindan, R., Al-Ansari, T., 2020. Swarm optimisation for shipping fleet scheduling, routing and delivery in sustainable liquified natural gas (LNG) supply chain models. Computer Aided Chemical Engineering 48, 1225–1230. https://doi.org/10.1016/B978-0-12-823377-1.50205-6.

Ali, S.S., Paksoy, T., Torğul, B., Kaur, R., 2020. Reverse logistics optimization of an industrial air conditioner manufacturing company for designing sustainable supply chain: a fuzzy hybrid multi-criteria decision-making approach. Wireless Network 26, 5759–5782. https://doi.org/10.1007/s11276-019-02246-6.

Amer, H.H., Galal, N.M., El-Kilany, K.S., 2018. A simulation study of sustainable agri-food supply chain. In: Proceedings of the International Conference on Industrial Engineering and Operations Management. Paris, France.

Andriolo, A., Battini, D., Persona, A., Sgarbossa, F., 2015. Haulage sharing approach to achieve sustainability in material purchasing: new method and numerical applications. Int. J. Prod. Econ. 164, 308–318. https://doi.org/10.1016/j.ijpe.2014.12.011.

Arikan, E., Fichtinger, J., Ries, J.M., 2014. Impact of transportation lead-time variability on the economic and environmental performance of inventory systems. In: International Journal of Production Economics. Elsevier B.V., pp. 279–288. https://doi.org/10.1016/j.ijpe.2013.06.005

Asadi, E., Habibi, F., Nickel, S., Sahebi, H., 2018. A bi-objective stochastic location-inventory-routing model for microalgae-based biofuel supply chain. Appl. Energy 228, 2235–2261. https://doi.org/10.1016/j.apenergy.2018.07.067.

Asghari, M., Mirzapour Al-e-hashem, S.M.J., 2021. Green vehicle routing problem: a state-of-the-art review. Int. J. Prod. Econ. https://doi.org/10.1016/j.ijpe.2020.107899.

Baller, A.C., van Ee, M., Hoogeboom, M., Stougie, L., 2020. Complexity of inventory routing problems when routing is easy. Networks 75, 113–123. https://doi.org/10.1002/net.21908.

Battini, D., Persona, A., Sgarbossa, F., 2014. A sustainable EOQ model: theoretical formulation and applications. Int. J. Prod. Econ. 149, 145–153. https://doi.org/10.1016/j.ijpe.2013.06.026.

Bazan, E., Jaber, M.Y., el Saadany, A.M.A., 2015. Carbon emissions and energy effects on manufacturing-remanufacturing inventory models. Comput. Ind. Eng. 88, 307–316. https://doi.org/10.1016/j.cie.2015.07.002.

Bazan, E., Jaber, M.Y., Zanoni, S., 2017. Carbon emissions and energy effects on a two-level manufacturer-retailer closed-loop supply chain model with remanufacturing subject to different coordination mechanisms. Int. J. Prod. Econ. 183, 394–408. https://doi.org/10.1016/j.ijpe.2016.07.009.

Benjaafar, S., Li, Y., Daskin, M., 2013. Carbon footprint and the management of supply chains: Insights from simple models. IEEE Trans. Autom. Sci. Eng. 10 (1), 99–116. https://doi.org/10.1109/TASE.2012.2203304.

Bostel, N., Dejax, P., Lu, Z., 2005. The design, planning, and optimization OF reverse logistics networks. In: Logistics Systems: Design and Optimization. Springer, Boston, MA, pp. 171–212. https://doi.org/10.1007/0-387-24977-X_6.

Bouchery, Y., Ghaffari, A., Jemai, Z., Dallery, Y., 2012. Including sustainability criteria into inventory models. Eur. J. Oper. Res. 222, 229–240. https://doi.org/10.1016/j.ejor.2012.05.004.

Bozorgi, A., Pazour, J., Nazzal, D., 2014. A new inventory model for cold items that considers costs and emissions. Int. J. Prod. Econ. 155, 114–125. https://doi.org/10.1016/j.ijpe.2014.01.006.

Brundtland, G.H., 1989. Report of the world commission on environment and development: our common future towards sustainable development 2. Part II. Common Challenges Population and Human Resources 4.

Calmon, A.P., Graves, S.C., 2017. Inventory management in a consumer electronics closed-loop supply chain. Manuf. Serv. Oper. Manag. 19, 568–585. https://doi.org/10.1287/msom.2017.0622.

Carrasco-Gallego, R., 2010. A Management Model for Closed-Loop Supply Chains of Reusable Articles. Madrid.

Chen, H.C., Hsieh, Y.H., 2013. A newsboy model for apparel items under different backordering situations and inflations of green supply chain. In: Advanced Materials Research, pp. 2876–2881. https://doi.org/10.4028/www.scientific.net/AMR.807-809.2876.

Chen, W., Kucukyazici, B., Verter, V., Jesús Sáenz, M., 2015. Supply chain design for unlocking the value of remanufacturing under uncertainty. Eur. J. Oper. Res. 247, 804–819. https://doi.org/10.1016/j.ejor.2015.06.062.

Castellano, D., Gallo, M., Grassi, A., Santillo, L.C., 2019. The effect of GHG emissions on production, inventory replenishment and routing decisions in a single vendor-multiple buyers supply chain. Int. J. Prod. Econ. 218, 30–42. https://doi.org/10.1016/j.ijpe.2019.04.010.

Chen, Y.K., Chiu, F.R., Chang, Y.C., 2019. Implementing green supply chain management for online pharmacies through a vadd inventory model. Int. J. Environ. Res. Publ. Health 16. https://doi.org/10.3390/ijerph16224454.

Chibeles-Martins, N., Pinto-Varela, T., Barbosa-Póvoa, A.P., Novais, A.Q., 2016. A multi-objective meta-heuristic approach for the design and planning of green supply chains - MBSA. Expert Syst. Appl. 47, 71–84. https://doi.org/10.1016/j.eswa.2015.10.036.

Ching, P.L., Mutuc, J.E., Jose, J.A., 2019. Assessment of the quality and sustainability implications of FIFO and LIFO inventory policies through system dynamics. Advances in Science, Technology and Engineering Systems 4, 69–81. https://doi.org/10.25046/aj040509.

Daniel, V., Guide, R., Harrison, T.P., van Wassenhove, L.N., 2003. The challenge of closed-loop supply chains. Source: Interfaces 33, 3–6.

Darvish, M., Archetti, C., Coelho, L., 2019. Trade-offs between environmental and economic performance in production and inventory-routing problems. Int. J. Prod. Econ. 217, 269–280. https://doi.org/10.1016/j.ijpe.2018.08.020.

Dekker, R., van Asperen, E., Ochtman, G., Kusters, W., 2009. Floating stocks in FMCG supply chains: using intermodal transport to facilitate advance deployment. Int. J. Phys. Distrib. Logist. Manag. 39, 632–648. https://doi.org/10.1108/09600030910996297.

Deng, S., Li, Y., Zhou, T., Cao, Y., 2014. Study on recyclable reserve logistics network optimization based on e-commerce. In: Proceedings - 2014 International Conference on Management of E-Commerce and E-Government, ICMeCG 2014. Institute of Electrical and Electronics Engineers Inc., pp. 337–340. https://doi.org/10.1109/ICMeCG.2014.75

Dey, B.K., Bhuniya, S., Sarkar, B., 2021. Involvement of controllable lead time and variable demand for a smart manufacturing system under a supply chain management. Expert Syst. Appl. 184 https://doi.org/10.1016/j.eswa.2021.115464.

Díaz-Madroñero, M., Mula, J., Peidro, D., 2014. A review of discrete-time optimization models for tactical production planning. Int. J. Prod. Res. https://doi.org/10.1080/00207543.2014.899721.

Eiselt, H.A., 2000. Heuristic algorithms. In: Integer Programming and Network Models. Springer, Berlin.

Fichtinger, J., Ries, J.M., Grosse, E.H., Baker, P., 2015. Assessing the environmental impact of integrated inventory and warehouse management. Int. J. Prod. Econ. 170, 717–729. https://doi.org/10.1016/j.ijpe.2015.06.025.

Franco, C., López-Santana, E.R., Méndez-Giraldo, G., 2016. A column generation approach for solving a green bi-objective inventory routing problem. In: Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Verlag, pp. 101–112. https://doi.org/10.1007/978-3-319-47955-2_9.

Galal, N.M., El-Kilany, K.S., 2016. Sustainable agri-food supply chain with uncertain demand and lead time. Int. J. Simul. Model. 15 (3), 485–496. https://doi.org/10.2507/IJSIMM15(3)8.350.

Galanopoulos, C., Barletta, D., Zondervan, E., 2018. A decision support platform for a bio-based supply chain: application to the region of Lower Saxony and Bremen (Germany). Comput. Chem. Eng. 115, 233–242. https://doi.org/10.1016/j.compchemeng.2018.03.024.

Ganev, E.I., Dzhelil, Y.R., Ivanov, B.B., Vaklieva-Bancheva, N.G., Kirilova, E.G., 2020. Optimal design of a sustainable integrated biodiesel/diesel supply chain using first and second generations bioresources. Chemical Engineering Transactions 81, 67–72. https://doi.org/10.3303/CET2081012.

Geisendorf, S., Pietrulla, F., 2018. The circular economy and circular economic concepts—a literature analysis and redefinition. Thunderbird Int. Bus. Rev. 60, 771–782. https://doi.org/10.1002/tie.21924.

George, J., Madhusudanan Pillai, V., 2019. A study of factors affecting supply chain performance. In: Journal of Physics: Conference Series. Institute of Physics Publishing. https://doi.org/10.1088/1742-6596/1355/1/012018.

Glock, C.H., Kim, T., 2015. Coordinating a supply chain with a heterogeneous vehicle fleet under greenhouse gas emissions. Int. J. Logist. Manag. 26 (3), 494–516. https://doi.org/10.1108/IJLM-09-2013-0107.

Govindan, K., Mina, H., Esmaeili, A., Gholami-Zanjani, S.M., 2020. An integrated hybrid approach for circular supplier selection and closed loop supply chain network design under uncertainty. J. Clean. Prod. 242 https://doi.org/10.1016/j.jclepro.2019.118317.

Guo, H., Li, C., Zhang, Y., Zhang, C., Lu, M., 2018. A location-inventory problem in a closed-loop supply chain with secondary market consideration. Sustainability 10. https://doi.org/10.3390/su10061891.

Halat, K., Hafezalkotob, A., 2019. Modeling carbon regulation policies in inventory decisions of a multi-stage green supply chain: a game theory approach. Comput. Ind. Eng. 128, 807–830. https://doi.org/10.1016/j.cie.2019.01.009.

Harris, F.W., 1990. How many parts to make at once. Oper. Res. 38, 947–950. https://doi.org/10.1287/opre.38.6.947.

Hua, G., Cheng, T.C.E., Wang, S., 2011. Managing carbon footprints in inventory management. Int. J. Prod. Econ. 132, 178–185. https://doi.org/10.1016/j.ijpe.2011.03.024.

Huang, G.Q., Lau, J.S.K., Mak, K.L., 2003. The impacts of sharing production information on supply chain dynamics: a review of the literature. Int. J. Prod. Res. https://doi.org/10.1080/0020754031000069625.

Iassinovskaia, G., Limbourg, S., Riane, F., 2017. The inventory-routing problem of returnable transport items with time windows and simultaneous pickup and delivery in closed-loop supply chains. Int. J. Prod. Econ. 183, 570–582. https://doi.org/10.1016/j.ijpe.2016.06.024.

Ivanov, B., 2018. Multi-period deterministic model of sustainable integrated of hybrid first and second generation bioethanol supply chains for synthesis and renovation. Bulgarian Chemical Communications 50, 24–35.

Jemai, J., Chung, B. do., Sarkar, B., 2020. Environmental effect for a complex green supply-chain management to control waste: A sustainable approach. J. Clean. Prod. 277 https://doi.org/10.1016/j.jclepro.2020.122919.

Ji, S., Wang, W., Dong, Y., 2012. ILP model research of electronic manufacturing enterprise green supply chain inventory & transportation decision-making. In: Advanced Materials Research, pp. 255–259. https://doi.org/10.4028/www.scientific.net/AMR.479-481.255.

Jindal, A., Sangwan, K.S., Saxena, S., 2015. Network design and optimization for multi-product, multi-time, multiechelon closed-loop supply chain under uncertainty. In: Procedia CIRP. Elsevier B.V., pp. 656–661. https://doi.org/10.1016/j.procir.2015.01.024

Kamble, S.S., Gunasekaran, A., Gawankar, S.A., 2020. Achieving sustainable performance in a data-driven agriculture supply chain: a review for research and applications. Int. J. Prod. Econ. https://doi.org/10.1016/j.ijpe.2019.05.022.

Kang, K., Pu, W., Ma, Y., 2018. A dynamic programming-based sustainable inventory-allocation planning problem with carbon emissions and defective item disposal under a fuzzy random environment. Math. Probl Eng. https://doi.org/10.1155/2018/9376080, 2018.

Kannan, D., Diabat, A., Alrefaei, M., Govindan, K., Yong, G., 2012. A carbon footprint based reverse logistics network design model. Resour. Conserv. Recycl. 67, 75–79. https://doi.org/10.1016/j.resconrec.2012.03.005.

Karimi, M., Niknamfar, A.H., Pasandideh, S.H.R., 2017. Two-stage single period inventory management for a manufacturing vendor under green-supplier supply chain. Int. J. Syst. Assur. Eng. 8 (4), 704–718. https://doi.org/10.1007/s13198-016-0557-5.

Khademi, A., Eksioglu, B., 2018. Spare parts inventory management with substitution-dependent reliability. Inf. J. Comput. 507–521. https://doi.org/10.1287/ijoc.2017.0794.

Khan, M., Hussain, M., Saber, H.M., 2016. Information sharing in a sustainable supply chain. Int. J. Prod. Econ. 181, 208–214. https://doi.org/10.1016/j.ijpe.2016.04.010.

Khouja, M., Goyal, S., 2008. A review of the joint replenishment problem literature: 1989-2005. Eur. J. Oper. Res. 186, 1–16. https://doi.org/10.1016/j.ejor.2007.03.007.

Konur, D., Campbell, J.F., Monfared, S.A., 2017. Economic and environmental considerations in a stochastic inventory control model with order splitting under different delivery schedules among suppliers. Omega 71, 46–65. https://doi.org/10.1016/j.omega.2016.08.013.

Konur, D., Schaefer, B., 2016. Economic and environmental comparison of grouping strategies in coordinated multi-item inventory systems. J. Oper. Res. Soc. 67, 421–436. https://doi.org/10.1057/jors.2015.67.

Kovács, G., Illés, B., 2019. Development of an optimization method and software for optimizing global supply chains for increased efficiency, competitiveness, and sustainability. Sustainability 11. https://doi.org/10.3390/su11061610.

Kumar, Vishwa v., Liou, F.W., Balakrishnan, S.N., Kumar, Vikas, 2015. Economical impact of RFID implementation in remanufacturing: a chaos-based interactive artificial bee colony approach. J. Intell. Manuf. 26, 815–830. https://doi.org/10.1007/s10845-013-0836-9.

Kuo, T.C., 2011. The study of production and inventory policy of manufacturing/remanufacturing environment in a closed-loop supply chain. International Journal of Sustainable Engineering 4, 323–329. https://doi.org/10.1080/19397038.2011.593008.

Kuo, T.C., Chen, G.Y.H., Wang, M.L., Ho, M.W., 2014. Carbon footprint inventory route planning and selection of hot spot suppliers. Int. J. Prod. Econ. 150, 125–139. https://doi.org/10.1016/j.ijpe.2013.12.005.

Lee, A.H.I., Kang, H.Y., Ye, S.J., Wu, W.Y., 2018. An integrated approach for sustainable supply chain management with replenishment, transportation, and production decisions. Sustainability 10 (11). https://doi.org/10.3390/su10113887.

Lejeune, M.A., 2006. A variable neighborhood decomposition search method for supply chain management planning problems. Eur. J. Oper. Res. 175, 959–976. https://doi.org/10.1016/j.ejor.2005.05.021.

Li, L., Yang, Y., Qin, G., 2019. Optimization of integrated inventory routing problem for cold chain logistics considering carbon footprint and carbon regulations. Sustainability 11. https://doi.org/10.3390/su11174628.

Longo, F., 2014. Testing the behaviour of different inventory control policies in case of extended reverse logistics by using simulation. Int. J. Simulation and Process Modelling. https://doi.org/10.1504/IJSPM.2014.064390.

Mohammadnazari, Z., Ghannadpour, S.F., 2020. Sustainable Construction Supply Chain Management with the Spotlight of Inventory Optimization under Uncertainty. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-020-01095-0.

Moslemi, S., Zavvar Sabegh, M.H., Mirzazadeh, A., Ozturkoglu, Y., Maass, E., 2017. A multi-objective model for multi-production and multi-echelon closed-loop pharmaceutical supply chain considering quality concepts: NSGAII approach. International Journal of Systems Assurance Engineering and Management 8, 1717–1733. https://doi.org/10.1007/s13198-017-0650-4.

Nativi, J.J., Lee, S., 2012. Impact of RFID information-sharing strategies on a decentralized supply chain with reverse logistics operations. Int. J. Prod. Econ. 136, 366–377. https://doi.org/10.1016/j.ijpe.2011.12.024.

Niknamfar, A.H., Niaki, S.A.A., karimi, M., 2018. A series-parallel inventory-redundancy green allocation system using a max-min approach via the interior point method. Assemb. Autom. 38, 323–335. https://doi.org/10.1108/AA-07-2017-085.

Nikolopoulou, A., Ierapetritou, M.G., 2012. Optimal design of sustainable chemical processes and supply chains: a review. Comput. Chem. Eng. https://doi.org/10.1016/j.compchemeng.2012.05.006.

Novais, L., Maqueira, J.M., Ortiz-Bas, Á., 2019. A systematic literature review of cloud computing use in supply chain integration. Comput. Ind. Eng. 129, 296–314. https://doi.org/10.1016/j.cie.2019.01.056.

Paam, P., Berretta, R., Heydar, M., García-Flores, R., 2019. The impact of inventory management on economic and environmental sustainability in the apple industry. Comput. Electron. Agric. 163 https://doi.org/10.1016/j.compag.2019.06.003.

Palak, G., Eksioglu, S.D., Geunes, J., 2013. Models for cost efficient and environmentally friendly inventory replenishment decisions for perishable products. In: Industrial and Systems Engineering Research Conference. San Juan, Puerto Rico.

Pati, R.K., Vrat, P., Kumar, P., 2006. Economic analysis of paper recycling vis-à-vis wood as raw material. Int. J. Prod. Econ. 103, 489–508. https://doi.org/10.1016/j.ijpe.2005.08.006.

Pati, Rupesh Kumar, Vrat, Prem, Kumar, Pradeep, Pati, R.K., Vrat, P., Kumar, P., 2004. Cost optimisation model in recycled waste reverse logistics system. Int. J. Bus. Perform. Manag. 6, 245–261. https://doi.org/10.1504/ijbpm.2004.005631.

Prieto-Sandoval, V., Jaca, C., Ormazabal, M., 2018. Towards a consensus on the circular economy. J. Clean. Prod. 179, 605–615. https://doi.org/10.1016/j.jclepro.2017.12.224.

Rahimi, M., Baboli, A., Rekik, Y., 2017. Multi-objective inventory routing problem: a stochastic model to consider profit, service level and green criteria. Transport. Res. E Logist. Transport. Rev. 101, 59–83. https://doi.org/10.1016/j.tre.2017.03.001.

Rau, H., Budiman, S.D., Widyadana, G.A., 2018. Optimization of the multi-objective green cyclical inventory routing problem using discrete multi-swarm PSO method. Transp. Res. E Logist. Transp. Rev. 120, 51–75. https://doi.org/10.1016/j.tre.2018.10.006.

Reike, D., Vermeulen, W.J.V., Witjes, S., 2018. The circular economy: new or refurbished as CE 3.0? — exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. Resour. Conserv. Recycl. 135, 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027.

Rezapour, S., Farahani, R.Z., Fahimnia, B., Govindan, K., Mansouri, Y., 2015. Competitive closed-loop supply chain network design with price-dependent demands. J. Clean. Prod. 93, 251–272. https://doi.org/10.1016/j.jclepro.2014.12.095.

Roozbeh Nia, A., Hemmati Far, M., Niaki, S.T.A., 2015. A hybrid genetic and imperialist competitive algorithm for green vendor managed inventory of multi-item multi-constraint EOQ model under shortage. Applied Soft Computing Journal 30, 353–364. https://doi.org/10.1016/j.asoc.2015.02.004.

Ross, A.D., Jayaraman, V., Rodrigues, A., Mollenkopf, D.A., 2010. Repositioning of reusable containers in a sustainable global supply chain environment. Transportation Journal, Int. J. Physical Distribution and Logistics Management and Industrial Marketing 2, 178–204. https://doi.org/10.1504/IJMOR.2010.030816.

Saif, A., Elhedhli, S., 2016. Cold supply chain design with environmental considerations: A simulation-optimization approach. Eur. J. Oper. Res. 251 (1), 274–287. https://doi.org/10.1016/j.ejor.2015.10.056.

Solina, V., Mirabelli, G., 2021. Integrated production-distribution scheduling with energy considerations for efficient food supply chains. Procedia Comput. Sci. 180, 797–806. https://doi.org/10.1016/j.procs.2021.01.355.

Soysal, M., Bloemhof-Ruwaard, J.M., Haijema, R., van der Vorst, J.G.A.J., 2015. Modeling an Inventory Routing Problem for perishable products with environmental considerations and demand uncertainty. Int. J. Prod. Econ. 164, 118–133. https://doi.org/10.1016/j.ijpe.2015.03.008.

Stenius, O., Marklund, J., Axsäter, S., 2018. Sustainable multi-echelon inventory control with shipment consolidation and volume dependent freight costs. Eur. J. Oper. Res. 267, 904–916. https://doi.org/10.1016/j.ejor.2017.12.029.

Sun, Q., Chien, S., Hu, D., Ma, B., 2018. Optimizing the location-inventory-routing problem for perishable products considering food waste and fuel consumption. In: CICTP 2018: Intelligence, Connectivity, and Mobility - Proceedings of the 18th COTA International Conference of Transportation Professionals. https://doi.org/10.1061/9780784481523.048. Beijing.

Takeda Berger, S.L., Tortorella, G.L., Frazzon, E.M., 2018. Simulation-based analysis of inventory strategies in lean supply chains. IFAC-PapersOnLine 51, 1453–1458. https://doi.org/10.1016/j.ifacol.2018.08.310.

Tang, J., Ji, S., Jiang, L., 2016. The design of a sustainable location-routing-inventory model considering consumer environmental behavior. Sustainability 8. https://doi.org/10.3390/su8030211.

Tighazoui, A., Turki, S., Sauvey, C., Sauer, N., 2019. Optimal design of a manufacturing-remanufacturing-transport system within a reverse logistics chain. Int. J. Adv. Manuf. Technol. 101, 1773–1791. https://doi.org/10.1007/s00170-018-2945-2.

Tiwari, S., Daryanto, Y., Wee, H.M., 2018. Sustainable inventory management with deteriorating and imperfect quality items considering carbon emission. J. Clean. Prod. 192, 281–292. https://doi.org/10.1016/j.jclepro.2018.04.261.

Tsolakis, N., Srai, J.S., 2017. Inventory planning and control in 'green' pharmacies supply chains – a System Dynamics modelling perspective. In: Computer Aided Chemical Engineering. Elsevier B.V., pp. 1285–1290. https://doi.org/10.1016/B978-0-444-63965-3.50216-6

Ugarte, G.M., Golden, J.S., Dooley, K.J., 2016. Lean versus green: the impact of lean logistics on greenhouse gas emissions in consumer goods supply chains. J. Purch. Supply Manag. 22, 98–109. https://doi.org/10.1016/j.pursup.2015.09.002.

Ullah, M., Asghar, I., Zahid, M., Omair, M., AlArjani, A., Sarkar, B., 2021. Ramification of remanufacturing in a sustainable three-echelon closed-loop supply chain management for returnable products. J. Clean. Prod. 290 https://doi.org/10.1016/j.jclepro.2020.125609.

Wang, W., Xu, X., Peng, Y., Zhou, Y., Jiang, Y., 2020. Integrated scheduling of port-centric supply chain: a special focus on the seaborne uncertainties. J. Clean. Prod. 262 https://doi.org/10.1016/j.jclepro.2020.121240.

Wang, X., Rodrigues, V.S., Demir, E., 2019. Managing your supply chain pantry: food waste mitigation through inventory control. IEEE Eng. Manag. Rev. 47, 97–102. https://doi.org/10.1109/EMR.2019.2915064.

Wu, W., Zhou, W., Lin, Y., Xie, Y., Jin, W., 2021. A hybrid metaheuristic algorithm for location inventory routing problem with time windows and fuel consumption. Expert Syst. Appl. 166 https://doi.org/10.1016/j.eswa.2020.114034.

Yadav, D., Kumari, R., Kumar, N., Sarkar, B., 2021. Reduction of waste and carbon emission through the selection of items with cross-price elasticity of demand to form a sustainable supply chain with preservation technology. J. Clean. Prod. 297 https://doi.org/10.1016/j.jclepro.2021.126298.

Yang, T., Fu, C., Liu, X., Pei, J., Liu, L., Pardalos, P.M., 2018. Closed-loop supply chain inventory management with recovery information of reusable containers. J. Combin. Optim. 35, 266–292. https://doi.org/10.1007/s10878-015-9987-2.

Yılmaz Balaman, Ş., Selim, H., 2016. Sustainable design of renewable energy supply chains integrated with district heating systems: a fuzzy optimization approach. J. Clean. Prod. 133, 863–885. https://doi.org/10.1016/j.jclepro.2016.06.001.

Zarta Ávila, P., 2018. La sustentabilidad o sostenibilidad: un concepto poderoso para la humanidad. Tabula Rasa 409–423. https://doi.org/10.25058/20112742.n28.18.

Zhalechian, M., Tavakkoli-Moghaddam, R., Zahiri, B., Mohammadi, M., 2016. Sustainable design of a closed-loop location-routing-inventory supply chain network under mixed uncertainty. Transport. Res. E Logist. Transport. Rev. 89, 182–214. https://doi.org/10.1016/j.tre.2016.02.011.

Zhang, F., Johnson, D.M., Johnson, M.A., 2012. Development of a simulation model of biomass supply chain for biofuel production. Renew. Energy 44, 380–391. https://doi.org/10.1016/j.renene.2012.02.006.

Zhang, Y., Huang, G.H., He, L., 2014. A multi-echelon supply chain model for municipal solid waste management system. Waste Manag. 34, 553–561. https://doi.org/10.1016/j.wasman.2013.10.002.

Zhang, Y.M., Huang, G.H., He, L., 2011. An inexact reverse logistics model for municipal solid waste management systems. J. Environ. Manag. 92, 522–530. https://doi.org/10.1016/j.jenvman.2010.09.011.

Žic, J., Žic, S., 2020. Multi-criteria decision making in supply chain management based on inventory levels, environmental impact and costs. Advances in Production Engineering And Management 15, 151–163. https://doi.org/10.14743/APEM2020.2.355.