sustainability

Review

Integrating Resilience and Sustainability Criteria in the Supply Chain Network Design. A Systematic Literature Review

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Abstract: Nowadays, Supply Chain Networks (SCNs) must respond to economic, environmental, social, and uncertain considerations. Thus, sustainable and resilience criteria need to be incorporated as key criteria into the Supply Chain Network Design (SCND). This paper, as part of an emerging subject, reviews the literature between 2010 and 2021 that integrates sustainability and resilience on the SCND. The article classifies the literature according to the levels of the SCND, levels of the decision-making (i.e., strategic, tactical, and operational), resilience and sustainability criteria, solving approach, objective criteria, contributions to the Sustainable Development Goals (SDGs), and real-world applications. The main findings allow us to conclude that the decisions regarding the supply chain network design with sustainability and resilience criteria are mainly strategic, focusing on the forward flow. Most works address resilience through the evaluation of scenarios (risk assessment perspective), and in terms of the sustainability perspective, authors mainly focus on the economic dimension through the evaluation of income and costs along the chain. Based on the review and the proposed taxonomy, the paper proposes ideas for future research.

Keywords: supply chain network design; resilience; sustainability

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1. Introduction

Supply chains (SCs) are vital for economic development in a globalized world. In its most general form, the SC is defined as a system in which raw materials are converted into final products and are delivered to consumers [1]. However, companies are concerned about a broader complex system called Supply Chain Network (SCN). The SCN is defined as a network of organizations and processes where various stakeholders (i.e., suppliers, manufacturers, distributors, retailers, among others) collaborate to acquire raw materials, convert them into final products, and deliver them to costumers [2–4].

Considering the types of decision-making in the SCN, one of the most expensive and irreversible long-term, strategic decisions is the Supply Chain Network Design (SCND) [5]. The SCND is a problem whose decisions include "the assignment of facility role; location of manufacturing-, storage-, or transportation-related facilities; and the allocation of capacity and markets to each facility" [6] (p. 108). As stated by Yu and Solvang [7], SCND involves several decision levels. The strategic level includes the optimal network configuration and at a tactical level the optimal use of such infrastructure. Particularly, operational decisions in the SCND include fulfillment of customer demands, pricing, and provided service level [8].

Therefore, the complexity of the decisions in the SCND is related to the strategies needed for increasing the value-added, efficiency, resilience, and sustainability of the network structures. Hence, the integration of resilience and sustainability into the SCND has emerged as key criteria, considering that a system that cannot recover from disruptions will not be able to recover its original quality and therefore will not be able to fulfill its social, environmental, and economic function [9].

The concept of resilience has had multiple definitions in various contexts, starting with Holling's study on the stability of ecosystems [10]. Other definitions are related to individual and community (psychology) and organizational and supply chain contexts [11,12]. Resilience can be defined as "the ability of a system to return to its original state or move to a new more desirable state after being disturbed" [13] (p. 2). In terms of the supply chain, resilience can be defined as "The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and functions." [12] (p. 131).

In the case of micro and small enterprises (MSEs), additional complexities arise compared to the supply chains of medium and large companies, mainly that are influenced by factors such as market structures, institutions, and the business environment. The design of resilient chains for MSEs must consider these complexities because these companies have important contributions in regional development due to their local character and history [14]. This fact has been magnified due to the pandemic of COVID-19 that has generated a great impact in supply chains both in magnitude (scale of the impact) and duration (length of the impact) [15]. Thus, the resilience of supply chains has become important considering the local disturbances that can spread upstream and downstream affecting the entire chain. This phenomenon is known as the ripple effect [16].

In the literature, different frameworks of resilient SC have been studied. For example, Christopher and Peck [13] proposed four fundamental aspects for the creation of resilient supply chains: (i) the engineering or re-engineering that focus on risk reduction, (ii) collaboration across the network, (iii) agility, and (iv) a risk management culture. Another work is presented by Ponomarov and Holcomb [12] who established the relationship between specific capabilities (i.e., control, coherence, and connectedness) throughout the phases of resilience, i.e., readiness, response, and recovery. Furthermore, recently, Purvis et al. [17] developed the RALF resilience framework in which resilience is defined through Robustness, Agility, Leanness, and Flexibility.

Regarding sustainability, its economic dimension was first defined by the United Nations Brundtland Commission as the "development of the needs of the present without compromising the ability of the future generations to meet their own needs" [18] (p. 14). Since then, different theories have emerged for complementing the original concept of sustainability, e.g., the Triple Bottom Line (TBL) [19,20]. Therefore, the concept of sustainability has evolved into the so-called Sustainable Development Goals (SDGs) [21], defined into 17 goals as a United Nations agenda for 2030.

The analysis of the SDGs in supply chain management starts addressing materials and information flows [22]. For example, Genc [23] studied the closed-loop supply chain structures relations considering industry investment, innovation, affordability, clean product, and responsible consumption/production; Jouzdani and Govindan [24] proposed a mathematical model of sustainable network design for perishable products and established its contribution to the objectives of zero hunger, affordable and clean energy, decent work and economic growth, climate actions, among others; and Tsolakis et al. [25] studied the design of blockchain-centric supply chains to achieve SDGs.

Particularly, the intersection between resilience and organizational sustainability and its relationship with business continuity management emerges as an important topic in academia and industry [26]. This integration can be seen as a complex but relevant criterion in the SCND. Thus, contributions including frameworks in the subject have increased over time. For example, de Souza et al. [27] propose a framework that migrates the design of supply networks from an anthropocentric vision to a biocentric and transdisciplinary vision; this can lead to long-term SCND and ensure sustainable functionality and feasibility while adapting to disruptions.

The difficulty in implementing sustainability and resilience practices in supply chains lies in the contradictory objectives that entail, for example, focusing on efficiency (sustainable) or flexibility (resilient); the study developed by Rajesh [28] identifies these underlying contradictory objectives and the trade-offs among them. Despite its academic and practical relevance, the existing literature reviews study separately resilience and sustainability criteria in the SCND. Thus, this work wants to contribute to fulfilling this gap by providing a systematic review of Resilient and Sustainable Supply Chain Network Design (SRSCND).

The following contributions are given in this study: (i) Provides recent development in the field of Supply Chain Network Design, (ii) highlights the importance of considering sustainability and resilience criteria in the supply chain design decisions, (iii) addresses the Sustainable Development Goals in the SCND, and (iv) identifies research gaps and proposes future research trends.

The remainder of this document is organized as follows: Section 2 describes previous reviews of SCND considering resilience or sustainability criteria. Section 3 explains the review methodology. Section 4 shows a descriptive analysis of the selected documents. The main findings of this paper are presented in Section 5. Section 6 presents the insights and the future research directions, and Section 7 presents the concluding remarks.

2. Previous Reviews and Position of Our Work

This section will summarize some of the most representative related reviews that consider resilience, sustainability, or both on the SCND.

An effective, responsive, and sustainable supply chain network design (SCND) is a vital component for companies to deal with the dynamic, uncertainty, and competitiveness of the market. Thus, academics and practitioners have contributed to the SCND providing a spectrum of applications, frameworks, methods, paradigms, decisions, and analysis, through the years. For example, the COVID-19 pandemic related SC studies [29] and SC decision making supported by the Internet of Things and Big Data Analytics [30].

For instance, Klibi et al. [31] discussed the SCND under uncertainty and presented a critical review of the optimization models found in the literature. The authors analyzed the supply chain's uncertainty, major disruptive events threatening, and risk exposures. It also discussed relevant strategic SCND evaluation criteria.

Farahani et al. [8] considered the trends of markets and their effects on SCND. A general framework for modeling competitive SCND is provided, linking market types, SC network configuration, competition types (e.g., developing market, growth market, steady market, and mature market), and structural attributes.

Ivanov et al. [32] synthesized research on supply chain design with disruption considerations in terms of the ripple effect in the supply chain. Features such as risks, affected areas, recovery, and affected performance were considered with its respecting bullwhip effect, i.e., operational, lost sales, short-term coordination to balance demand and supply, and current performance like daily stock-out/overage costs.

Govindan et al. [33] provided a comprehensive review of studies in the fields of SCND and reverse logistics network design under uncertainty. Two main parts were investigated. The first part studied the planning decisions, network structure, paradigms, and aspects related to SCM. In the second part, existing optimization techniques were explored for dealing with uncertainty such as recourse-based stochastic programming, risk-averse stochastic programming, robust optimization, and fuzzy mathematical programming.

Moreno-Camacho et al. [34] assessed sustainability in real-case applications of the supply chain considering strategic, tactical, and operational levels, in which at least two or three dimensions of sustainability are considered. The authors studied the forward, reverse, and closed-loop supply chains.

Esmizadeh and Mellat Parast [35] examined the logistics network designs and evaluated their performance concerning cost, quality, delivery, flexibility, and resilience. Additionally, the authors provided an assessment of the strengths and weaknesses of each logistics design for different operations strategies.

Dolgui et al. [36] considered a holistic framework on SC that includes digitalization, resilience, sustainability, and leagility (combination of lean and agile). In the paper, reconfigurability is considered as an integral perspective giving a new concept for complex value-adding systems in highly vulnerable environments, called the X-network.

Aldrighetti et al. [37] presented a systematic literature review of quantitative models of SCND under disruption risks in industrial SCM and logistics. The authors analyzed the costs induced by the planning of proactive investments in robustness and through adaptation at the recovery stage. Besides, the integration of different SCM dimensions i.e., social and environmental impact, responsiveness, and risk-aversion, are discussed.

Finally, Tordecilla et al. [38] provided a review of contributions on simulation–optimization methods for designing and assessing resilient supply chain networks under uncertainty. The authors considered the solving approaches, uncertain parameters, objective criteria, supply chain design, and application to real-world cases.

As can be seen, there is a lack of studies dedicated to analyzed contributions that combine sustainable and resilience criteria on the SCND. In this context, this paper aims to contribute to this subject, considering: levels in the SCND, levels of the decision-making, i.e., strategic, tactical, and operational, resilience and sustainability criteria, solving approach, objective criteria, and real-world applications.

3. Review Methodology

The present review is based on the Systematic Literature Review (SLR) approach [39]. The SLR steps are (i) question formulation; (ii) location of studies; (iii) study selection and evaluation; (iv) analysis and synthesis; and (v) reporting and use of results.

For this review, a general question and some specific ones were formulated. The general question is ¿How resilience and sustainability criteria are considered in the supply chain network design? The specific questions were formulated as follows:

- What elements of sustainability are considered?
- What kinds of disruptions are taken into account?
- What is the term of decisions?
- How resilience and sustainability are linked?
- Which links in the supply chain are considered?
- How is the supply chain modeled?

The search for documents was carried out in the Scopus and Web of Science, which are the major citation databases [40]. The search was conducted from the next combinations of terms:

- "supply chain" AND network AND design AND (resilien* OR disrupt*) AND (sustainab* OR green);
- "supply chain design" AND (resilien* OR disrupt*) AND (sustainab* OR green).

The search was filtered by publication period (between 2010 and April 2021), by document type (research article and book chapter), and by language (English). The search terms were located in the title, abstract, and keywords. Two initial filters were carried out to select the documents: (i) the first filter considers just research articles, and (ii) the second filter eliminates papers that do not consider network design, sustainability, or resilience together and those that do not consider sustainability as a design criterion. Figure 1 shows the detail of the paper selection for this study. A total of 54 papers were selected for the analysis.

To analyze the selected papers, a review taxonomy was built. All papers were classified according to three main components: Network design, Resilience, and Sustainability; details are explained later. Figure 2 shows a graphical representation of the taxonomy.

In terms of network design, the scope of decisions was established as the number of links considered in the supply chain between suppliers (S), manufacturing centers (M), distribution centers (D), primary markets (R), collection centers (C), remanufacturing, recycling and recovering (Y), secondary and tertiary markets (U), and disposal centers (G). Figure 3 shows the possible generic links in forward and reverse flows.

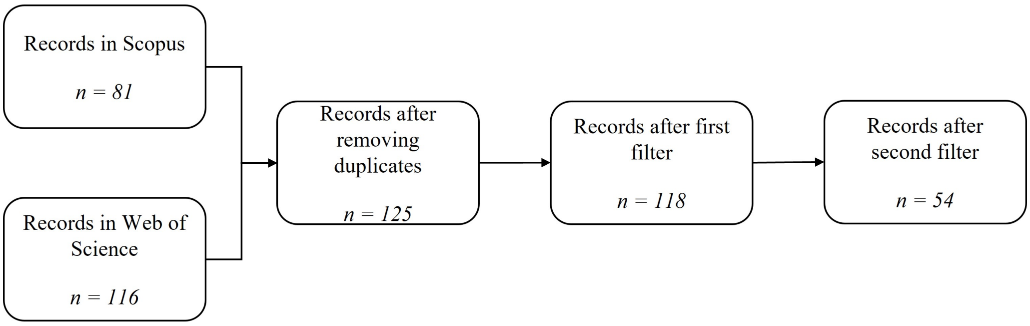

Figure 1. Document screening.

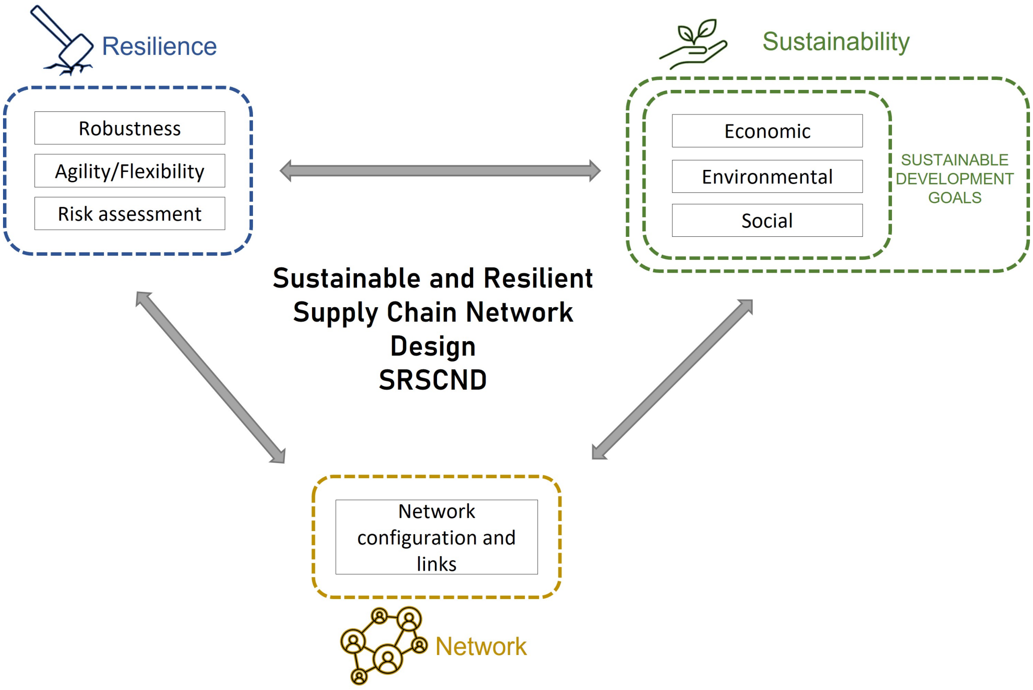

Figure 2. Review taxonomy.

From the resilience perspective, the classification contemplates the strategic level for dealing with disruptions and uncertainties. The three categories are explained below:

- Robustness: the ability of a supply chain to resist or avoid change [41].
- Agility/Flexibility: supply chain abilities to adjust its operations and tactics to respond to opportunities, threats, and environmental changes in turbulent markets [42,43] and to adapt to changes in demand, customer requirements, customer service levels, and delivery conditions [44].
- Risk assessment: is a stage of the supply chain risk management in which mitigation strategies are determined to be implemented when a disruption occurs [45].

In the literature, flexibility and agility are considered as different concepts, i.e., flexibility is related to known situations at the operational level, and agility is considered as a wider concept at the business level [17]. However, we consider both terms as a single category that encompasses the adaptability of the SC to disruptions and uncertainties.

Regarding sustainability, the classification includes the network design decisions criteria and the impact on sustainable development, i.e., economic, environmental, and social, in the SDGs (See Figure 4). The numbers in Figure 4 correspond to the official numbers of the SDG's [21]: (1) No poverty, (2) Zero hunger, (3) Good health and well-being, (4) Quality education, (5) Gender quality, (6) Clean water and sanitation, (7) Affordable and clean energy, (8) Decent work and economic growth, (9) Industry, innovation and infrastructure,

(10) Reduced inequalities, (11) Sustainable cities and communities, (12) Responsible consumption and production, (13) Climate action, (14) Life bellow water, (15) Life on land, (16) Peace, justice and institutions, and (17) Partnership for the goals.

Finally, the objective criteria that each article addressed are considered. In many cases, the objective shows the relationship between sustainability and resilience. Additionally, the solution methods are registered to characterize the methodologies and tools that allow addressing the SRSCND. The term of decisions, whether strategic, tactical, or operational, is also examined.

Figure 3. Generic links of the network.

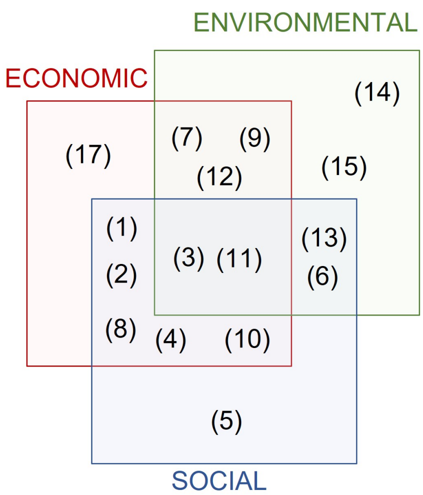

Figure 4. SDGs classification.

4. Descriptive Analysis

The integration of resilience and sustainability in the supply chain network design is recent and its interest has grown over the years. Although this review was carried out in the last decade, the first article can be found in 2014. Figure 5 shows the distribution of the number of publications through the years. As can be seen, the trend is growing, and almost 58% of the documents were published between 2020 and 2021.

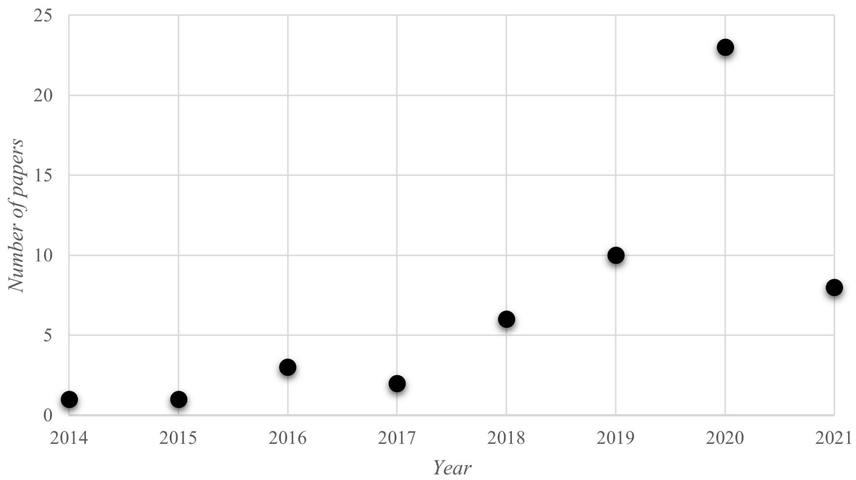

Figure 5. Distribution of publications per year.

Regarding the type of document, only one is a book chapter [46], and the rest are research articles. The articles are distributed in 32 journals, 23 of them with one publication. A summary of the numbers of papers per journal is presented in Figure 6. This figure includes only journals with two or more papers with the SRSCND.

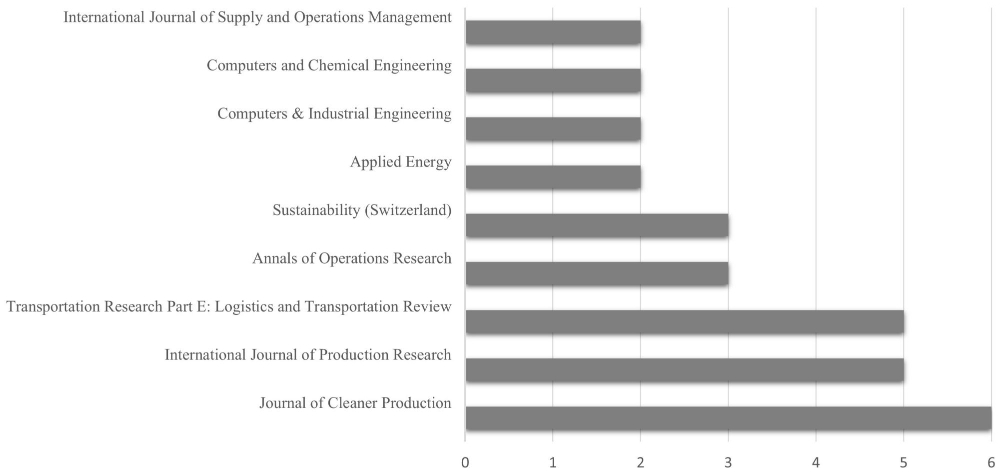

Figure 6. Distribution of papers per journal.

The selected articles are written by 116 authors, 30 of them with two or more contributions, being Armin Jabbarzadeh, Behnam Fahimnia, and Mir Saman Pishvaee the ones with more articles on the SRSCND. Figure 7 shows the authors with three or more contributions. The authors' frequency contribution does not consider their position in the paper. In terms of the geographical location of the authors' affiliation, the countries that appear the most are Iran (29 articles), Australia, the United States, and France (five articles each).

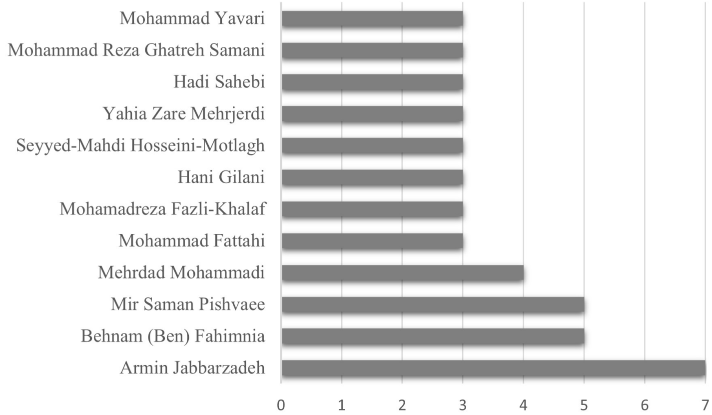

Figure 7. Distribution of papers by author.

As mentioned above, the SCND is a complex decision-making process, so it is common to be approached from a mathematical modeling perspective. Consequently, 52 of the analyzed articles propose optimization models and the remaining is a conceptual framework [27].

Regarding the academic visibility of the papers, the three most cited are: Sustainable design of a closed-loop location-routing-inventory supply chain network under mixed uncertainty [47] with 148 citations according to Scopus, 124 citations according to Web of Science, and 222 citations according to Google Scholar; Marrying supply chain sustainability and resilience: A match made in heaven [48] with 107 citations according to Scopus, 88 citations according to Web of Science, and 149 citations according to Google Scholar; and Toward an integrated sustainable-resilient supply chain: A pharmaceutical case study [49] with 64 citations according to Scopus, 53 citations according to Web of Science, and 96 citations according to Google Scholar.

5. Main Findings

A detailed analysis of the selected papers is presented below according to the taxonomy presented in Figure 2 for the SRSCND.

5.1. Network Design

A fundamental part of the SCND is to establish the number of actors involved as well as their roles. We characterize the SC according to the structure and codification presented in Figure 3. The results are shown in Table 1, the x in columns S to G means that said link, or links, are modeled through a set, and in the remaining two columns they are associated with the the decision terms. Note that with this classification it is not necessary to highlight whether the SC is forward flow, reverse flow, or closed loop. Transportation is not considered part of the classification as it is a ubiquitous element in all SCND problems.

Considering the particularities of some supply chains, details about the classification of the links are provided as follows. In the case of biofuel production in [50], the feedstock supplier (crops) and the feedstock storage are classified as Suppliers. In sugar beet SC [51], the sugar beet farms are considered as Suppliers. Kaur and Singh [52] presented a lot-sizing and inventory model that only considers suppliers in the SC. In the biofuel SC by [53] the sugarcane fields are considered as Suppliers and biorefineries as Manufacturing facilities. In the wheat SC by [54] the silos are considered as Suppliers since they are used for raw material, which is the same case for biomass storage facilities in [55]. In [56] the model refers to three generic related links, i.e., Farms (classified as Suppliers), Abattoirs (classified as Manufacturing facilities), and Retailers. In [57] the links for reverse flows are the same as those in forward flow since they can provide both services.

Special considerations in intermodal transportation problems are also found in [58]. In this article, generic links are not considered since the initial and final terminals can be any link in the supply chain. Cases oriented to intermodal transport with hub location, only consider Warehouses, which are the starting and ending links of the SC [59,60]. Other cases only deal with links that include raw material procurement from suppliers [52].

Two contributions present interdependent two-layer SCs integrating the power and the supply networks [61,62]. In both cases, the power stations are classified as manufacturers or transformation nodes and the transformers and substations as part of the power distribution. The same classification is made for the electricity supply chain networks [63–65].

The most considered SCN links in the analyzed papers are those related to demand (R), (87% approximately). This behavior makes sense due to the main objective of supply chains which is providing finished products to consumers. The next most used links are those related to transformation and value addition (M), i.e., focal companies (83% approx.). The intermediate or distribution links (D) can be found in 70% of the models; their importance lies in the consolidation of products, geographic coverage, and coordination of the production and demand cycles.

On the reverse flow links, the most used are the recovery (Y) and collection (C) (35% and 30% respectively). The final links of the reverse flow, secondary markets (U), and final disposal centers (G) are the least used (13% and 15% respectively). The latter is justified since much of the product flow is reintegrated into the forward flow after value recovery. The most complete chains found are the ones that contain all links defined in this classification [66–68].

Table 1. Network and decision terms.

Reference	Network								Decision Terms	
	S	**M**	**D**	**R**	**C**	**Y**	**U**	**G**	**Strategical**	**Tactical**
[69]	x	x	x	x					x	
[46]		x	x	x					x	
[48]	x	x	x	x					x	
[70]	x	x		x	x	x	x		x	
[47]	x		x	x		x			x	x
[71]		x	x	x	x	x		x	x	
[49]		x	x	x	x	x		x	x	
[72]		x	x	x	x	x	x	x	x	
[50]	x	x		x					x	
[73]		x		x						x
[74]		x	x	x						
[58]			x							x
[75]	x	x		x					x	
[56]									x	
[76]	x	x	x	x					x	
[61]		x	x	x		x			x	
[66]	x	x	x	x	x	x	x	x	x	
[51]	x	x		x					x	
[63]		x	x	x					x	
[77]			x	x					x	
[59]			x						x	
[52]	x									x
[64]		x	x	x					x	
[53]	x	x	x	x					x	
[54]	x	x		x					x	
[57]		x	x	x	x	x			x	
[78]	x	x	x	x	x		x	x	x	
[79]	x	x	x	x		x			x	x
[80]	x	x	x	x	x	x		x	x	
[81]		x	x	x					x	
[82]		x	x	x					x	
[62]		x	x	x		x			x	

Table 1. *Cont.*

Reference	Network								Decision Terms	
	S	M	D	R	C	Y	U	G	Strategical	Tactical
[65]		x	x	x					x	
[83]	x	x	x	x	x				x	
[84]	x	x	x	x	x	x			x	
[85]	x	x	x	x					x	
[86]	x	x	x	x		x			x	x
[87]	x	x	x	x	x	x			x	
[88]	x	x		x					x	
[89]	x	x	x	x					x	
[60]			x							x
[90]	x	x		x					x	
[55]	x	x							x	
[91]	x	x		x					x	
[92]	x	x		x	x	x	x		x	
[93]	x	x	x	x					x	
[67]	x	x	x	x	x	x	x	x	x	
[94]	x	x	x						x	
[95]		x	x	x					x	x
[68]	x	x	x	x	x	x	x	x	x	
[96]				x	x	x			x	
[97]				x	x	x			x	
[98]	x	x	x	x					x	

There are cases with considerations about the resulting network structure. In [71], authors determined that a focus on minimizing environmental impact (emissions) led to centralize the designed network structures since the model tends to select for opening facilities with potential locations, high demands, and low transportation costs and that minimize the emissions emanating from production and transportation. In [57], it is shown that the result of disrupted demand due to a disaster is the modification of the network to have more spread facilities to supply partially or totally the demand after a disruption. In [92] there is a relationship between the decentralization of the reverse flow network and the reduction of CO_2 emissions during transport.

5.2. Sustainability

The classification of the sustainability criteria in SCND is presented in Tables 2 and 3. The tables include the way sustainability is incorporated in the SCND. Columns E, Env and S correspond to the economic, environmental, and social dimension, respectively, in which it is specified whether the sustainability dimension is addressed in the objective function (O) and/or in the constraints (C). The x in the other columns indicate whether the factor is entered into the model as a parameter. The economic perspective is presented between Columns E(1) and E(12): (E1) profit, E(2) income or revenue, E(3) facilities opening/closing costs, E(4) production or manufacturing costs that include the fixed and variable costs of any link in forward and reverse flows, E(5) purchasing and procurement costs including those related to suppliers and imports, E(6) inventory costs, E(7) transportation/shipping costs, E(8) unsatisfied demand and lost sales costs, E(9) environmental and emissions costs, E(10) social costs, E(11) resilience/disruptions costs, and E(12) other costs such as an increase in capacity, financial costs, purchase of technology, among others.

The environmental perspective is presented between Columns Env(1) and Env(2) associated with emissions and other environmental factors such as carbon footprint, environmental scores, energy usage, among others, respectively. Finally, social perspective is presented in Columns S(1) and S(2) dedicated to employment and other social factors such as balanced economic development, social scores, among others, respectively.

As can be seen, the economic dimension of sustainability is very important since it is usually the main criterion in corporate decision-making. This statement is confirmed by the large number of parameters that affect the economic dimension in the SCND and the number of articles that consider this criterion as the main objective (See Tables 2 and 3). In this literature review, just one paper does not consider the economic dimension of sustainability [97].

The most common decisions in SCND problems are those concerning the selection of the facilities to be used in the network as well as the flow between links. So, a vast majority of papers take into account facilities opening (or closing) costs as well as transportation and distribution costs. There are a few cases that do not consider either of them: Darom et al. [73] since it models an inventory model in a two-echelon supply chain with fixed facilities and only considers transportation between facilities for environmental assessment purposes; and Özçelik et al. [97] whose objective function is to maximize the flow of products but does not consider the cost of transport or the facilities used, although they are decision variables.

The economic dimension of sustainability has also the characteristic of integrating the other two dimensions in the form of associated costs. Two articles consider costs related to environmental criteria. Zahiri et al. [49] include carbon credits as cost and emissions of CO_2 as one of the objective functions, and Gilani et al. [90] include the fine for violating environmental standards as a cost and the environmental impact as an objective function. In terms of social criteria, the social costs of carbon emissions, the economic impact of road transport (noise, congestion, and accidents), and the cost of the externalities in the rail transport are studied in [59]; the social cost of opening a renewable energy generation unit is studied in [64]. In several articles, environmental aspects are included as a cost criteria [52,57–60,64,65,73,86,91,95].

Regarding the environmental dimension, the most common parameters of the SC are CO_2 and greenhouse gas (GHG) emissions in facility establishment and production and transportation stages, among others. Other parameters include carbon footprint [69,70], fuel consumption and wasted energy [47], energy consumption [66], useful energy extraction [78], and other environmental effects [53]. In other cases, external evaluation scores and not direct measurements are incorporated into the models [48,75,77].

The social dimension is the least included in the models. When it is included, it is done through job creation. Other aspects are: balanced economic development [47,49,85] and lost workdays due to disruptions [54,87].

Table 2. Sustainability criteria—Part a.

Reference	Sustainability			Environ. Criteria		Social Criteria	
	E	Env	S	Env (1)	Env (2)	S(1)	S(2)
[69]	O	O		x	x		
[46]	O	C		x			
[48]	O	O	O		x		x
[70]	O	O		x	x		
[47]	O	O	O	x	x	x	x
[71]	O	O		x			
[49]	O	O	O	x		x	x
[72]	O	O		x			
[50]	O	C	C	x		x	
[73]	O	O					
[74]	O	C					
[58]	O	O					
[75]	O	O			x		
[56]	O			x			
[76]	O	O	O	x		x	x
[61]	O	O		x			
[66]	O	O	O	x	x	x	
[51]				x			
[63]	O	O		x			
[77]	O	O	O		x		x

Table 2. *Cont.*

Reference	Sustainability			Environ. Criteria		Social Criteria	
	E	Env	S	Env (1)	Env (2)	S(1)	S(2)
[59]	O	O	O				
[52]	O	C					
[64]	O	O	O				
[53]	O	O	O		x	x	
[54]	O		O			x	x
[57]	O	O					
[78]	O	O		x	x		
[79]	O	O		x			
[80]	O	O		x			
[81]	O	O	O	x		x	x
[82]	O		O			x	x
[62]	O	O		x			
[65]	O	O					
[83]	O	O		x			
[84]	O	O	O	x		x	
[85]	O		O			x	x
[86]	O	O					
[87]	O		O		x	x	x
[88]	O	C		x			
[89]	O	C		x			
[60]	O	O					
[90]	O	O	O	x		x	
[55]	O	C	C	x			x
[91]	O	O,C					
[92]	O	O	O	x		x	x
[93]	O	O		x			
[67]	O	O	O	x	x	x	
[94]	O	O		x			
[95]	O	O					
[68]	O	O			x		
[96]	O	C		x			
[97]		C	C	x		x	
[98]	O	O		x			

Table 3. Sustainability criteria—Part b.

Reference	Economic Criteria											
	E(1)	E(2)	E(3)	E(4)	E(5)	E(6)	E(7)	E(8)	E(9)	E(10)	E(11)	E(12)
[69]			x	x	x	x						
[46]			x	x			x	x				
[48]			x	x	x		x	x				
[70]			x	x	x		x					
[47]			x			x	x					
[71]			x	x			x					
[49]			x			x	x		x			x
[72]	x	x	x	x	x	x	x					x
[50]			x	x		x	x	x			x	
[73]						x		x	x		x	
[74]			x	x			x	x				
[58]			x						x			
[75]					x		x	x				x
[56]				x	x		x					
[76]	x	x	x	x		x	x					x

Table 3. *Cont.*

Reference	Economic Criteria											
	E(1)	**E(2)**	**E(3)**	**E(4)**	**E(5)**	**E(6)**	**E(7)**	**E(8)**	**E(9)**	**E(10)**	**E(11)**	**E(12)**
[61]			x	x		x						
[66]			x				x					x
[51]	x	x		x	x		x					
[63]		x	x	x								
[77]			x	x	x		x					x
[59]							x			x		
[52]					x	x	x		x			
[64]			x	x					x	x		
[53]	x	x		x	x	x	x					
[54]			x		x	x	x					
[57]				x		x	x		x			x
[78]							x					
[79]	x	x	x	x	x		x					
[80]	x	x	x	x	x	x	x					x
[81]			x	x		x	x	x				
[82]			x	x		x	x	x				
[62]			x		x	x	x	x				x
[65]				x			x		x			x
[83]			x		x	x	x	x				
[84]			x	x	x		x					
[85]			x	x	x	x	x					
[86]			x	x		x			x		x	
[87]	x	x	x	x	x	x	x					x
[88]		x	x	x	x	x	x					
[89]			x	x	x	x	x	x				x
[60]			x				x		x		x	
[90]	x	x	x	x		x	x	x	x			
[55]	x	x	x	x	x	x	x					
[91]			x		x		x		x			
[92]			x	x			x	x				
[93]	x	x	x	x	x	x	x	x				
[67]			x			x	x					x
[94]		x	x	x	x		x					
[95]			x	x		x	x	x	x			
[68]												x
[96]			x				x					
[97]												
[98]			x	x	x	x	x	x				x

5.3. Resilience

For the resilience analysis, results are summarized in Table 4. Since resilience is the ability to anticipate and overcome disruptive events, it is important to know which links are subjected to disruption in the models. Table 5 shows the result of this classification, using the same SC link notation shown in Figure 3 and the characterization of the network in Section 5.1. In this classification, the cases in which there is explicit mention of disruption in the nodes are included.

In the case disruptions that are modeled, normally the links are associated with the forward flow, and only 9% of the cases show disruptions in the reverse flow links. In particular, many models consider disruptions on a single link, i.e., manufacturing (*M*), Suppliers (*S*), or Distribution links (*D*). Furthermore, only a few cases show disruptions in more than three links [66–68,83].

Table 4. Classification of the resilience approach.

Resilience Factor	Reference(s)
Robustness	[47,50,58,60,63,64,77,78,81,83,89,92,97]
Agility/Flexibility	[51]
Risk Assessment	[46,48,55,62,69,70,72–75,82,84,86–88,90,91,94,95,98]
Robustness - Agility/Flexibility	[49,54,56,59,65,79,85]
Robustness - Risk Assessment	[57,93,96]
Agility/Flexibility - Risk Assessment	[67,68,71,80]

The electricity SC proposed by Jabbarzadeh et al. [63] uses failure (disruption) probabilities in generation nodes (Supplier) and in transmission lines. The latter is considered part of the distribution process. In [61], the disruptions are only considered in the power network, in a two-layer model.

In [49], the resilience assessment is done through Node criticality that measures how much a node is used in the network; New technology that establish the use of new or old technology due to disruption; Flow that measures interaction between nodes; Node complexity that establishes the number of active nodes; and Customer de-service level as the unmet demand.

Table 5. Links disrupted in models.

Place of Disruption	Reference(s)
M	[49,65,73,78,80,90,95]
S	[48,50,72,75,84,86]
D	[52,59,60]
R	[71]
M-D	[46,74,81,85,98]
S-D	[61,63,64,87]
C-Y	[96,97]
S-M-D	[62,69,70,92]
M-D-R	[53]
S-M-D-C	[83]
S-M-D-R-C-Y-G	[66–68]

For the wheat SC in [54], the same indicators from Zahiri et al. [49] are used, except the technology one. In [85] the indicator are: Coverage radius that measures accessibility of facilities, Foreign suppliers that is related to the imported level of raw material, Capacity expansion of facilities between upper and low boundaries, and the indicators of Node complexity and Flow complexity, as already mentioned.

In the electricity SC by Hosseini-Motlagh et al. [65], the reliability indicators are Successive establishment that measures the establishment of facilities, Congestion on electrical lines that is the physical limitation of the lines, DGs inadequacy that determines the capacity of Distributed Generators (DGs) for supply during outages, and Maximum energy dissatisfaction level as a measure of dissatisfied energy.

In [56], the resilience is addressed through the RALF framework. The importance weight of Robustness, Agility, Leanness, and Flexibility is determined by expert judgment and evaluated using the Fuzzy Analytic Hierarchy Process. These weights are used as parameters in the resilience objective function.

In the food SC modeled by [77], the sustainability–resilience-based design is proposed through Lean Green Prevention Steps (LGPV). This approach considers waste prevention strategies from overstocking, product deterioration, failure to collect the right quality food, and transportation to collection points or warehouses. For the case of disaster SC in [52], the resilience evaluation is done by varying the carrier capacity in deterministic scenarios to evaluate the efficiency of the model.

In the Closed-Loop Supply Chain (CLSC) by [78], the total time is used as a resilience metric. In particular, the lost production time and the re-work time due to the disruptive performance of the machines are analyzed. Other CLSCs use the LARG (Lean, Agile, Resilient, and Green) approach for the assessment of conflicting points, specifically: capacity surplus, scattered facility, and transportation vehicles. One can conclue that as a resilience strategy, it is better to have a capacity surplus, scattered facilities, and a variety of transportation vehicles to avoid disruptions [79].

Fazli-Khalaf et al. [81], Ardakani et al. [82], and Hasani et al. [93] use the exponential distribution to model failure probability of some facilities. In all cases, these probabilities are used to model the network reliability as a measure of resilience. For the cases of the two-layer design models, the disruptions are located in different places. Yavari and Zaker [61] consider disruptions only in the power network. On the other hand, Yavari and Zaker [62] study disruptions in the power network and the supply network facilities.

The most popular way to assess resilience is through scenario evaluation. In this case, parameters are varied and the response is evaluated. Articles that use this strategy (about 60%) are classified in the Risk assessment category in Table 4. These scenarios can be probabilistic or discrete deterministic, and some of them can be generated by a structured process such as Monte Carlo simulation [55].

Contributions are classified under the category of Robustness when uncertain parameters are used to evaluate the capacity of the network to face disruptions or when certain variables serve to evaluate said response, such as authors in [79] that propose a capacity surplus as a measure of resilience in the LARG approach. All the papers that use reliability as a measure of resilience [64,81,92] are also classified under the Robustness category.

Finally, the Agility/Flexibility category includes those models in which responses to changes (i.e., demand) are analyzed. These categories are not mutually exclusive and the models can be classified into more than one category, for example, Fazli-Khalaf et al. [71] assess scenarios in which demand is modeled as triangular fuzzy numbers.

5.4. Integration of Sustainability and Resilience and Terms of Decision

Three elements are considered in this section: the objective functions and modeling approach in Table 6 and the term of decisions in Table 1.

As can be seen, most of the models are multi-objective (approximately 72%) and several of these correspond to sustainability criteria (i.e., economic, environmental, and social). The integration of sustainability–resilience criteria is considered if at least one of the objectives refers to resilience and sustainability. The resilience objectives are: minimization of disruption costs [46,69,70], minimization of de-resiliency [49,54,65,85], maximization of resilience [56,63,81,92], maximization of reliability [81,92], and minimization of reliability cost [64]. Table 6 shows the detailed summary.

SCND issues span all decision terms (strategic, tactical, and operational) [8], so the SRSCND has the same characteristics. The term of the decisions transverses the sustainability, resilience, and structure of the network, so it is a criterion of integration.

As previously mentioned, the decisions in the network design problem tend to be strategic. Only some contributions combine strategic with tactical decisions, and a few focus on tactical decisions only. Table 1 shows the classification of the papers.

Tactical decisions can be found in [47], which uses a (Q, r) model to calculate inventory costs and a $M/M/c$ queuing model to measure environmental impacts as wasted energy while trucks are waiting. The authors also model routing to deliver products to the customers. Darom et al. [73] and Kaur and Singh [52] propose an inventory and lot-sizing model. In [79], a newspaper boy problem is used to calculate inventory levels in retailers. In [95], the inventory level in warehouses is modeled by a birth and death process (continuous-time Markov chain). Considering the intermodal transportation problems introduced by [58–60], the tactical decisions consist of selecting the mode of transport and the hubs in which the modes of transport are changed.

Considering the characteristics of the SCND, it is necessary to consider conceptual and mathematical tools for handling complex decision-making. Thus, a final classification in Tables 6 and 7 presents the way SCND was initially modeled by authors. It is important to note that these models undergo a series of transformations so that they are manageable in terms of solution, for example, converting multiple objectives (as mentioned, most models have them) into a single one, converting a probabilistic model into an equivalent deterministic model, converting a fuzzy model into its crisp version, or linearizing a non-linear model, among others. As it can be seen, Mixed Integer Linear Programming (MILP) and Mixed Integer Non-Linear Programming (MINLP) are the most used modeling tools (with 60% of the cases); other models are robust, stochastic, or fuzzy.

Table 6. Modeling approach and objective—Part a.

Authors	Modeling Approach
[69]	Mixed Integer Linear Programming (MILP)
[46]	Mixed Integer Linear Programming (MILP)
[48]	Stochastic Fuzzy Goal Programming
[70]	Mixed Integer Linear Programming (MILP)
[47]	Stochastic-Possibilistic Programming
[71]	Robust Programming
[49]	Fuzzy Possibilistic-Stochastic Programming
[72]	Fuzzy Bi-level Mixed Integer Non-Linear Programming
[50]	Multi-stage Stochastic programming
[73]	Inventory and lot-size model
[74]	Robust Programming
[58]	Mixed Integer Linear Programming (MILP)
[75]	Stochastic Programming
[56]	Fuzzy Programming
[76]	Mixed Integer Non-Linear Programming (MINLP)
[61]	Mixed Integer Linear Programming (MILP)
[66]	Mixed Integer Linear Programming (MILP)
[51]	Mixed Integer Linear Programming (MILP)
[63]	Robust Programming
[77]	Mixed Integer Linear Programming (MILP)
[59]	Mixed Integer Non-Linear Programming (MINLP)
[52]	Mixed Integer Non-Linear Programming (MINLP)
[64]	Fuzzy Robust Programming
[53]	Mixed Integer Linear Programming (MILP)
[54]	Stochastic Fuzzy-Robust Programming
[57]	Mixed Integer Non-Linear Programming (MINLP)
[78]	Mixed Integer Non-Linear Programming (MINLP)
[79]	Mixed Integer Non-Linear Programming (MINLP)
[80]	Mixed Integer Non-Linear Programming (MINLP)
[81]	Mixed Integer Linear Programming (MILP)
[82]	Mixed Integer Linear Programming (MILP)
[62]	Mixed Integer Non-Linear Programming (MINLP)
[65]	Robust Programming
[83]	Mixed Integer Linear Programming (MILP)
[84]	Mixed Integer Linear Programming (MILP)
[85]	Stochastic Fuzzy-Robust Programming
[86]	Non-Linear Programming
[87]	Mixed Integer Non-Linear Programming (MINLP)
[88]	Mixed Integer Linear Programming (MILP)
[89]	Robust Mixed Integer Linear Programming (ROMILP)

Table 6. *Cont.*

Authors	Modeling Approach
[60]	Robust Programming
[90]	Robust Mixed Integer Linear Programming (ROMILP)
[55]	Mixed Integer Linear Programming (MILP)
[91]	Mixed Integer Linear Programming (MILP)
[92]	Mixed Integer Linear Programming (MILP)
[93]	Mixed Integer Non-Linear Programming (MINLP)
[67]	Mixed Integer Linear Programming (MILP)
[94]	Mixed Integer Linear Programming (MILP)
[95]	Mixed Integer Non-Linear Programming (MINLP)
[68]	Mixed Integer Linear Programming (MILP)
[96]	Stochastic Mixed-Integer Programming
[97]	Robust Programming
[98]	Mixed Integer Linear Programming (MILP)

Table 7. Modeling approach and objective—Part b.

Authors	Objective Function			
	OF1	OF2	OF3	OF4
[69]	Network costs	Carbon emission	Embodied carbon footprint	Disruption cost
[46]	Supply chain costs (no disruption)	Supply chain costs (disruption)		
[48]	Costs	Environmental scores	Social scores	
[70]	SC Costs	Total carbon emission	Disruption costs	
[47]	Total costs	Environmental impacts	Social impacts	
[71]	Total costs	Emissions		
[49]	Total costs	Social impacts	Environmental impacts	Non resiliency
[72]	Profit	Emissions		
[50]	Total costs			
[73]	Manufacturer cost	Retailer cost	Total carbon emission cost	
[74]	Total costs			
[58]	Total costs			
[75]	Total costs	Sustainability scores		
[56]	Total costs	Emissions	Resilience	
[76]	Profit	Emissions	Social impacts	
[61]	Total costs	Emissions		
[66]	Costs	Emissions	Cumulative energy demand	Employment
[51]	Profit	Emissions		
[63]	Costs	Emissions	Resilience	
[77]	Production	Profit		
[59]	Costs			
[52]	Costs			
[64]	Sustainability costs	Reliability costs		
[53]	Profit	Emissions	Employment	
[54]	Costs	Resiliency		
[57]	Costs			
[78]	Total costs	Total time	Carbon emissions	
[79]	Profit	Emissions	Customer's satisfaction	
[80]	Profit	Emissions		
[81]	Total costs	Reliability	Emissions	Employment
[82]	Costs	Social responsability		
[62]	Costs	Emissions		
[65]	Costs	De-Resiliency	Employment	
[83]	Costs	Emissions	Customer's satisfaction	
[84]	Costs	Emissions	Employment	
[85]	De-Resiliency	Social impacts	Total costs	
[86]	Costs			
[87]	Profit	Employment	Environmental impacts	Risk
[88]	Total costs			
[89]	Total costs			
[60]	Total Relative Regret			
[90]	Profit	Environmental impacts	Employment	
[55]	Profit			
[91]	Costs			

Table 7. *Cont.*

Authors	Objective Function			
	OF1	OF2	OF3	OF4
[92]	Costs	Reliability	Emissions	Social responsability
[93]	Profit	Centralization of facilities	Emissions	
[67]	Costs	Emissions	Energy demand	Employment
[94]	Costs	Ecological performance		
[95]	Costs			
[68]	Costs	Emissions	Energy demand	Employment
[96]	Costs			
[97]	Total recovered products			
[98]	Costs	Emissions		

5.5. SRSCND and Sustainable Development Goals

SCs represents an important logistical challenge that includes geographic dispersion of stakeholders, lack of infrastructure, adverse climate conditions, natural and man-made disasters, among others. Thus, resilient and sustainable supply chains ensure the continuity of operations, minimize (or at least controlling) negative impacts on communities, generate employment and other positive social impacts, and make them cost-efficient. This last part of the analysis attempts to determine the SDGs related to the SCND.

- Goal 2: Zero hunger
  This goal aims to provide to the people sufficient and nutritious food. Thus, efficient supply chains are needed to guarantee continuity facing adverse events such as those that usually occur in emerging countries. The works that propose SCND for food supply are good starting points to help in this matter [51,54,56,59–62,77,98].
- Goal 3: Good health and well-being
  Guarantee universal health coverage is a challenging objective considering the training that must be provided to the personnel, together with adequate infrastructure, technology, and supplies. For significant progress in this goal, adequate public policies and effective and efficient supply systems are needed. Examples of such systems are the pharmaceuticals [49] and medical SC [93].
- Goal 4: Quality education
  Similar to Goal 3, achieving inclusive and quality education depends on meeting the needs for staff, infrastructure, technology, and supplies. An example of this is the SC of classroom equipment and furniture by [79].
- Goal 7: Affordable and clean energy
  It is no secret that the generation of energy for automotive, domestic, and industrial use is one of the main contributors to global warming. This SDG aims to expand the infrastructure and update the technology to provide clean, efficient, and reliable energy. Resilient and sustainable supply chain designs for electricity and fuels assist in this purpose [50,53,55,63–65,85,88,90,92,94].
- Goal 8: Decent work and economic growth
  This goal wants to achieve full and productive employment and decent work. One of the contributions of SRSCND is the generation of employment caused by the opening facilities such as factories and distribution centers [47,49,50,53,54,66,67,76,81,82,84,85,87,90,92,97], and other social impacts such as balanced economic [47,49,85], and immigration prevention [92].
- Goal 12: Responsible consumption and production
  This goal aims for economic growth and sustainable development reducing our ecological footprint by changing the production and consumption of goods and resources. One of the most important initiatives is to encourage industries, businesses, and consumers to recycle and reduce waste. Sustainable and resilient closed-loop and reverse supply chains contribute in this sense. In addition to reducing the environmental impact in its operations, the SRSCND provide a structure for

value recovery, second uses, or adequate final disposal of products [47,49,57,61,62,66–68,70–72,78–80,83,84,86,87,92,96,97].

5.6. Real-World Cases and Applications

In terms of real-world cases, it is evident that the SRSCND problems are applied mainly to local chains (to a single country). Table 8 shows the case studies applied to a single country; Iran is the country with more application cases, followed by India and Turkey. In [77], the SC is applied to some countries in North Carolina from the United States. The articles that carry out case studies with transnational chains are shown in Table 9. Most of the works apply to neighboring countries that could be considered as extensions of local chains. The cases of [48,74,89] are the only ones that respond to more global processes.

Table 8. Papers with applications in one country.

Country	Reference(s)
Iran	[50,54,55,62,63,65–68,72,80,81,85,90,92,94]
India	[59,60]
Turkey	[96,97]
France	[49]
Pakistan	[69]
United Kingdom	[56]
United States	[77]
Vietnam	[64]

Table 9. Papers with applications in more than one country.

Reference(s)	Countries
[48,74]	Autralia, Vietnam, Cambodia, Bangladesh, China
[89]	China, Bangladesh, India, Pakistan, Djibouti, Saudi Arabia, Turkey, Egypt, United Arab Emirates
[58]	Hungary, Slovakia, Czech Republic, Austria, Germany, Slovenia, Italy
[82]	China, Mexico, Germany, Russia and other unspecified countries
[53]	Iran, Armenia, Turkmenistan, Afghanistan, Pakistan
[88]	Iran, Azerbaijan
[93]	Iran, Azerbaijan, Turkey
[70]	Pakistan, India, Bangladesh, China

Another important aspect in the analyzed articles is the type of product or the specific industry for which the SC is designed. Figure 8 shows the percentage of applications found by type of industry. As can be seen, almost half of the cases are concentrated in industries dedicated to meeting basic needs (food and energy). The specific products of the case studies within these industries are detailed below.

The energy applications are divided into: biofuel [50,53,85,88,90,94], biomass based power [55], electricity [63–65], and hydrogen [92]. For the case of food industry there are general cases without any specific product [77]; dairy [61,62,98]; food grain [59,60]; meat [56]; sugar beet [51]; and wheat [54].

In the apparel industry, we can find the articles by [69,70,89] and the cases dedicated to Sportswear clothing by [48,74]. The automotive industry has three type of products in the case studies, automobile by [66–68]; lead-acid batteries by [71]; and tires by [81,84].

Considering the technology industry, there are the cases for households appliances by [96,97], LCD and LED TVs by [47], communications technology by [82], and medical devices by [93].

Other products, which are not classified into the industries mentioned above, are classroom equipment and furniture [79], filters [72,80], medicine (specifically Truvada®) [49], pipes [75], and spare parts [95].

Articles not mentioned in this section do not work with real cases and use synthetic data instances to test their solution methods.

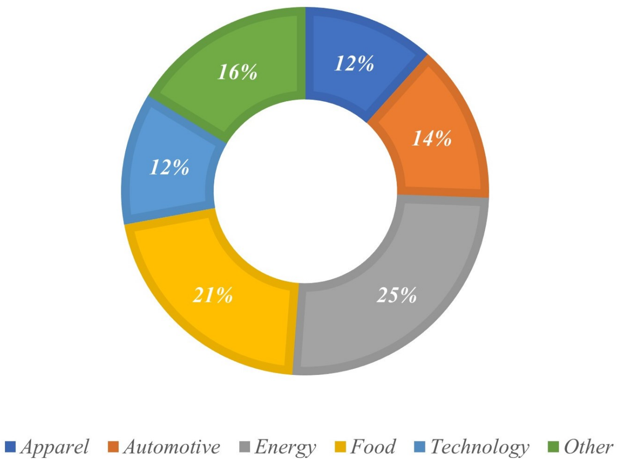

Figure 8. Distribution of applications per industry.

6. Insights and Future Research Directions

This section presents insights on SRSCND problems, as well as some suggestions for future research. In the literature, many models perform sensitivity trade-off and "what if" analysis as strategies for evaluating decisions. In addition, most contributions consider contradictory objectives, as shown in Table 9 and that confirms what is mentioned by Rajesh [28], that produce efficient boundaries for decision-makers to choose between non-dominated solutions. Since this is the classical procedure of operations research, the analysis of its use will not be deepened; instead, specific sustainability and resilience criteria in SCND are addressed.

Both the insights and the research trends are classified according to the elements of the framework shown in Figure 2.

6.1. Network Design

In Section 5.1 it was explained which characteristics were taken as parameters for the network design; however, if the decisions include the determination of which facilities to open or put into operation (a generalized strategic decision in the models) and if these decisions are taken for different regions or geographic locations, then the result of the model is a network design with certain characteristics. This is why Figure 2 shows bidirectional relationships between the components of the analysis. This section analyzes in which cases the introduction of sustainability and resilience criteria produced insights about these structures.

In Fazli-Khalaf et al. [71] authors determined that a focus on the objective function of minimizing environmental impact (emissions) led to the centralization of designed network structures since the model tends to select for opening facilities with potential locations with high demands and low transportation costs and that minimize the emissions emanating from production and transportation. Mishra and Singh [57] show that the result of disrupted demand due to a disaster is the modification of the network to have more spread facilities to supply partially or totally the demand after a disruption. In Fazli-Khalaf et al. [81] there is a relationship between the decentralization of the reverse flow network and the reduction of CO_2 emissions during transport.

Future contributions could consider a deeper analysis of the network structure's characteristics. This could facilitate higher-level decision-making that must go beyond purely economic aspects such as the location and size of industrial parks and free zones, command and control posts in emergency or disaster situations, the supply that affects natural reserve or protected areas, among others.

6.2. Sustainability

In the SRSCND, the sustainability dimension is evaluated and incorporated into the models through direct measurements. The economic perspective includes revenues and costs, the environmental dimension contemplates emissions, and as social criteria, the main objective is generally job creation. In terms of sustainability in the design of networks, the economic dimension has the property of containing the other two. This is achieved through specific environmental [49,52,57,58,64,73,86,90,91,95] and social costs [59,64]. In this sense, sustainability can be approached holistically without the need for direct impact measurements.

Future research could incorporate considerations on differentiated regional development, that is, having the possibility of privileging the use of logistics facilities in areas that are to be developed. This can also favor decision-making in public policies on infrastructure development.

Since freight transportation is responsible for up to 8% of greenhouse gas emissions (rises to 11% if warehouses and ports are included) [99], it is a research challenge that supply network design includes considerations on fuel efficiency, the use of biofuels, and electric vehicles.

6.3. Resilience

The assessment of resilience in the SRSCND has several forms, including uncertainty and disruptions, indicators, or a combination of these. Such as in sustainability, there are also costs associated with resilience or disruptions in the models [50,60,73,86]. Given this heterogeneity of concepts, the emphasis on resilience is established using three categories: Robustness, Agility/Flexibility, and Risk Assessment, the last being the most used. In addition to using mathematical tools to model uncertainty, such as probability and fuzzy sets, indicators and other resilience measurement methods, such as Ecosystem Network Analysis (ENA) [51], resilience pillars [56], or LARG approach [79], can be used.

There is a lack of contributions that address the three categories of resilience, i.e., robustness, agility/flexibility, and risk assessment in an integrated way. Thus, research opportunities that consider this integration could generate efficient designs for facing disruptions and responding to changes. In this context, optimization–simulation models can be useful methods for this purpose.

6.4. Term of Decisions

The decision term shows an important pattern, the prevalence of strategic decisions, some models with tactical decisions, and no consideration of operational decisions. The tactical decisions include inventory level policy [47,52,73,79,95], waiting processes [47], and transport mode selection [58–60].

In this regard, there are research opportunities by incorporating other tactical and operational aspects such as pricing, product quality, perishability, vehicle routing, and the possibility of direct sales, vertical integration, and other commercial distribution strategies into decisions.

6.5. Real World Cases and Relationship with Sustainable Development Goals

Supply chains play a vital role in achieving sustainable development goals, as they are the link between producers and consumers in all aspects of the global economy. In the articles analyzed, in addition to dealing with sustainability aspects in their network designs, the proposed applications show alignment with some sustainable development objectives. In particular, applications were identified for SDGs 2, 3, 4, 7, 8, and 12.

Future research may address the problem of network design for local logistics systems such as urban logistics and last-mile distribution that can improve the quality of life, the satisfaction of basic needs, and the management of disruptions due to social and mobility problems. In this way, it would contribute to the fulfillment of SDGs number 9 Industry, innovation, and infrastructure and number 11 Sustainable cities and communities.

7. Conclusions

This paper has provided a systematic literature review on recent works about the supply chain network design with sustainability and resilience criteria. This study shows that the integration of sustainability and resilience in the SCND is gaining the interest of academics and practitioners due to its practical impact. Its applications cover products ranging from raw materials to high added value goods, and the scope of networks can be from regional to transnational influence. In terms of quantity, the largest number of developments have occurred in Middle Eastern countries, mainly Iran.

The scope of the majority of the networks analyzed considers only the forward flow, with a predominance of the demand, manufacturing, and distribution center links. In cases where the reverse flow was taken into account (as in closed-loop supply chains), the most commonly used links are transformation (value recovery) and collection centers.

Regarding the sustainability criteria, economic considerations prevail over the others dimensions. The most common objective in economic sustainability is the minimization of costs and profit maximization. In some cases, this sustainable dimension contains the evaluation of the environmental and social dimension through associated costs, such as carbon taxes and the cost of resilience (or non-resilience).

For environmental sustainability, the CO_2 emissions are the most used indicators either in the objective function or in the constraints. Other indicators are the carbon footprint and energy consumption. The social component of sustainability is the least used in the SCND and mainly considers job creation. When all dimensions of sustainability are included as objectives, they are commonly contradictory, which is why a Pareto frontier is generated for the decision-maker to choose between the non-dominated solutions.

The resilience assessment was carried out through three categories that are not mutually exclusive: Robustness, Agility / Flexibility, and Risk Assessment. In addition, through the identification of the links subjected to disruption. Unlike sustainability, which has pre-established standards, resilience is much more varied in the way it is approached in the models; the forms range from scenario evaluation to the introduction as an indicator in the models.

On the other hand, the design of sustainable and resilient networks contributes to the SDGs of Zero hunger, Good health and well-being, Quality education, Affordable and clean energy, Decent work and economic growth, and Responsible consumption and production.

Future research may include detailed analysis of the structures resulting from the SCs that help to make high-level decisions such as public policy as well as the incorporation of operative level aspects to the SRSCND and the design of local networks with resilience and sustainability criteria.

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