*sustainability*

*Review*

# Multi-Objective Optimization for Sustainable Supply Chain and Logistics: A Review

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**Abstract:** There are several methods available for modeling sustainable supply chain and logistics (SSCL) issues. Multi-objective optimization (MOO) has been a widely used method in SSCL modeling (SSCLM), nonetheless selecting a suitable optimization technique and solution method is still of interest as model performance is highly dependent on decision-making variables of the model development process. This study provides insights from the analysis of 95 scholarly articles to identify research gaps in the MOO for SSCLM and to assist decision-makers in selecting suitable MOO techniques and solution methods. The results of the analysis indicate that economic and environmental aspects of sustainability are the main context of SSCLM, where the social aspect is still limited. More SSCLMs for sourcing, distribution, and transportation phases of the supply chain are required. Additionally, more sophisticated techniques and solution methods, including hybrid metaheuristics approaches, are needed in SSCLM.

**Keywords:** multi-objective optimization; sustainable supply chain; sustainable logistics; supply chain uncertainty; classical optimization methods; metaheuristics optimization methods



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## 1. Introduction

Supply chain modeling has become more applied and feasible in supply chain management and logistics research as it facilitates decision-making to achieve various objectives, including economic, environmental, and social [1]. Traditional supply chain models have focused only on operational efficiency by reducing the total cost, lead time, defective items, unused capacity, and processing time [2–4], but novel supply chain models incorporate environmental and social objectives in addition to economic performance [5–8]. This phenomenon is evident by the growing research on sustainable supply chain and logistics modeling (SSCLM) [9,10]. SSCLM is aimed at optimizing economic, environmental, and social objectives simultaneously. SSCLM is a complex process as it involves diverse stakeholders from suppliers to customers for managing products and services accounting for economic, environmental, and social impacts [11]. This complexity becomes more emphasized when different phases of the supply chain (sourcing, manufacturing, warehousing, distribution, and transportation), different types of a supply chain (forward, reverse, and close loop), different levels of decision-making (strategic, tactical, and operational), and supply chain environment (certainty or uncertainty) are considered.

In this study, the authors explore the scholarly literature to identify the research gaps in multi-objective optimization (MOO) for SSCLM and to assist decision-makers in selecting suitable optimization techniques and solution methods based on various SSCL issues. Numerous review studies are currently available; however, they are limited to certain factors. Some have concentrated more broadly on operational research (OR) methods not specific to MOO [11,12] while others have focused on limited aspects of different sustainability dimensions [4,13] or have not considered decision levels and supply chain phases [14–16]. Further, most of these research efforts did not take uncertainty into account [17–19].

Given these limitations in this research, the authors reviewed SSCL problems with a modeling perspective focusing on various aspects such as sustainability dimensions, indicators, different supply chain phases, decision levels, optimization techniques, and solution methods. The structure of the paper is outlined as follows. Section 2 provides the methodology. Section 3 presents the data analysis. Section 4 shows the results and discussion. Lastly, Section 5 presents the conclusion and recommendations for future research.

## 2. Methodology

The study at hand follows a semi-systematic review methodology where formulating research questions, locating studies, screening, and selection were carried out according to the review methodology proposed by Denyer and Transfield [20], and reviewing and analyzing were carried out according to the narrative review methods [21]. The authors described these review steps as follows.

Step 1: Formulation of research questions

Adhering to Denyer and Transfield [20], the current study used an acronym CIMO (context, intervention, mechanism, outcome) to specify well-built review questions. As the aim of this paper is to identify the research gaps in MOO for SSCLM (C) and to assist decision-makers (I) in selecting suitable MOO techniques and solution methods (O) based on their varied SSCL issues addressed by the literature (M), the authors developed the following research questions.

(i) What dimensions and indicators of sustainability are over-presented in MOO of supply chain and logistics models?
(ii) Which supply chain phases and decision levels are discussed in the SSCLM?
(iii) Which type of optimization technique and solution method is used to address SSCLM?
(iv) To what extent uncertainty has been incorporated into SSCLM and what optimization techniques and solution methods are used to address uncertainty in SSCLM?

Step 2: Locating studies

The authors searched for publications from the Science Direct and Google Scholar databases for the last decade (2010–2020). The authors used specific keywords of 'sustainable supply chain' OR 'sustainable logistics' AND 'multi-objective optimization' to identify the relevant high-quality papers. The total results as of 1 December 2020, were 323 including review papers, research articles, conference papers, book chapters, and editorials.

Step 3: Screening and selection

The authors selected 122 for the current study of which 27 papers are reviews articles. The authors used these 27 papers to identify the gap in the existing reviews and the remaining 95 papers for the main analysis. The relevancy was determined by considering several inclusion criteria: (1) included the papers published in peer-reviewed scientific journals in English, (2) content including any supply chain decision variable, and (3) included at least two out of three sustainability dimensions for the MOO model, (4) excluded review papers, conference papers, book chapters, and journal papers with no citations (except papers published in 2020).

Step 4: Reviewing and analyzing

First, the authors analyzed the selected 27 review papers to confirm the validity, relevance, and contribution of our article to the overall literature. A summary of the existing review analysis is provided in Table 1. Most papers covered sustainability objectives (a) and their indicators (b), but a thorough review of how these objectives are optimized in a model is limited—only four appear to have the MOO focus. Of these studies, Trisna et al. [22] did not consider sustainability aspects, Moreno-Camacho et al. [23] did not discuss optimization methods and solution techniques, Van Engeland et al. [24] limited their study to one phase of the supply chain (reverse logistics), and Zahraee et al. [25] explored specific supply chain (biomass supply chain) in their reviews. Supply chain decision levels (c), types of the supply chain (d), and supply chain environment (e) were also considered, but no clear idea on which supply chain decision, type, and environment were addressed with a sustainability dimension. Eleven papers looked at different assessment methods (f) or multi-criteria decision-making approaches (g), but they were not specific to the MOO (h) except one study [25]. Optimization techniques (i) and solution methods (j) were widely addressed but not in SSCLM. These general findings emphasize the need for a study that specifically focuses on MOO methods and solutions for SSCLM. According to the analysis of review papers and the best of our knowledge, the authors found that no studies covered all the factors considered here (a–j in Table 1) within one study before. Therefore, the current study provides a detailed and comprehensive analysis of the existing literature of MOO for SSCL. Following the content analysis as a narrative review method [21], the authors reviewed the other 95 research papers using the categories based on authors, supply chain problem, sustainability dimensions, sustainability indicators, supply chain phases, decision levels, supply chain environment, optimization techniques, and solution methods. These categories were carefully analyzed using descriptive analysis to respond to each research question.

**Table 1.** Overview of the available review studies.

| Reference | No of Papers | Time-Period | a | b | c | d | e | f | g | h | i | j |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [4] | 60 | n/a | * | | | * | | | * | | | |
| [11] | 220 | 1999–2016 | * | * | * | * | * | * | | | | |
| [12] | 188 | 2000–2015 | * | * | | | * | | * | | * | * |
| [13] | 89 | 2007–2017 | * | | * | | | * | | | * | * |
| [14] | 174 | 1987–2015 | * | | | | | | | | | |
| [15] | 445 | 1989–2012 | * | * | | | | | | | | |
| [16] | 134 | 1994–2012 | * | | | | | | | | * | * |
| [17] | 145 | 1995–2018 | * | * | | | | | | | * | * |
| [18] | 384 | 2000–2003 | * | | | | | | | | * | |
| [19] | 36 | 1994–2010 | * | | | | | | * | | | |
| [22] | 98 | 2005–2015 | | | * | | * | | | * | * | * |
| [23] | 113 | 2015–2018 | * | * | * | | * | | | | | |
| [24] | 207 | 1995 –2017 | * | * | * | * | * | | | * | | * |
| [25] | 300 | 1980–2020 | * | * | * | | * | | * | * | | * |
| [26] | 540 | 1999–2010 | * | | | * | * | * | | | | |
| [27] | 134 | 1983–2011 | * | | | * | | | | | | |
| [28] | 87 | 2000–2010 | * | * | | | | | | | | |
| [29] | 56 | n/a | | | | * | | * | | | | |
| [30] | 160 | 1980–2013 | | | * | | * | | | | | |
| [31] | 185 | 1994–2004 | * | | | | * | | | | | |
| [32] | 190 | 1999–2010 | | | | | | | * | | * | * |
| [33] | 87 | 1990–2014 | * | * | | | * | | | | * | * |
| [34] | 115 | n/a | * | * | | | | | | | | |
| [35] | 190 | 2000–2015 | * | * | | * | | * | | | | |
| [36] | 40 | 1900–2018 | * | * | | * | | | | * | | |
| [37] | 142 | 2009–2019 | * | * | | * | | * | * | | | * |
| [38] | 247 | 1997–2019 | * | * | | | * | | | | * | * |

**Notes:** (a) sustainability dimension focus, (b) sustainability indicator categorization, (c) supply chain decision levels, (d) type of supply chain, (e) supply chain environment, (f) OR methods, (g) multi-criteria decision-making, (h) multi-objective framework, (i) optimization techniques, and (j) solution method. * Consideration of above categories (a–j) in the review papers.

*Framework of the Study*

The multi-objective optimization problem is traditionally aimed at addressing forward supply chain issues where raw materials are converted to the final product and carried through suppliers, manufacturers, warehouses, transporters, and distributors, to end customers. This tradition has now changed to considering closed-loop supply chains in the MOO problem. A closed-loop supply chain considers reverse logistics in addition to a forward supply chain. The authors classify closed-loop supply chain phases as sourcing, manufacturing, transportation, distribution, and reverse logistics. To incorporate sustainability in to supply chain and logistics context, the authors consider three pillars of economic, environmental, and social dimensions as addressed by the literature [11,23,35]. MOO problems in the supply chain are based on the different phases in a closed-loop supply chain and those problems are addressed through strategic, tactical, and operational level decisions. Decisions that have long-term implications are considered strategic decisions, such as supplier selection and facility location. Tactical decisions have medium-term implications that support strategic decisions such as order allocation, and vehicle routine problems. Operational decisions are related to day-to-day operations and have short-term implications. Examples include scheduling logistics tasks and the quantity discount model. Addressing MOO problems becomes complex and dynamic due to uncertain factors. Therefore, SSCLM can be designed as a deterministic or stochastic model. These models can be solved using different solution methods mainly categorized as classical, metaheuristics, or both. Accordingly, the authors present this review paper for MOO in SSCLM based on the following framework (Figure 1).

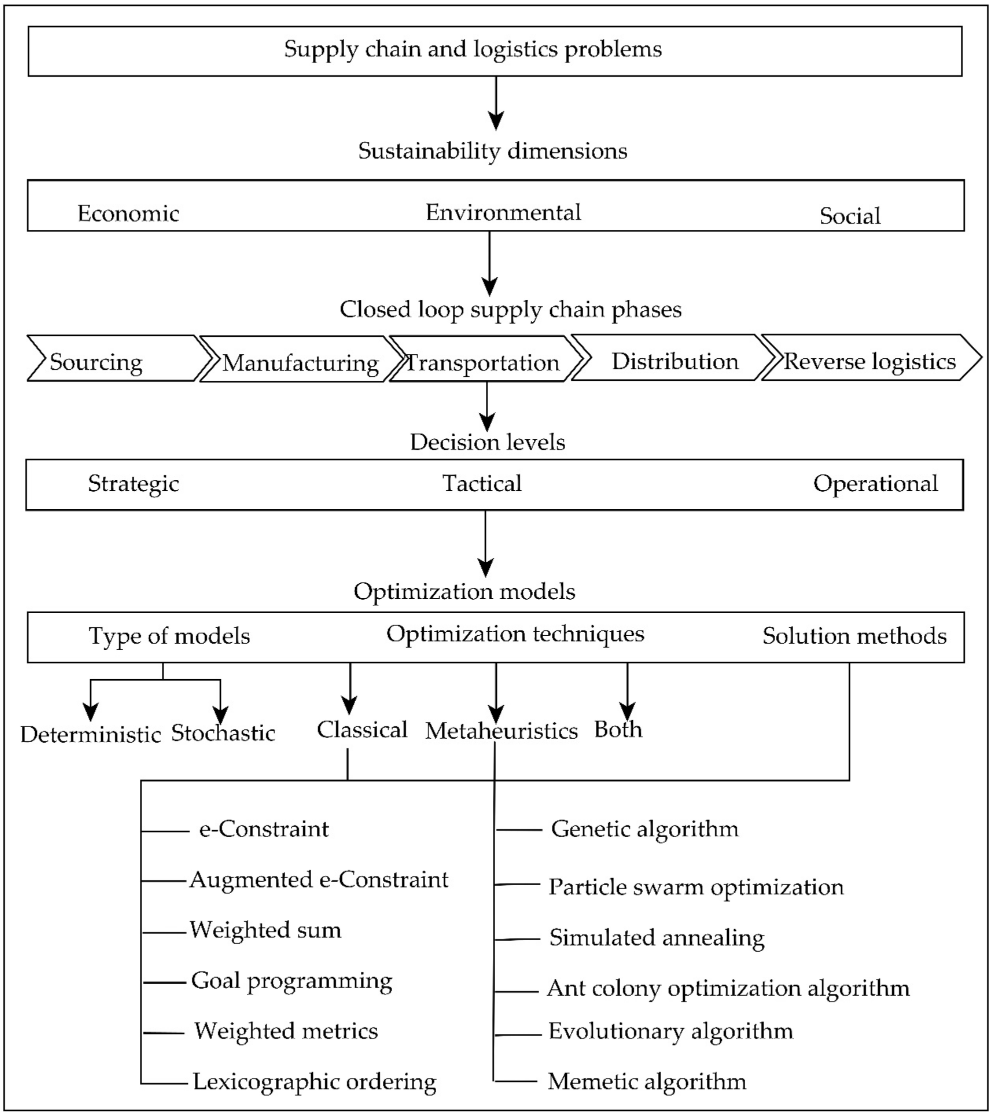


**Figure 1.** Framework for multi-objective optimization of sustainable supply chain and logistics.

## 3. Data Analysis

The data analysis includes the descriptive analysis of the distribution of reference papers by time and journal, reference papers by sustainability dimensions and indicators, supply chain phases, and decision levels from a sustainable perspective, optimization techniques, and solution methods.

### 3.1. Distribution of Articles by Time and Outlet

Figure 2 shows the distribution of papers over the last decade (2010–2020). There has been a growing trend of publishing papers during the considered period. In terms of selected papers, the highest number of selected papers are from the last three years, respectively. No publication was found in 2010 relating to the considered criteria of the current study.

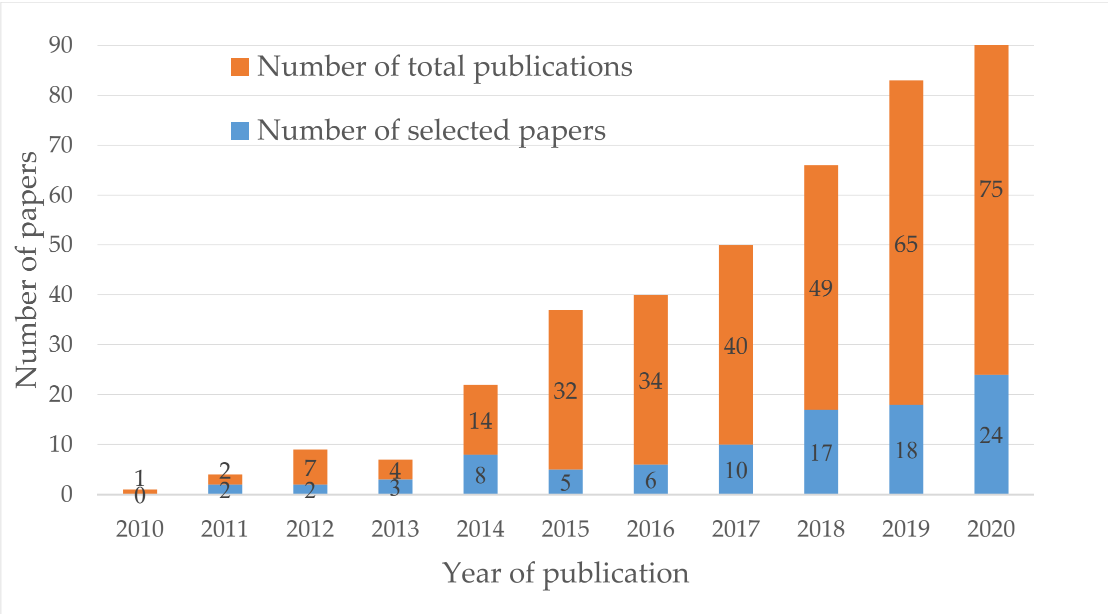


**Figure 2.** Distribution of articles by time.

Figure 3 shows papers are distributed across 39 journals, and 30 journals have only one publication. The highest number of selected papers are from the Journal of Cleaner Production, which is approximately 34% of the total papers selected.

### 3.2. Analysis of Articles by Sustainability Dimensions and Indicators

Most of the sustainable supply chain models are multi-objective and many authors consider economic objectives as traditional objectives and incorporate environmental or social objectives as extensions [33]. The authors analyzed the distribution of reference papers among the sustainability dimensions and found that more than half (55%) of the reference papers (52 papers) focused on economic and environmental combinations and 42% of the reference papers (40 papers) focused on all three dimensions of sustainability. Two papers focused on the economic and social combination [39,40], and only one paper focused on environmental and social combinations [41]. Furthermore, most of the papers (99%) considered economic and environmental pillars as one of the objectives in SSCLM. These facts reveal the importance of economic and environmental pillars for assessing sustainability in supply chain and logistics models. Social dimension was considered in limited papers (45%) compared to economic and environmental dimensions. The reason for the limited consideration in the social dimension is the difficulty of measuring social sustainability as most of the social indicators are qualitative. There remains an imbalance in the distribution of papers among these three dimensions, thus in SSCL research, there is still outstanding work as these three pillars are equally important for sustainability.

In MOO models, numerous indicators were used from each sustainability dimension (Table 2). From the economic aspect, widely used indicators were the minimization of cost, maximization of profit, or operational performance. From the environmental dimension, most of the models used minimization of greenhouse gas (GHG), $CO_2$ emission, or global warming potential. From the social perspective, the highest number of models focused on minimizing the social impact or maximizing the social benefit. The detailed analysis of reference papers by each sustainable objective with its indicators is presented in Appendices A and B.

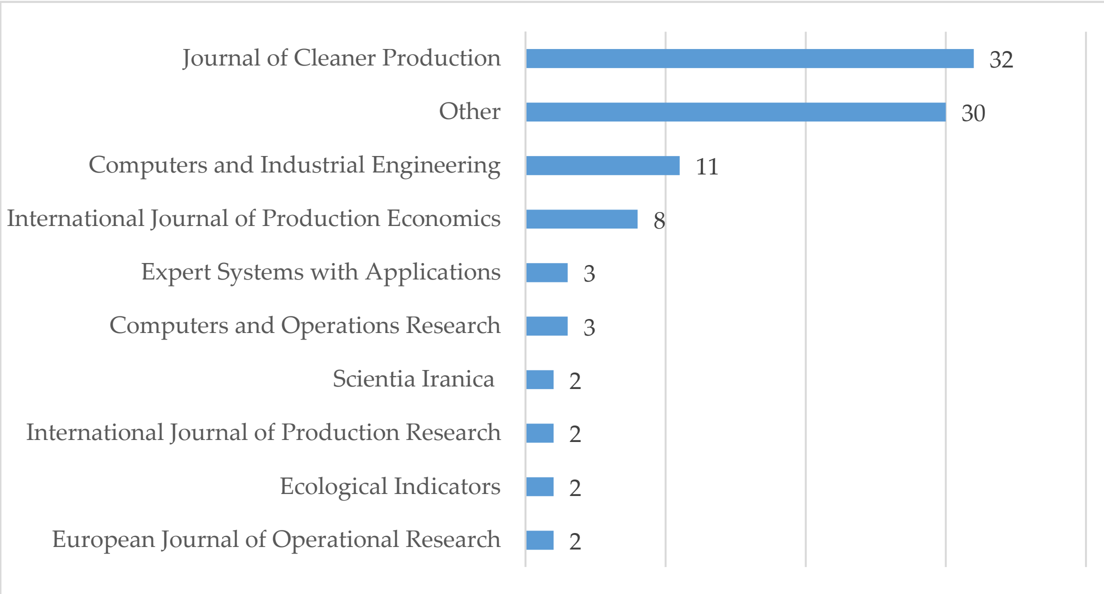


**Figure 3.** Distribution of articles by journal outlet.

**Table 2.** Summary of sustainability objectives by articles.

| Economic Objectives (Min./Max) | No. of Papers | Environmental Objectives (Min./Max.) | No. of Papers | Social Objectives (Min./Max.) | No. of Papers |
|---|---|---|---|---|---|
| Total cost/Profit/ Operational performance | 85 | GHG/$CO_2$ emission/Global warming potential | 49 | Social benefit/ social impact | 25 |
| Delivery lead time/ traveling time | 12 | Environmental impact/performance | 41 | Job opportunities | 14 |
| Economic benefits | 5 | Energy consumption/energy recovery | 8 | Employee injuries | 2 |
| NPV/PV of costs | 4 | Water consumption | 5 | Human resource variations | 1 |
| Resilience | 2 | Waste | 4 | Lost working days | 1 |
| Total quality | 2 | Noise pollution | 1 | Community development | 1 |
| Financial risk | 1 | | | | |
| Travel distance | 1 | | | | |
| Reliability | 2 | | | | |
| Responsiveness | 1 | | | | |
| Supplier performance | 1 | | | | |

### 3.3. Supply Chain Phases and Decision Levels from a Sustainable Perspective

Table 3 shows the decision levels distributed across every phase in the supply chain. Most of the researchers analyzed the strategic decisions (55 out of 95), such as supply chain network design, supplier selection, hub location, facility location, logistic network configuration, and most of these (23 out of 55) focused on the overall supply chain [5,14,42,43] focused on strategic level decisions in the overall supply chain. Tactical decisions were integrated into 20 papers; those decisions involve order allocation, vehicle routine problem, aggregate production planning, and selecting transportation mode. Most of the tactical decisions were related to the manufacturing phase [44–47]. Operational decisions, such as the quantity discount model, the selection of transport mode, and production methods were incorporated into only one paper, which is related to manufacturing and distribution phases [48]. Only Govindan et al. [49] focused on strategic and operational decisions, which are related to the distribution phase and only Wang et al. [50] focused on tactical and operational decisions in the overall supply chain. In total, 14 papers have investigated strategic and tactical decisions, most of which are related to the overall supply chain [51–55]. Only three papers have looked at all three decision levels, two of which are related to the overall supply chain [56,57] and the other one is related to the manufacturing phase [58].

**Table 3.** Distribution of decision levels across the supply chain phases.

| Decision Levels | Total | OSC | S | M | D | T | RL | S/D | M/D | T/RL | T/D | S/M/D | S/M/T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Strategic | 55 | 23 | 5 | 6 | 3 | - | 8 | 2 | 4 | - | 3 | 1 | - |
| Tactical | 20 | 1 | - | 5 | 4 | 3 | 3 | - | 2 | 1 | - | - | 1 |
| Operational | 1 | - | - | - | - | - | - | - | 1 | - | - | - | - |
| Strategic/Tactical | 14 | 10 | 1 | - | - | - | - | - | 1 | - | - | 1 | 1 |
| Strategic/Operational | 1 | - | - | | 1 | - | - | - | - | - | - | - | - |
| Tactical/Operational | 1 | 1 | - | | - | - | - | - | - | - | - | - | - |
| Strategic/Tactical/Operational | 3 | 2 | - | 1 | - | - | - | - | - | - | - | - | - |
| Total | 95 | 37 | 6 | 12 | 8 | 3 | 11 | 2 | 8 | 1 | 3 | 2 | 2 |

**Notes:** OSC: overall supply chain, S: sourcing, M: manufacturing, D: distributing, T: transporting, RL: reverse logistics. All the references relating to Table 3 are presented in Appendix C. Full references can be found in Supplementary Materials.

Table 4 indicates the sustainability aspects of supply chain phases in MOO models. Most of the models are designed on the overall supply chain and 16 papers considered all three dimensions and 19 papers considered economic and environmental dimensions. The second and third most frequent focus was on manufacturing (12 papers) and reverse logistics (11 papers) phases in MOO models. In manufacturing issues, nine papers investigated economic and environmental aspects e.g., [46,47,59], and three papers investigated all three dimensions [58,60,61]. In reverse logistics models, seven papers considered all three dimensions [62–68] and three papers considered economic and environmental aspects [69–71]. Overall, the highest number of papers (52) have considered economic and environmental aspects of sustainability, whereas 40 papers have incorporated all three aspects of sustainability. Two papers have focused on economic and social aspects of the overall supply chain [40] and reverse logistics [39], only one paper looked at the environmental and social aspects of sustainability, which is also focused on the overall supply chain [72].

**Table 4.** Sustainability aspects of supply chain phases.

| Sustainability Dimensions | OSC | S | M | D | T | RL | S/D | M/D | T/RL | T/D | S/M/D | S/M/T | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eco/Env/Soc | 16 | 3 | 3 | 2 | 1 | 7 | 1 | 5 | - | - | 1 | 1 | 40 |
| Eco/Env | 19 | 3 | 9 | 6 | 2 | 3 | 1 | 3 | 1 | 3 | 1 | 1 | 52 |
| Eco/Soc | 1 | - | - | - | - | 1 | - | - | - | - | - | - | 2 |
| Env/Soc | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Total | 37 | 6 | 12 | 8 | 3 | 11 | 2 | 8 | 1 | 3 | 2 | 2 | 95 |

**Notes:** OSC: overall supply chain, S: sourcing, M: manufacturing, D: distributing, T: transporting, RL: reverse logistics, Eco: economic, Env: environmental, Soc: social. All the references relating to Table 4 are presented in Appendix C. Full references can be found in Supplementary Materials.

In terms of sustainability aspects of decision levels (Table 5), 58% of the SSCLM was used to make strategic decisions and 40% of which have focused on all three dimensions of sustainability, and 56% of which focused on economic and environmental aspects; 21% of the SSCLM were used for tactical decisions, 30% of which focused on all three dimensions, and 65% focused on economic and environmental aspects. Only 1% of the models was used for operational decisions and focused on all three dimensions.

**Table 5.** Sustainability aspects of supply chain decision levels.

| Decision Levels | Total | Eco/Env/Soc | Eco/Env | Eco/Soc | Env/Soc |
|---|---|---|---|---|---|
| Strategic | 55 | 22 | 31 | 1 | 1 |
| Tactical | 20 | 6 | 13 | 1 | - |
| Operational | 1 | 1 | - | - | - |
| Strategic/Operational | 1 | 1 | - | - | - |
| Tactical/Operational | 1 | 1 | - | - | - |
| Strategic/Tactical | 14 | 8 | 6 | - | - |
| Strategic/Tactical/Operational | 3 | 1 | 2 | - | - |
| Total | 95 | 40 | 52 | 2 | 1 |

**Note**: All the references relating to Table 5 are presented in Appendix C. Full references can be found in Supplementary Materials.

### *3.4. Optimization Techniques and Solution Methods*

Most of the optimization models are deterministic models (consider certain environment) (58%) and 42% of the models are stochastic models (consider uncertain environment) (Table 6). In terms of modeling technique, 66% of the reference papers used classical optimization methods, 33% of the optimization models used metaheuristics methods and 1% used both methods. Of the classical methods, e-constraint, augmented e-constraint, and weighted sum were largely used (Table 7). From metaheuristics methods, hybrid metaheuristic algorithms, particle swarm optimization, and genetic algorithm were largely used methods (Table 8).

**Table 6.** Classification of articles by modeling techniques and type of model.

| Modeling Technique | Number of Papers | Deterministic Models | Stochastic Models |
|---|---|---|---|
| Classical | 63 | 32 | 31 |
| Metaheuristics | 31 | 22 | 9 |
| Hybrid (C/M) | 1 | 1 | - |
| Total | 95 | 55 | 40 |

**Note:** All the references relating to Table 6 are presented in Appendix C. Full references can be found in Supplementary Materials.

**Table 7.** Distribution of classical solution methods.

| Classical Methods | Total | Certain | Uncertain |
|---|---|---|---|
| e-Constraint | 22 | 13 | 9 |
| Augmented e-constraint | 9 | 4 | 5 |
| Weighted sum | 7 | 2 | 5 |
| Fuzzy programming | 5 | - | 5 |
| Normalized normal constraint methods | 3 | 3 | - |
| Weighted goal programming | 2 | 1 | 1 |
| Fuzzy goal programming | 1 | - | 1 |
| Weighted comprehensive criteria method | 1 | - | 1 |
| Weighted min max | 1 | - | 1 |
| Weighted metrics | 1 | - | 1 |
| LP metric based compromising programming | 1 | - | 1 |
| Meta goal programming and simulation | 1 | - | 1 |
| Scenario method | 1 | 1 | - |
| AHP and ordered weighted averaging (OWA) | 1 | 1 | - |
| Augmented e-constraint and TOPSIS. | 1 | 1 | - |
| Exact solution approach (non-dominated points) | 1 | 1 | - |
| Goal programming/e-constraint | 1 | 1 | - |
| Goal programming MINMAX | 1 | 1 | - |
| Lexicographic ordering | 1 | 1 | - |
| PROMTHEE and goal programming | 1 | 1 | - |
| Weighted sum/Augmented e-constraint | 1 | 1 | - |
| Total | 63 | 32 | 31 |

**Note:** All the references relating to Table 7 are presented in Appendix C. Full references can be found in Supplementary Materials.

**Table 8.** Distribution of metaheuristics solution methods.

| Metaheuristics Methods | Total | Certain | Uncertain |
|---|---|---|---|
| Hybrid meta-heuristic algorithm | 6 | 4 | 2 |
| Genetic algorithm (GA) * | 4 | 4 | - |
| Particle swarm optimization (PSO) | 4 | 3 | 1 |
| GA/PSO | 2 | 1 | 1 |
| Non-dominated sorting genetic algorithm (NSGA II)/PSO | 2 | 2 | - |
| Non-dominated sorting genetic algorithm (NSGA II) | 2 | - | 2 |
| Simulated-annealing (SA)/NSGA-II | 1 | 1 | - |
| Swarm intelligence | 1 | 1 | - |
| Hybrid swarm intelligence meta-heuristic | 1 | 1 | - |
| Memetic algorithm | 1 | 1 | - |
| Non-dominated ranking generic algorithm (NRGA) | 1 | 1 | - |
| Ant colony optimization (ACO) | 1 | 1 | - |
| AugMathFix | 1 | 1 | - |
| Centre of gravity/K means clustering | 1 | 1 | - |
| Evolutionary Algorithm (EA) | 1 | - | 1 |
| Simulated annealing (SA) | 1 | - | 1 |
| Lagrangian relaxation (LR) | 1 | - | 1 |
| Total | 31 | 22 | 3 |

**Note**: All the references relating to Table 8 are presented in Appendix C. Full references can be found in Supplementary Materials. * Some papers have not specified which GA methods they have used.

### *3.5. Uncertainty in Supply Chains*

Different solution methods were used to address the uncertainty in optimization models, the most common being fuzzy programming (Figure 4). Azadeh et al. [53] used fuzzy programming to solve their model of the crude oil supply chain. The uncertain parameters considered in their model were cost and production capacity of refined products along with the consumption rate of petroleum products. Govindan et al. [68] used this method for uncertainty in a sustainable reverse logistics network design model. Pourjavad and Mayorga [73] considered uncertain parameters of return rates of products from customers, the capacity of all facilities, and product demand in designing a closed-loop supply chain model. The fuzzy AHP method for uncertain input including purchasing and transportation costs, purchasing quantities, demands, $CO_2$ emission, and capacity levels were used by Mohammad et al. [74] (for green and resilient supply chain network design) and Mohammad et al. [75] (for supplier selection and order allocation problem). Stochastic programming was used by Rahimi et al. [76] (for sustainable supply chain network design with uncertain parameters of transportation cost, demand, and price), Ebrahimi et al. [77] (for supplier selection and location-allocation model with demand uncertainty), Ruiz Femenia [78] (to incorporate the effect of demand uncertainty on the chemical supply chains). Wang et al. [79] used robust optimization for CLSC network design under the uncertainty factors of the supply side, customer demand, and return quantities. Sharifi et al. [40] used a hybrid stochastic fuzzy robust approach in designing biofuel supply chain network designing. Rabbani et al. [80] used a hybrid robust probabilistic method for location-allocation network designing with uncertain factors of transportation cost and $CO_2$ emission.

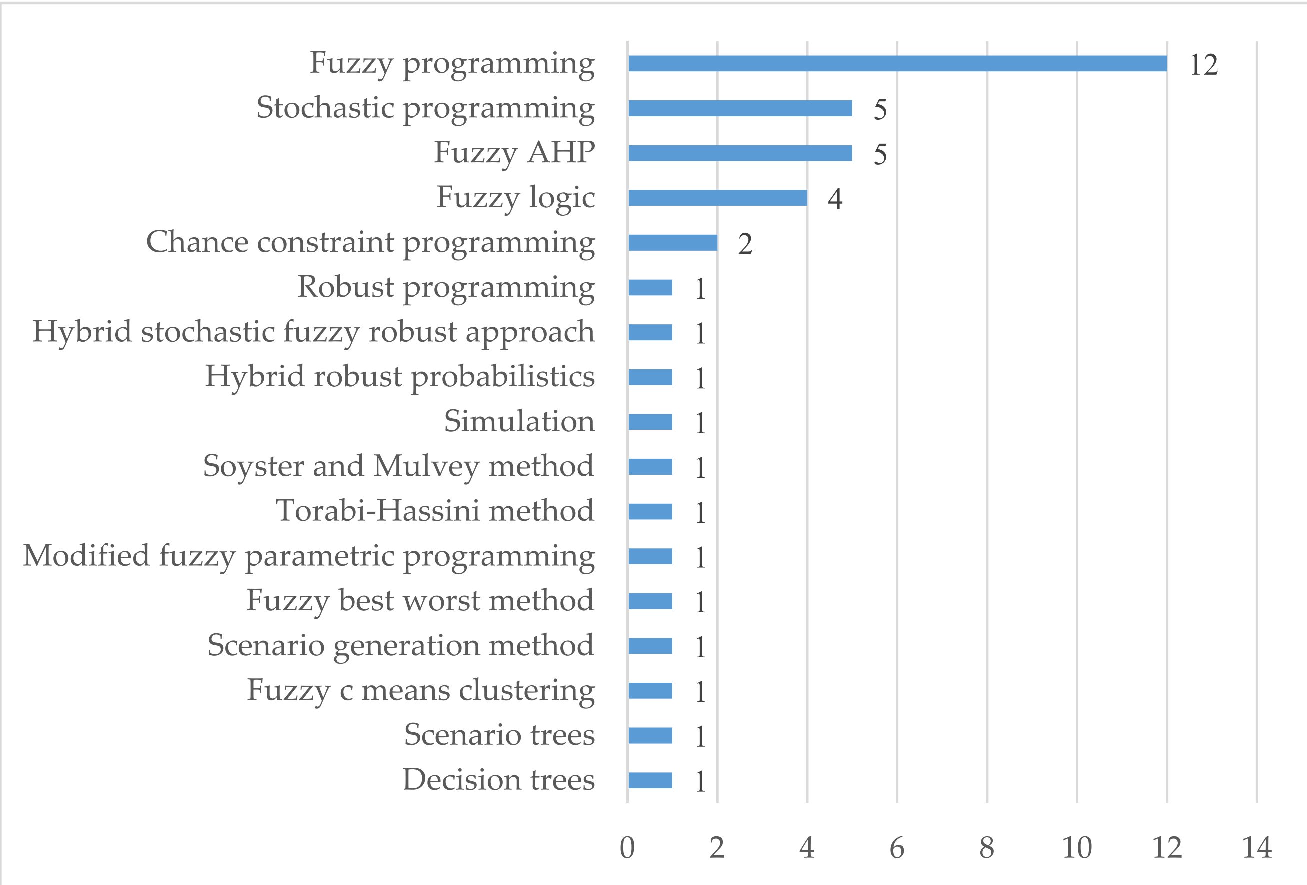


**Figure 4.** Distribution of solution methods for models with uncertainty.

## 4. Results and Discussion

Most of the optimization models used the e-constraint method to solve the sustainable supply chain issues because of the following advantages [64,81]: (i) it is simple and computationally faster, (ii) it helps produce a set of non-extreme Pareto solutions, (iii) it is not necessary to scale the objective functions to a common scale, and (iv) we can control the number of generated efficient solutions by properly adjusting the number of grid points in each one of the objective function ranges. The second most used solution method was the augmented e-constraint method. This method was developed using appropriate slack variables to the objective function due to the weekly solutions produced using the e-constraint method [77,80,81]. To find approximate solutions for large complex models, metaheuristics methods are recommended [32,82]. Our results show hybrid metaheuristics algorithms, GA and PSO are largely used metaheuristics methods. GA leads to accurate Pareto front identification as it does not depend on the objective and constraint functions but requires a large computational effort [83]. Azadeh et al. [53] and Chiandussai et al. [83] found that EA seems particularly suitable for large-size multi-objective optimization problems, but its computational cost is high.

In sustainability aspects, most of the referenced models focused on economic and environmental dimensions, and less than 50% focused on all three dimensions of sustainability, especially in the overall supply chain, manufacturing, and reverse logistics phases. For the sourcing, distribution, and transportation phases, limited studies were incorporated into sustainability aspects. Minimization of cost and $CO_2$ emission were the popular objectives for most of these phases of the supply chain. From the social dimension, minimization of social impact and maximization of job opportunities were described. Although the consideration of social dimension in the SSCLM is still less than the economic and environmental dimensions, it is now being considered in the SSCLM. This trend is facilitated using quantitative social indicators such as social cost, social investments, number of job opportunities, lost working days, and number of employee injuries. However, qualitative aspects of the social dimension such as customer or employee satisfaction, employee discrimination, and social equality are still be missed.

In sustainability modeling, selecting indicators of economic objectives should be carefully chosen as it depends on the purpose of analysis, such as operational purpose (cost) or investment purpose (NPV) [11]. The authors highlighted the cost of implementing sustainability practices should also be incorporated into economic objectives. For environmental objectives, the use of energy, water, and other natural resources should be incorporated into the optimization model together with greenhouse gas (GHG) emissions. For that purpose, the LCA (life cycle analysis) method can be used, which is largely neglected in optimization models [84,85]. For the social component, social-LCA (S-LCA) may be a better option to address social sustainability. To consider the qualitative indicators of the social dimension, optimization methods are needed to be combined with other OR methods, such as decision analysis, expert systems, data analysis, and neural networks. Researchers suggest interdisciplinary approaches combining exact science and social sciences to quantify the social impact of sustainability [11,31].

The design of SSCLM is a critical decision and most of the SSCLM were designed to make strategic and tactical decisions such as supplier selection, order allocation, location-allocation, vehicle routine problems. The design of SSCLM for operational decision-making has largely been neglected in the reviewed papers. This phenomenon happens because sustainability is complex, has upfront costs, is time-consuming, and operational decisions are short-term. However, the integration of strategic, tactical, and operational decisions within one model has considerable potential to study sustainability aspects.

Uncertainty is a crucial factor that supply chain decision-makers should handle carefully. Researchers face difficulty in incorporating uncertainty into SSCLM due to the dynamic and complex nature of such models. In the literature, three main approaches were used to incorporate uncertainty into the model including fuzzy programming, stochastic programming, and robust programming. Fuzzy programming is applicable when there is no specific distribution for uncertain data, but it is possible to determine the boundaries and association functions for the data [53]. Stochastic programming is used when the collected data have specific distribution [53]. Robust methods are more restricted to convex problems, such as linear, linear discrete problems, and convex constrained continuous minimax problems [86]. Our results revealed that most of the uncertainty models used fuzzy programming. This highlights the lack of data regarding the uncertainty of the supply chain.

In uncertainty, several parameters were considered in SSCLM, the majority of which focused on uncertain data relating to economic dimensions, such as cost, demand, price, and capacity level. Uncertainty on environmental and social data has more space in research on SSCLM. In addition to the demand-side uncertainty, uncertainty at supply-side resources can be considered in SSCLM [87]. Barbosa Povoa et al. [11] described three challenges in optimization modeling, including sustainability modeling, uncertainty modeling, and risk and resilience. In our review, modeling sustainability and uncertainty were adequately addressed, but risk and resilience were barely studied. Silva et al. [88] are the only authors who considered risk objective in their model and used the conditional value-at-risk (CVaR) as a measure of risk in this review. Cardoso et al. [89] state that CVaR is one of the most used risk methods within the literature. Resilience was considered by Sharifi et al. [40] and Mohammad et al. [74] and in a later study, the resilience pillar was represented in terms of robustness, agility, leanness, and flexibility.

## 5. Conclusions and Recommendations for Future Research

This study provided a review of 95 published papers in the field of MOO for SSCLM. The review aimed to identify the research gaps in MOO for SSCLM and to assist decision-makers in selecting suitable MOO methods and solutions in developing SSCLM. These purposes were achieved through different research questions covering sustainability dimensions, indicators, supply chain phases, decision levels, optimization techniques, solution methods, and uncertainty in SSCLM. The results revealed that the economic and environmental aspects of sustainability still dominate in the SSCLM, and they are limited to a few indicators. Sourcing, distribution, and transportation issues in the supply chain were not adequately addressed. Most of the models used classical methods of optimization of which the epsilon constraint (e-constraint) method is widely used and from metaheuristics methods, hybrid metaheuristics methods were highlighted. Less than 50% of the reference papers considered uncertainty in the models, and fuzzy programming was commonly used to address the uncertainty. There are several optimization techniques and solution methods available but selecting one of them depends on several factors such as the purpose of the decision-maker, nature of the problem, and availability of the data. This study has presented a comprehensive analysis of the MOO of SSCLM, and the results of the study significantly contributed to the development of the field of sustainable supply chain and logistics modeling. Specifically, the current study provided the research gaps in the MOO of SSCLM from sustainability dimensions, sustainability indicators, different supply chain phases, decision levels, optimization techniques, and solution methods. Accordingly, future researchers and decision-makers can use the following key considerations for their potential works in modeling sustainable supply chain and logistics issues.

- In the absence of broad indicators of sustainability assessment and limited focus on the social dimension, the authors suggest incorporating more social aspects and integrating economic, environmental, and social indicators into the future of SSCLM. For example, innovation can be considered as an economic indicator in addition to cost, quality, and delivery flexibility to maximize competitive advantage [90], which is one of the main economic objectives in supply chain modeling. As indicated in the GRI (Global Reporting Initiative) standard [91], indirect economic impact, anti-corruption, and anti-competitive behavior from economic aspects, the material used, biodiversity, supplier environmental assessment from environmental aspects, training and development, non-discrimination, human rights, and supplier social assessment from social aspects can be considered as sustainability indicators. Comprehensive economic, environmental, and social indicators proposed by [92] can also be used in SSCLM.
- To incorporate the sustainability indicators into the optimization models, quantification is a barrier. Direct and indirect economic benefits can be quantified using the cost of implementing green practices, cost savings of using reverse logistics practices, and return on environmental and social investment. Social impact can be quantified using factors, including the number of health and safety training, cost of health and

safety training, average hours of training on anti-corruption policies and procedures, reported cases of corruption and bribery, employee happiness index, community satisfaction rate, and number of CSR initiatives. The use of comprehensive techniques, including LCA and S-LCA, for measuring environmental and social impact have more research potential in this case. The authors propose to combine social science research techniques, including surveys and case research, especially for social sustainability assessment in optimization models, to avoid its limitations and ensure data quality.

- More SSCLMs for sourcing, distribution, and transportation phases of the supply chain are required. Of these phases, the transportation phase requires more focus on strategic decisions, for example, a decision to use electric vehicles to reduce Co2 emissions. The integration of all levels of decision with uncertainty factors to the model is also emphasized as a solution method to address uncertainty is limited to fuzzy programming. Incorporating more demand and supply-related uncertainty factors in a model can lead to exploring other solution methods, such as simulation, scenario and robust programming. Dividing the optimization model into different phases, including decision levels or supply chain phases, is recommended as it will help reduce problem space and the solution time. As all these considerations make optimization models more complex and larger, more sophisticated techniques and solution methods, the inclusion of hybrid metaheuristics approaches will be more useful in SSCLM. Furthermore, the authors propose the use of more hybrid and decomposed optimization methods that have direct implications for solving many real-world cases. Other OR methods, including simulation and system dynamics modeling, can also be applied and combined in future research, which facilitates decision-makers to acquire a more comprehensive picture of the sustainable supply chain and logistics issues.

The authors acknowledge that the current study was conducted using the publications of limited databases. Future studies can expand the search databases and enhance the contribution to developing the field of sustainable supply chain and logistics modeling.

**Supplementary Materials:** The following are available online at https://www.mdpi.com/article/10.3390/su132413617/s1. The list of references of analyzed articles is provided in Supplementary Materials.

**Author Contributions:** C.P.J.: conceptualization, methodology, formal analysis, writing original draft; D.A.: conceptualization, writing—reviewing, editing, and supervision; L.D.: writing—reviewing, editing, and supervision and T.Y.: writing—reviewing and editing. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** Economic objectives of the sustainability used by articles.

| Reference | Min. Cost/ Max. Profit/ Max. Oper. Performance | Min. Lead Time/ Travel Time | Max. Eco. Benefits | Max. NPV/ Min. PV of Cost | Max. Resilience | Max. Total Quality | Min. Financial Risk | Min. Travel Distance | Max. Reliability | Max. Responsiveness | Max. Supplier Performance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [5] | * | | | | | | | | | | |
| [6] | * | | | | | | | | | | |
| [9] | * | | | | | | | | | | |
| [10] | * | * | | | | | | | | | |
| [14] | * | | | | | | | | | | |
| [39] | * | | | | | | | | | | |
| [40] | * | | | | * | | | | | | |
| [41] | * | | | | | | | | | | |
| [42] | * | * | | | | | | | | | |
| [43] | * | | | | | | | | | | |
| [44] | * | | | | | | | | | | |
| [45] | * | | | | | | | | | | |
| [46] | * | | | | | | | | | | |
| [47] | * | | | | | | | | | | |
| [48] | * | | | | | | | | | | |
| [49] | * | | | | | | | | | | |
| [50] | * | * | | | | | | | | | |
| [51] | * | | | | | | | | | | |
| [52] | * | | | | | | | | | | |
| [53] | | | | * | | | | | | | |
| [54] | * | | | | | | | | | | |
| [55] | * | | | | | | | | | | |
| [56] | * | | | | | | | | | | * |
| [57] | * | | | | | | | | | | |
| [58] | * | | | | | | | | | | |
| [59] | * | | | | | | | | | | |
| [60] | * | | | | | | | | | | |
| [61] | * | | | | | | | | | | |
| [62] | * | | | | | | | | | | |
| [63] | * | | | | | | | | | | |

**Table A1.** *Cont.*

| Reference | Min. Cost/ Max. Profit/ Max. Oper. Performance | Min. Lead Time/ Travel Time | Max. Eco. Benefits | Max. NPV/ Min. PV of Cost | Max. Resilience | Max. Total Quality | Min. Financial Risk | Min. Travel Distance | Max. Reliability | Max. Responsiveness | Max. Supplier Performance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [64] | * | | | | | | | | | | |
| [65] | * | | | | | | | | | | |
| [66] | * | | | | | | | | | | |
| [67] | * | | | | | | | | | | |
| [68] | | | | * | | | | | | | |
| [69] | * | | | | | | | | | | |
| [70] | | | | | | | | * | | | |
| [71] | * | | | | | | | | | | |
| [72] | * | | | | | | | | | | |
| [73] | * | | | | | | | | | | |
| [74] | * | | | | * | | | | | | |
| [75] | * | * | | | | | | | | | |
| [76] | * | | | | | | | | | | |
| [77] | * | | | | | | | | | * | |
| [78] | | | | * | | | | | | | |
| [79] | * | | | | | | | | | | |
| [80] | * | | | | | | | | | | |
| [87] | * | | | | | | | | | | |
| [88] | | | | * | | | * | | | | |
| [93] | * | | | | | | | | | | |
| [94] | * | | | | | | | | | | |
| [95] | | | * | | | | | | | | |
| [96] | * | * | | | | | | | | | |
| [97] | * | | | | | | | | | | |
| [98] | * | | | | | | | | | | |
| [99] | * | | | | | | | | | | |
| [100] | * | | | | | | | | | | |
| [101] | * | | | | | | | | | | |
| [102] | * | | | | | | | | | | |
| [103] | | | * | | | | | | | | |
| [104] | * | | | | | | | | | | |
| [105] | * | * | | | | | | | | | |
| [106] | | | * | | | | | | | | |
| [107] | * | | | | | | | | | | |
| [108] | * | | | | | | | | | | |

**Table A1.** *Cont.*

| Reference | Min. Cost/ Max. Profit/ Max. Oper. Performance | Min. Lead Time/ Travel Time | Max. Eco. Benefits | Max. NPV/ Min. PV of Cost | Max. Resilience | Max. Total Quality | Min. Financial Risk | Min. Travel Distance | Max. Reliability | Max. Responsiveness | Max. Supplier Performance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [109] | * | | | | | | | | | | |
| [110] | * | | | | | | | | | | |
| [111] | * | * | | | | | | | | | |
| [112] | * | | | | | * | | | | | |
| [113] | | | * | | | | | | | | |
| [114] | * | | | | | | | | | | |
| [115] | * | | | | | | | | | | |
| [116] | * | * | | | | | | | | | |
| [117] | * | * | | | | | | | | | |
| [118] | * | | | | | | | | | | |
| [119] | * | | | | | | | | | | |
| [120] | * | | | | | | | | | | |
| [121] | * | | | | | | | | | | |
| [122] | * | | | | | | | | | | |
| [123] | * | | | | | | | | | | |
| [124] | * | | | | | | | | | | |
| [125] | * | | | | | | | | * | | |
| [126] | * | | | | | | | | | | |
| [127] | * | | | | | | | | | | |
| [128] | * | | | | | | | | | | |
| [129] | * | | | | | | | | | | |
| [130] | * | | | | | | | | | | |
| [131] | * | | | | * | | | | * | | |
| [132] | * | * | | | | * | | | | | |
| [133] | * | | | | | | | | | | |
| [134] | * | | | | | | | | | | |
| [135] | * | * | | | | | | | | | |
| [136] | * | | | | | | | | | | |
| [137] | | | * | | | | | | | | |
| [138] | * | * | | | | | | | | | |
| | 85 | 12 | 5 | 4 | 3 | 2 | 1 | 1 | 2 | 1 | 1 |

## Appendix B

**Table A2.** Environmental and social objectives of the sustainability used by articles.

| | Environmental Objectives | | | | | | Social Objectives | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reference** | **Min. $GHG/CO_2$ Emission/GWP** | **Min. env. Impact/ Max. env. Performance** | **Min. Energy Consumption/ Max. Energy Recovery** | **Min. Waste** | **Min. Noise Pollution** | **Min. Water Consumption** | **Max. Social Benefits/ Min. Social Impact** | **Max. Job OPPORTUNITIES** | **Min. emp. Injuries** | **Min. Human Resource Variations** | **Min. Lost Working Days** | **Max. Community Development** |
| [5] | * | | | | | | | | | | | |
| [6] | | * | | | | | * | | | | | |
| [9] | | * | | | | | | * | | | | |
| [10] | | * | | | | | * | | | | | |
| [14] | * | | | | | | | | | | | |
| [39] | | | | | | | | | * | | | |
| [40] | | | | | | | * | | | | | |
| [41] | * | | | | | | * | | | | | |
| [42] | * | | | | | | | | | | | |
| [43] | * | | | | | * | | * | | | | |
| [44] | * | | | | | | | | | | | |
| [45] | * | | | | | | | | | | | |
| [46] | * | | | | | | | | | | | |
| [47] | * | | | | | | | | | | | |
| [48] | * | | | | | | | | * | | | |
| [49] | | * | | | | | * | | | | | |
| [50] | * | | | | | | | | | | | |
| [51] | * | | | | | | | | | | | |
| [52] | | * | | | | | * | | | | | |
| [53] | | * | | | | | | | | | | |
| [54] | * | * | | | | | * | | | | | * |
| [55] | * | | | | | | | | | | | |
| [56] | * | | | | | | | | | | | |
| [57] | * | | | | | | | | | | | |
| [58] | | * | | | | | * | | | | | |
| [59] | * | | * | | | | | | | | | |
| [60] | | | | | | * | | * | | | | |

**Table A2.** *Cont.*

| | Environmental Objectives | | | | | | Social Objectives | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | Min. GHG/$CO_2$ Emission/GWP | Min. env. Impact/ Max. Env. Performance | Min. Energy Consumption/ Max. Energy Recovery | Min. Waste | Min. Noise Pollution | Min. Water Consumption | Max. Social Benefits/ Min. Social Impact | Max. Job OPPORTUNITIES | Min. Emp. Injuries | Min. Human Resource Variations | Min. Lost Working Days | Max. Community Development |
| [61] | | * | | | | | * | | | | | |
| [62] | | * | | | | | * | | | | | |
| [63] | | * | | | | | * | | | | | |
| [64] | * | | | | | | | * | | | | |
| [65] | | | | * | | | | * | | | | |
| [66] | * | | * | | | * | | * | | | * | |
| [67] | * | | | | | | | * | | | | |
| [68] | | * | | | | | | * | | | | |
| [69] | * | | * | | | | | | | | | |
| [70] | * | | | | | | | | | | | |
| [71] | | * | | | | | | | | | | |
| [72] | | * | | | | | * | | | | | |
| [73] | | * | | | | | * | | | | | |
| [74] | * | * | | | | | | | | | | |
| [75] | | * | | | | | * | | | | | |
| [76] | | * | | | | | | | | | | |
| [77] | * | | | | | | | | | | | |
| [78] | * | | | | | | | | | | | |
| [79] | * | | | | | | | | | | | |
| [80] | | * | | | | | * | | | | | |
| [87] | | * | | | | | | * | | | | |
| [88] | | * | | | | | | | | | | |
| [94] | * | | | | | | | | | | | |
| [95] | | * | | | | | | | | | | |
| [96] | * | | | | | | | | | | | |
| [97] | | * | | | | | * | | | | | |
| [98] | * | | | | | | | | | | | |
| [99] | * | | | | | | | | | | | |
| [100] | | * | | | | | | | | | | |
| [101] | | * | | | | | * | | | | | |

**Table A2.** *Cont.*

| | Environmental Objectives | | | | | | Social Objectives | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reference** | **Min. GHG/$CO_2$ Emission/GWP** | **Min. env. Impact/ Max. Env. Performance** | **Min. Energy Consumption/ Max. Energy Recovery** | **Min. Waste** | **Min. Noise Pollution** | **Min. Water Consumption** | **Max. Social Benefits/ Min. Social Impact** | **Max. Job OPPORTUNITIES** | **Min. Emp. Injuries** | **Min. Human Resource Variations** | **Min. Lost Working Days** | **Max. Community Development** |
| [102] | | | * | | | | | | | | | |
| [103] | | * | | | | | | | | | | |
| [104] | * | | * | * | | | * | | | | | |
| [105] | * | | | | | | | | | | | |
| [106] | | * | | | | | | | | | | |
| [107] | * | | | | | | | | | | | |
| [108] | * | | * | | | | | | | | | |
| [109] | | * | * | | | * | | | | | | |
| [110] | * | | | * | | | * | | | | | |
| [111] | | | * | | | | | * | | | | |
| [112] | * | | | | | | | | | | | |
| [113] | | * | | | | | | | | | | |
| [114] | | * | | | | | * | | | | | |
| [115] | | * | | | | | * | | | | | |
| [116] | * | | | | | | | | | | | |
| [117] | | * | | | | | * | | | | | |
| [118] | | * | | | | | | | | | | |
| [119] | | * | | | | | * | | | | | |
| [120] | | * | | | | | | | | | | |
| [121] | * | | | | | | | | | * | | |
| [122] | | * | | | | | | | | | | |
| [123] | * | | | | | | | * | | | | |
| [124] | * | | | | | | | * | | | | |
| [125] | * | | | | | | | | | | | |
| [126] | | * | | | | | * | | | | | |
| [127] | | * | | | | | * | | | | | |
| [128] | * | | | | | | | | | | | |
| [129] | * | | | | | | | | | | | |
| [130] | * | | | | | | | | | | | |
| [131] | * | * | | | | | | | | | | |
| [132] | | * | | | | | | | | | | |

**Table A2.** *Cont.*

| | Environmental Objectives | | | | | | Social Objectives | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reference** | **Min. GHG/$CO_2$ Emission/GWP** | **Min. env. Impact/ Max. Env. Performance** | **Min. Energy Consumption/ Max. Energy Recovery** | **Min. Waste** | **Min. Noise Pollution** | **Min. Water Consumption** | **Max. Social Benefits/ Min. Social Impact** | **Max. Job OPPORTUNITIES** | **Min. Emp. Injuries** | **Min. Human Resource Variations** | **Min. Lost Working Days** | **Max. Community Development** |
| [133] | * | | | | | | | | | | | |
| [134] | * | | | | | * | | | | | | |
| [135] | | | | | * | | | | | | | |
| [136] | | * | | | | | * | | | | | |
| [137] | | * | | | | | | | | | | |
| [138] | * | | | | | | | | | | | |
| | 48 | 42 | 8 | 3 | 1 | 5 | 26 | 12 | 2 | 1 | 1 | 1 |

## Appendix C

**Table A3.** References related to Tables 3–8.

| Reference | Sustainability Dimension | Supply Chain (SC) Phases | SC Decision Level | SC Environment | Optimization Technique | Solution Method |
|---|---|---|---|---|---|---|
| [5] | Eco/Env | Overall Supply Chain | Strategic | Uncertainty | Classical | Weighted sum/Torabi-Hassini method |
| [6] | Eco/Env/Soc | Overall Supply Chain | Strategic | Certain | Metaheuristic | PSO |
| [9] | Eco/Env/Soc | Overall Supply Chain | Strategic/Tactical | Uncertainty | Classical | Fuzzy goal programming/Fuzzy best worst method |
| [10] | Eco/Env/Soc | Overall Supply Chain | Strategic | Certain | Classical | Augmented e-Constraint |
| [14] | Eco/Env | Overall Supply Chain | Strategic | Certain | Metaheuristic | PSO |
| [39] | Eco/Soc | Reverse Logistics | Tactical | Certain | Classical/Metaheuristic | e-Constraint/NSGA-II |
| [40] | Eco/Soc | Overall Supply Chain | Strategic | Uncertainty | Classical | Weighted sum/hybrid stochastic fuzzy-robust |
| [41] | Eco/Env/Soc | Overall Supply Chain | Strategic | Certain | Classical | Augmented e-Constraint |
| [42] | Eco/Env | Overall Supply Chain | Strategic | Uncertainty | Classical | e-Constraint/Soyster and Mulvey method |
| [43] | Eco/Env/Soc | Overall Supply Chain | Strategic | Certain | Classical | AHP and Ordered weighted averaging (OWA) |
| [44] | Eco/Env | Manufacturing | Tactical | Uncertainty | Classical | Weighted sum/Fuzzy logic |
| [45] | Eco/Env | Manufacturing | Tactical | Certain | Classical | weighted sum |
| [46] | Eco/Env | Manufacturing | Tactical | Uncertainty | Metaheuristic | Lagrangian relaxation (LR) algorithm/stochastic programming |
| [47] | Eco/Env | Manufacturing | Tactical | Certain | Classical | Weighted goal programming |
| [48] | Eco/Env/Soc | Manufacturing/Distribution | Operational | Certain | Classical | Weighted sum |

**Table A3.** *Cont.*

| Reference | Sustainability Dimension | Supply Chain (SC) Phases | SC Decision Level | SC Environment | Optimization Technique | Solution Method |
|---|---|---|---|---|---|---|
| [49] | Eco/Env/Soc | Distribution | Operational/Strategic | Certain | Metaheuristic | Hybrid swarm intelligence meta-heuristic |
| [50] | Eco/Env/Soc | Overall Supply Chain | Tactical/Operational | Certain | Metaheuristic | NSGA II/PSO |
| [51] | Eco/Env | Overall Supply Chain | Strategic/Tactical | Uncertainty | Classical | Augmented e-Constraint/Decision trees |
| [52] | Eco/Env/Soc | Overall Supply Chain | Strategic/Tactical | Uncertainty | Metaheuristic | Fuzzy possibilistic programming/Simulated annealing |
| [53] | Eco/Env | Overall Supply Chain | Strategic/Tactical | Uncertainty | Metaheuristic | EA/Fuzzy programming |
| [54] | Eco/Env/Soc | Overall Supply Chain | Strategic/Tactical | Certain | Classical | Goal programming/e-Constraint method |
| [55] | Eco/Env | Overall Supply Chain | Strategic/Tactical | Uncertainty | Classical | e-Constraint/Fuzzy logic |
| [56] | Eco/Env | Overall Supply Chain | Strategic/Tactical/Operational | Uncertainty | Classical | Fuzzy programming/Weighted min max |
| [57] | Eco/Env | Overall Supply Chain | Strategic/Tactical/Operational | Certain | Metaheuristic | Mematic algorithm/Taguchi |
| [58] | Eco/Env/Soc | Manufacturing | Strategic/Tactical/Operational | Certain | Classical | Exact solution approach (Non dominated points) |
| [59] | Eco/Env | Manufacturing | Strategic | Certain | Classical | e-Constraint |
| [60] | Eco/Env/Soc | Manufacturing | Strategic | Uncertainty | Classical | Meta goal programming/simulation |
| [61] | Eco/Env/Soc | Manufacturing | Strategic | Uncertainty | Classical | Fuzzy AHP/Max-min |
| [62] | Eco/Env/Soc | Reverse Logistics | Strategic | Certain | Classical | Augmented e-Constraint |
| [63] | Eco/Env/Soc | Reverse Logistics | Strategic | Uncertainty | Classical | Weighted goal programming/chance constraint method |

**Table A3.** *Cont.*

| Reference | Sustainability Dimension | Supply Chain (SC) Phases | SC Decision Level | SC Environment | Optimization Technique | Solution Method |
|---|---|---|---|---|---|---|
| [64] | Eco/Env/Soc | Reverse Logistics | Strategic | Certain | Classical | Weighted sum/Augmented e-Constraint |
| [65] | Eco/Env/Soc | Reverse Logistics | Tactical | Certain | Classical | e-Constraint |
| [66] | Eco/Env/Soc | Reverse Logistics | Strategic | Uncertainty | Classical | Fuzzy programming |
| [67] | Eco/Env/Soc | Reverse Logistics | Strategic | Certain | Metaheuristic | NSGA II/PSO |
| [68] | Eco/Env/Soc | Reverse Logistics | Tactical | Uncertainty | Metaheuristic | PSO/Fuzzy programming |
| [69] | Eco/Env | Reverse Logistics | Strategic | Uncertainty | Classical | Fuzzy AHP/Weighted comprehensive criterian method |
| [70] | Eco/Env | Reverse Logistics | Strategic | Certain | Metaheuristic | Centre of gravity/K means clustering |
| [71] | Eco/Env | Reverse Logistics | Strategic | Uncertainty | Classical | e-Constraint/Senario generation method |
| [72] | Env/Soc | Overall Supply Chain | Strategic | Certain | Classical | PROMTHEE/Goal programming |
| [73] | Eco/Env/Soc | Overall Supply Chain | Strategic/Tactical | Uncertainty | Metaheuristic | NSGA II/Fuzzy programming |
| [74] | Eco/Env | Manufacturing | Strategic | Uncertainty | Classical | e-Constraint/Fuzzy AHP |
| [75] | Eco/Env/Soc | Sourcing | Strategic | Uncertainty | Classical | e-Constraint/Fuzzy AHP |
| [76] | Eco/Env/Soc | Manufacturing/Distribution | Strategic | Uncertainty | Classical | e-Constraint/stochastic programming |
| [77] | Eco/Env | Sourcing/Distribution | Strategic | Uncertainty | Classical | e-Constraint/stochastic programming |
| [78] | Eco/Env | Manufacturing | Tactical | Uncertainty | Classical | e-Constraint/stochastic programming |
| [79] | Eco/Env | Overall Supply Chain | Strategic | Uncertainty | Classical | LP metric based compromising/Robust programming |

**Table A3.** *Cont.*

| Reference | Sustainability Dimension | Supply Chain (SC) Phases | SC Decision Level | SC Environment | Optimization Technique | Solution Method |
|---|---|---|---|---|---|---|
| [80] | Eco/Env/Soc | Manufacturing/Distribution | Tactical | Uncertainty | Classical | Improved Augmented e-Constraint method/Hybrid robust probabilistic programming (HRPP II) |
| [87] | Eco/Env/Soc | Distribution | Tactical | Uncertainty | Metaheuristic | GA/PSO/Chance constraint method |
| [88] | Eco/Env | Overall Supply Chain | Strategic | Uncertainty | Classical | Augmented e-Constraint/Senario tree approach |
| [93] | Eco/Env/Soc | Overall Supply Chain | Strategic | Uncertainty | Classical | Augmented e-Constraint/Fuzzy logic |
| [94] | Eco/Env | Manufacturing | Strategic | Uncertainty | Classical | e-Constraint/Fuzzy logic |
| [95] | Eco/Env | Manufacturing/Distribution | Tactical | Certain | Classical | e-Constraint |
| [96] | Eco/Env | Distribution | Tactical | Certain | Classical | Normalized normal constraint method |
| [97] | Eco/Env/Soc | Overall Supply Chain | Strategic | Certain | Metaheuristic | Hybrid meta-huristic algorithms (AICA/HIV/NIV) |
| [98] | Eco/Env | Manufacturing/Distribution | Strategic | Certain | Classical | e-Constraint |
| [99] | Eco/Env | Overall Supply Chain | Strategic | Certain | Metaheuristic | Hybrid meta-huristic algorithm (MOHEV) |
| [100] | Eco/Env | Distribution/Transportation | Strategic | Certain | Metaheuristic | Hybrid meta-huristic algorithm (MOHEV) |
| [101] | Eco/Env/Soc | Sourcing/Distribution | Strategic | Uncertainty | Classical | Augmented e-Constraint/Fuzzy c-means clustering |
| [102] | Eco/Env | Overall Supply Chain | Strategic | Certain | Metaheuristic | PSO |
| [103] | Eco/Env | Manufacturing/Distributing | Strategic | Certain | Classical | e-Constraint |
| [104] | Eco/Env/Soc | Sourcing | Strategic/Tactical | Uncertainty | Classical | Fuzzy AHP/Weighted sum |
| [105] | Eco/Env | Transportation | Tactical | Certain | Metaheuristic | Ant colony optimization (IACO) algorithm |

**Table A3.** *Cont.*

| Reference | Sustainability Dimension | Supply Chain (SC) Phases | SC Decision Level | SC Environment | Optimization Technique | Solution Method |
|---|---|---|---|---|---|---|
| [106] | Eco/Env | Transportation/Reverse Logistics | Tactical | Certain | Metaheuristic | GA |
| [107] | Eco/Env | Sourcing/Manufacturing/Distribution | Strategic/Tactical | Certain | Classical | Senario method |
| [108] | Eco/Env | Transportation/Distribution | Strategic | Certain | Classical | e-Constraint |
| [109] | Eco/Env | Overall Supply Chain | Strategic | Certain | Classical | Goal programming MINMAX |
| [110] | Eco/Env/Soc | Overall Supply Chain | Strategic | Certain | Classical | Lexicographic ordering |
| [111] | Eco/Env/Soc | Overall Supply Chain | Strategic | Uncertainty | Classical | Modified fuzzy parametric programming (MFPP)/weighted metrics |
| [112] | Eco/Env | Transportation/Distribution | Strategic | Certain | Classical | e-Constraint |
| [113] | Eco/Env | Sourcing | Strategic | Uncertainty | Classical | Fuzzy AHP/Weighted sum |
| [114] | Eco/Env/Soc | Overall Supply Chain | Strategic/Tactical | Uncertainty | Metaheuristic | NSGA II/Fuzzy programming |
| [115] | Eco/Env/Soc | Overall Supply Chain | Strategic/Tactical | Certain | Classical | Augmented e-Constraint and TOPSIS. |
| [116] | Eco/Env | Transportation | Tactical | Certain | Classical | e-Constraint |
| [117] | Eco/Env | Sourcing | Strategic | Certain | Metaheuristic | GA/PSO |
| [118] | Eco/Env | Sourcing/Manufacturing/Transportation | Strategic/Tactical | Certain | Classical | e-Constraint |
| [119] | Eco/Env/Soc | Sourcing | Strategic | Certain | Metaheuristic | Hybrid meta-heuristic algoritham (MOHEV) |
| [120] | Eco/Env | Overall Supply Chain | Strategic | Certain | Metaheuristic | GA |
| [121] | Eco/Env/Soc | Transportation | Tactical | Uncertainty | Classical | Fuzzy programming |
| [122] | Eco/Env | Overall Supply Chain | Tactical | Certain | Classical | e-Constraint |
| [123] | Eco/Env/Soc | Manufacturing/Distribution | Strategic | Certain | Classical | Normalized normal constraint method |
| [124] | Eco/Env/Soc | Overall Supply Chain | Strategic | Certain | Metaheuristic | AugMathFix |

**Table A3.** *Cont.*

| Reference | Sustainability Dimension | Supply Chain (SC) Phases | SC Decision Level | SC Environment | Optimization Technique | Solution Method |
|---|---|---|---|---|---|---|
| [125] | Eco/Env | Distribution | Tactical | Certain | Metaheuristic | Simulated-annealing Algorithm (MOSA)/NSGA-II |
| [126] | Eco/Env/Soc | Manufacturing/Distribution | Strategic/Tactical | Uncertainty | Classical | Fuzzy programming |
| [127] | Eco/Env/Soc | Sourcing/Manufacturing/Distribution | Strategic | Certain | Classical | Augmented e-Constraint |
| [128] | Eco/Env | Distributing | Tactical | Certain | Metaheuristic | GA |
| [129] | Eco/Env | Distributing | Strategic | Certain | Metaheuristic | Non-dominated generic algorithm (NRGA) |
| [130] | Eco/Env | Overall Supply Chain | Strategic | Certain | Classical | Normalized normal constraint |
| [131] | Eco/Env | Manufacturing | Strategic | Certain | Classical | e-Constraint |
| [132] | Eco/Env | Sourcing | Strategic | Certain | Metaheuristic | GA |
| [133] | Eco/Env | Overall Supply Chain | Strategic | Certain | Classical | e-Constraint |
| [134] | Eco/Env | Overall Supply Chain | Strategic/Tactical | Uncertainty | Classical | Fuzzy programming |
| [135] | Eco/Env/Soc | Sourcing/Manufacturing/Transportation | Tactical | Uncertainty | Metaheuristic | Hybrid meta-heuristic algorithm/stochastic programming |
| [136] | Eco/Env | Distribution | Strategic | Uncertainty | Metaheuristic | Hybrid meta-heuristic algorithm/Fuzzy programming |
| [137] | Eco/Env | Distribution | Strategic | Certain | Metaheuristic | Swarm intelligence/ABC |
| [138] | Eco/Env | Overall Supply Chain | Strategic | Certain | Classical | e-Constraint |

## References


1. Naidelage, C.; Agdas, D.; Rose, T.; Yigitcanlar, T. Stakeholder perception of reverse logistics practices on supply chain performance. *Bus. Strategy Environ.* **2020**, *30*, 60–70. [CrossRef]
2. Zandieh, M.; Aslani, B. A hybrid MCDM approach for order distribution in a multiple-supplier supply chain: A case study. *J. Ind. Inf. Integr.* **2019**, *16*, 100104. [CrossRef]
3. Liu, S.; Papageorgiou, L.G. Multi-objective optimization of production, distribution and capacity planning of global supply chains in the process industry. *Omega* **2013**, *41*, 369–382. [CrossRef]
4. Dekker, R.; Bloemhof, J.; Mallidis, I. Operations Research for green logistics-An overview of aspects, issues, contributions and challenges. *Eur. J. Oper. Res.* **2012**, *219*, 671–679. [CrossRef]
5. Darestani, S.A.; Hemmati, M. Robust optimization of a bi-objective closed-loop supply chain network for perishable goods considering queue system. *Comput. Ind. Eng.* **2019**, *136*, 277–292. [CrossRef]
6. Mota, B.; Gomes, M.I.; Carvalho, A.; Barbosa-Povoa, A.P. Towards supply chain sustainability: Economic, environmental and social design and planning. *J. Clean. Prod.* **2015**, *105*, 14–27. [CrossRef]
7. Jassim, S.; Al-Mubarak, M.; Hamdan, A. The Impact of Green Supply Chain Management on Firm's Performance. *J. Inf. Knowl. Manag.* **2020**, *19*, 2040026. [CrossRef]
8. Tukamuhabwa, B.; Mutebi, H.; Isabirye, D. Supplier performance in the public healthcare: Internal social capital, logistics capabilities and supply chain risk management capabilities as antecedents in a developing economy. *J. Bus. Socio-Econ. Dev.* **2021**. [CrossRef]
9. Nasr, K.A.; Tavana, M.; Alavi, B.; Mina, H. A novel fuzzy multi-objective circular supplier selection and order allocation model for sustainable closed-loop supply chains. *J. Clean. Prod.* **2020**, *287*, 124994. [CrossRef]
10. Resat, H.G.; Unsal, B. A novel multi-objective optimization approach for sustainable supply chain: A case study in packaging industry. *Sustain. Prod. Consum.* **2019**, *20*, 29–39. [CrossRef]
11. Barbosa-Póvoa, A.P.; da Silva, C.; Carvalho, A. Opportunities and challenges in sustainable supply chain: An operations research perspective. *Eur. J. Oper. Res.* **2018**, *268*, 399–431. [CrossRef]
12. Banasik, A.; Bloemhof-Ruwaard, J.M.; Kanellopoulos, A.; Claassen, G.D.H.; van der Vorst, J.G.A.J. Multi-criteria decision-making approaches for green supply chains: A review. *Flex. Serv. Manuf. J.* **2018**, *30*, 366–396. [CrossRef]
13. Crainic, T.G.; Perboli, G.; Rosano, M. Simulation of intermodal freight transportation systems: A taxonomy. *Eur. J. Oper. Res.* **2018**, *270*, 401–418. [CrossRef]
14. Chen, L.; Zhao, X.; Tang, O.; Price, L.; Zhang, S.; Zhu, W. Supply chain collaboration for sustainability: A literature review and future research agenda. *Int. J. Prod. Econ.* **2017**, *194*, 73–87. [CrossRef]
15. Ahi, P.; Searcy, C. An analysis of metrics used to measure performance in green and sustainable supply chains. *J. Clean. Prod.* **2015**, *86*, 360–377. [CrossRef]
16. Brandenburg, M.; Govindan, K.; Sarkis, J.; Seuring, S. Quantitative models for sustainable supply chain management: Developments and directions. *Eur. J. Oper. Res.* **2014**, *233*, 299–312. [CrossRef]
17. Rajeev, A.; Pati, R.K.; Padhi, S.S. Sustainable supply chain management in the chemical industry: Evolution, opportunities, and challenges. *Resour. Conserv. Recycl.* **2019**, *149*, 275–291. [CrossRef]
18. Taticchi, P.; Garengo, P.; Nudurupati, S.S.; Tonelli, F.; Pasqualino, R. A review of decision-support tools and performance measurement and sustainable supply chain management. *Int. J. Prod. Res.* **2015**, *53*, 6473–6494. [CrossRef]
19. Seuring, S. A review of modeling approaches for sustainable supply chain management. *Decis. Support Syst.* **2013**, *54*, 1513–1520. [CrossRef]
20. Denyer, D.; Tranfield, D. Producing a systematic review. In *The Sage Handbook of Organizational Research Methods*; Buchanan, D.A., Ed.; Sage: London, UK, 2009; Volume 738, pp. 671–689.
21. Snyder, H. Literature review as a research methodology: An overview and guidelines. *J. Bus. Res.* **2019**, *104*, 333–339. [CrossRef]
22. Trisna, T.; Marimin, M.; Arkeman, Y.; Sunarti, T. Multi-objective optimization for supply chain management problem: A literature review. *Decis. Sci. Lett.* **2016**, *5*, 283–316. [CrossRef]
23. Moreno-Camacho, C.A.; Montoya-Torres, J.R.; Jaegler, A.; Gondran, N. Sustainability metrics for real case applications of the supply chain network design problem: A systematic literature review. *J. Clean. Prod.* **2019**, *231*, 600–618. [CrossRef]
24. Van Engeland, J.; Beliën, J.; De Boeck, L.; De Jaeger, S. Literature review: Strategic network optimization models in waste reverse supply chains. *Omega* **2020**, *91*, 102012. [CrossRef]
25. Zahraee, S.M.; Shiwakoti, N.; Stasinopoulos, P. Biomass supply chain environmental and socio-economic analysis: 40-Years comprehensive review of methods, decision issues, sustainability challenges, and the way forward. *Biomass Bioenergy* **2020**, *142*, 105777. [CrossRef]
26. Ilgin, M.A.; Gupta, S.M. Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art. *J. Environ. Manag.* **2010**, *91*, 563–591. [CrossRef]
27. Ashby, A. Making connections: A review of supply chain management and sustainability literature. *Supply Chain Manag. Int. J.* **2012**, *17*, 497–516. [CrossRef]

28. Hassini, E.; Surti, C.; Searcy, C. A literature review and a case study of sustainable supply chains with a focus on metrics. *Int. J. Prod. Econ.* **2012**, *140*, 69–82. [CrossRef]
29. Tang, C.S.; Zhou, S. Research advances in environmentally and socially sustainable operations. *Eur. J. Oper. Res.* **2012**, *223*, 585–594. [CrossRef]
30. Alexander, A. Decision theory in sustainable supply chain management: A literature review. *Supply Chain Manag. Int. J.* **2014**, *19*, 504–522. [CrossRef]
31. Brandenburg, M.; Rebs, T. Sustainable supply chain management: A modeling perspective. *Ann. Oper. Res.* **2015**, *229*, 213–252. [CrossRef]
32. Ilgin, M.A.; Gupta, S.M.; Battaïa, O. Use of MCDM techniques in environmentally conscious manufacturing and product recovery: State of the art. *J. Manuf. Syst.* **2015**, *37*, 746–758. [CrossRef]
33. Eskandarpour, M.; Dejax, P.; Miemczyk, J.; Péton, O. Sustainable supply chain network design: An optimization-oriented review. *Omega* **2015**, *54*, 11–32. [CrossRef]
34. Ahi, P.; Searcy, C.; Jaber, M.Y. Energy-related performance measures employed in sustainable supply chains: A bibliometric analysis. *Sustain. Prod. Consum.* **2016**, *7*, 1–15. [CrossRef]
35. Rajeev, A.; Pati, R.K.; Padhi, S.S.; Govindan, K. Evolution of sustainability in supply chain management: A literature review. *J. Clean. Prod.* **2017**, *162*, 299–314. [CrossRef]
36. Malladi, K.T.; Sowlati, T. Sustainability aspects in Inventory Routing Problem: A review of new trends in the literature. *J. Clean. Prod.* **2018**, *197*, 804–814. [CrossRef]
37. Thies, C.; Kieckhäfer, K.; Spengler, T.S.; Sodhi, M.S. Operations research for sustainability assessment of products: A review. *Eur. J. Oper. Res.* **2019**, *274*, 1–21. [CrossRef]
38. Nematollahi, M.; Tajbakhsh, A. Past, present, and prospective themes of sustainable agricultural supply chains: A content analysis. *J. Clean. Prod.* **2020**, *271*, 122201. [CrossRef]
39. Farrokhi-Asl, H.; Makui, A.; Ghousi, R.; Rabbani, M. Developing a hazardous waste management system with consideration of health, safety, and environment. *Comput. Electr. Eng.* **2020**, *82*, 106553. [CrossRef]
40. Sharifi, M.; Hosseini-Motlagh, S.-M.; Samani, M.R.G.; Kalhor, T. Novel resilient-sustainable strategies for second-generation biofuel network design considering Neem and Eruca Sativa under hybrid stochastic fuzzy robust approach. *Comput. Chem. Eng.* **2020**, *143*, 107073. [CrossRef]
41. Varsei, M.; Polyakovskiy, S. Sustainable supply chain network design: A case of the wine industry in Australia. *Omega* **2017**, *66*, 236–247. [CrossRef]
42. Abdolazimi, O.; Salehi Esfandarani, M.; Salehi, M.; Shishebori, D. Robust design of a multi-objective closed-loop supply chain by integrating on-time delivery, cost, and environmental aspects, case study of a Tire Factory. *J. Clean. Prod.* **2020**, *264*, 121566. [CrossRef]
43. Allaoui, H.; Guo, Y.; Choudhary, A.; Bloemhof, J. Sustainable agro-food supply chain design using two-stage hybrid multi-objective decision-making approach. *Comput. Oper. Res.* **2018**, *89*, 369–384. [CrossRef]
44. Rout, C.; Paul, A.; Kumar, R.S.; Chakraborty, D.; Goswami, A. Cooperative sustainable supply chain for deteriorating item and imperfect production under different carbon emission regulations. *J. Clean. Prod.* **2020**, *272*, 122170. [CrossRef]
45. Tiammee, S.; Likasiri, C. Sustainability in corn production management: A multi-objective approach. *J. Clean. Prod.* **2020**, *257*, 120855. [CrossRef]
46. Zheng, M.; Li, W.; Liu, Y.; Liu, X. A Lagrangian heuristic algorithm for sustainable supply chain network considering $CO_2$ emission. *J. Clean. Prod.* **2020**, *270*, 122409. [CrossRef]
47. Sarkar, B.; Omair, M.; Choi, S.-B. A Multi-Objective Optimization of Energy, Economic, and Carbon Emission in a Production Model under Sustainable Supply Chain Management. NATO Advanced Science Institutes Series E. *Appl. Sci.* **2018**, *8*, 1744. [CrossRef]
48. Chen, Z.; Andresen, S. A Multi-objective Optimization Model of Production-Sourcing for Sustainable Supply Chain with Consideration of Social, Environmental, and Economic Factors. *Math. Probl. Eng.* **2014**, *2014*, 616107. [CrossRef]
49. Govindan, K.; Jafarian, A.; Nourbakhsh, V. Designing a sustainable supply chain network integrated with vehicle routing: A comparison of hybrid swarm intelligence metaheuristics. *Comput. Oper. Res.* **2019**, *110*, 220–235. [CrossRef]
50. Wang, Y.; Shi, Q.; Hu, Q.; You, Z.; Bai, Y.; Guo, C. An efficiency sorting multi-objective optimization framework for sustainable supply network optimization and decision making. *J. Clean. Prod.* **2020**, *272*, 122842. [CrossRef]
51. Mohebalizadehgashti, F.; Zolfagharinia, H.; Amin, S.H. Designing a green meat supply chain network: A multi-objective approach. *Int. J. Prod. Econ.* **2020**, *219*, 312–327. [CrossRef]
52. Eskandari-Khanghahi, M.; Tavakkoli-Moghaddam, R.; Taleizadeh, A.A.; Amin, S.H. Designing and optimizing a sustainable supply chain network for a blood platelet bank under uncertainty. *Eng. Appl. Artif. Intell.* **2018**, *71*, 236–250. [CrossRef]
53. Arampantzi, C.; Minis, I. A new model for designing sustainable supply chain networks and its application to a global manufacturer. *J. Clean. Prod.* **2017**, *156*, 276–292. [CrossRef]
54. Saffar, M.; Razmi, J. A new multi objective optimization model for designing a green supply chain network under uncertainty. *Int. J. Ind. Eng. Comput.* **2015**, *6*, 15–32. [CrossRef]
55. Azadeh, A.; Shafiee, F.; Yazdanparast, R.; Heydari, J.; Fathabad, A.M. Evolutionary multi-objective optimization of environmental indicators of integrated crude oil supply chain under uncertainty. *J. Clean. Prod.* **2017**, *152*, 295–311. [CrossRef]

56. Govindan, K.; Darbari, J.D.; Agarwal, V.; Jha, P.C. Fuzzy multi-objective approach for optimal selection of suppliers and transportation decisions in an eco-efficient closed loop supply chain network. *J. Clean. Prod.* **2017**, *165*, 1598–1619. [CrossRef]
57. Jamshidi, R.; Fatemi Ghomi, S.M.T.; Karimi, B. Multi-objective green supply chain optimization with a new hybrid memetic algorithm using the Taguchi method. *Sci. Iran.* **2012**, *19*, 1876–1886. [CrossRef]
58. Rasmi, S.A.B.; Kazan, C.; Türkay, M. A multi-criteria decision analysis to include environmental, social, and cultural issues in the sustainable aggregate production plans. *Comput. Ind. Eng.* **2019**, *132*, 348–360. [CrossRef]
59. Nujoom, R.; Mohammed, A.; Wang, Q. Drafting a cost-effective approach towards a sustainable manufacturing system design. *Comput. Ind. Eng.* **2019**, *133*, 317–330. [CrossRef]
60. Motevalli-Taher, F.; Paydar, M.M.; Emami, S. Wheat sustainable supply chain network design with forecasted demand by simulation. *Comput. Electron. Agric.* **2020**, *178*, 105763. [CrossRef]
61. Ozgen, D.; Gulsun, B. Combining possibilistic linear programming and fuzzy AHP for solving the multi-objective capacitated multi-facility location problem. *Inf. Sci.* **2014**, *268*, 185–201. [CrossRef]
62. Budak, A. Sustainable reverse logistics optimization with triple bottom line approach: An integration of disassembly line balancing. *J. Clean. Prod.* **2020**, *270*, 122475. [CrossRef]
63. Dutta, P.; Mishra, A.; Khandelwal, S.; Katthawala, I. A multiobjective optimization model for sustainable reverse logistics in Indian E-commerce market. *J. Clean. Prod.* **2020**, *249*, 119348. [CrossRef]
64. Gao, X.; Cao, C. A novel multi-objective scenario-based optimization model for sustainable reverse logistics supply chain network redesign considering facility reconstruction. *J. Clean. Prod.* **2020**, *270*, 122405. [CrossRef]
65. Huang, L.; Zhen, L.; Yin, L. Waste material recycling and exchanging decisions for industrial symbiosis network optimization. *J. Clean. Prod.* **2020**, *276*, 124073. [CrossRef]
66. Pourmehdi, M.; Paydar, M.M.; Asadi-Gangraj, E. Scenario-based design of a steel sustainable closed-loop supply chain network considering production technology. *J. Clean. Prod.* **2020**, *277*, 123298. [CrossRef]
67. Rabbani, M.; Heidari, R.; Farrokhi-Asl, H.; Rahimi, N. Using metaheuristic algorithms to solve a multi-objective industrial hazardous waste location-routing problem considering incompatible waste types. *J. Clean. Prod.* **2018**, *170*, 227–241. [CrossRef]
68. Govindan, K.; Paam, P.; Abtahi, A.-R. A fuzzy multi-objective optimization model for sustainable reverse logistics network design. *Ecol. Indic.* **2016**, *67*, 753–768. [CrossRef]
69. Abdallah, M.; Hamdan, S.; Shabib, A. A multi-objective optimization model for strategic waste management master plans. *J. Clean. Prod.* **2020**, *284*, 124714. [CrossRef]
70. Mohamed Sultan, A.A.; Mativenga, P.T. Sustainable Location Identification Decision Protocol (SuLIDeP) for determining the location of recycling centres in a circular economy. *J. Clean. Prod.* **2019**, *223*, 508–521. [CrossRef]
71. Yu, H.; Solvang, W.D. Incorporating flexible capacity in the planning of a multi-product multi-echelon sustainable reverse logistics network under uncertainty. *J. Clean. Prod.* **2018**, *198*, 285–303. [CrossRef]
72. de Vivas, R.C.; Sant'Anna, A.M.O.; Esquerre, K.P.S.O.; Freires, F.G.M. Integrated method combining analytical and mathematical models for the evaluation and optimization of sustainable supply chains: A Brazilian case study. *Comput. Ind. Eng.* **2020**, *139*, 105670. [CrossRef]
73. Pourjavad, E.; Mayorga, R.V. Multi-objective Fuzzy Programming of Closed-Loop Supply Chain Considering Sustainable Measures. *Int. J. Fuzzy Syst.* **2019**, *21*, 655–673. [CrossRef]
74. Mohammed, A.; Harris, I.; Soroka, A.; Nujoom, R. A hybrid MCDM-fuzzy multi-objective programming approach for a G-resilient supply chain network design. *Comput. Ind. Eng.* **2019**, *127*, 297–312. [CrossRef]
75. Mohammed, A.; Setchi, R.; Filip, M.; Harris, I.; Li, X. An integrated methodology for a sustainable two-stage supplier selection and order allocation problem. *J. Clean. Prod.* **2018**, *192*, 99–114. [CrossRef]
76. Rahimi, M.; Ghezavati, V.; Asadi, F. A stochastic risk-averse sustainable supply chain network design problem with quantity discount considering multiple sources of uncertainty. *Comput. Ind. Eng.* **2019**, *130*, 430–449. [CrossRef]
77. Ebrahimi, S.B. A stochastic multi-objective location-allocation-routing problem for tire supply chain considering sustainability aspects and quantity discounts. *J. Clean. Prod.* **2018**, *198*, 704–720. [CrossRef]
78. Ruiz-Femenia, R.; Guillén-Gosálbez, G.; Jiménez, L.; Caballero, J.A. Multi-objective optimization of environmentally conscious chemical supply chains under demand uncertainty. *Chem. Eng. Sci.* **2013**, *95*, 1–11. [CrossRef]
79. Wang, L.-C.; Chen, T.-L.; Chen, Y.-Y.; Chen, Y.-W.; Wang, A. Closed-Loop Sustainable Supply Chain Design under Uncertainties. In *Advances in Sustainable and Competitive Manufacturing Systems*; Springer: Berlin/Heidelberg, Germany, 2013; pp. 799–812. [CrossRef]
80. Rabbani, M.; Hosseini-Mokhallesun, S.A.A.; Ordibazar, A.H.; Farrokhi-Asl, H. A hybrid robust possibilistic approach for a sustainable supply chain location-allocation network design. *Int. J. Syst. Sci. Oper. Logist.* **2020**, *7*, 60–75. [CrossRef]
81. Mavrotas, G. Effective implementation of the ε-constraint method in Multi-Objective Mathematical Programming problems. *Appl. Math. Comput.* **2009**, *213*, 455–465. [CrossRef]
82. Atoei, F.; Teimory, E.; Amiri, A. Designing reliable supply chain network with disruption risk. *Int. J. Ind. Eng. Comput.* **2013**, *4*, 111–126. [CrossRef]
83. Chiandussi, G.; Codegone, M.; Ferrero, S.; Varesio, F.E. Comparison of multi-objective optimization methodologies for engineering applications. *Comput. Math. Appl.* **2012**, *63*, 912–942. [CrossRef]

84. Ingrao, C.; Messineo, A.; Beltramo, R.; Yigitcanlar, T.; Ioppolo, G. How can life cycle thinking support sustainability of buildings? Investigating life cycle assessment applications for energy efficiency and environmental performance. *J. Clean. Prod.* **2018**, *201*, 556–569. [CrossRef]
85. Ioppolo, G.; Cucurachi, S.; Salomone, R.; Shi, L.; Yigitcanlar, T. Strategic environmental assessment and material flow accounting: A novel approach for moving towards sustainable urban futures. *Int. J. Life Cycle Assess.* **2019**, *24*, 1269–1284. [CrossRef]
86. Bertsimas, D.; Nohadani, O.; Teo, K.M. Robust Optimization for Unconstrained Simulation-Based Problems. *Oper. Res.* **2010**, *58*, 161–178. [CrossRef]
87. Biuki, M.; Kazemi, A.; Alinezhad, A. An integrated location-routing-inventory model for sustainable design of a perishable products supply chain network. *J. Clean. Prod.* **2020**, *260*, 120842. [CrossRef]
88. Silva, W.H.; Guarnieri, P.; Carvalho, J.M.; Farias, J.S.; Reis, S.A.D. Sustainable Supply Chain Management: Analyzing the Past to Determine a Research Agenda. *Logistics* **2019**, *3*, 14. [CrossRef]
89. Cardoso, S.R.; Barbosa-Póvoa, A.P.; Relvas, S. Integrating financial risk measures into the design and planning of closed-loop supply chains. *Comput. Chem. Eng.* **2016**, *85*, 105–123. [CrossRef]
90. Tukamuhabwa, B.; Mutebi, H.; Kyomuhendo, R. Competitive advantage in SMEs: Effect of supply chain management practices, logistics capabilities and logistics integration in a developing country. *J. Bus. Socio-Econ. Dev.* **2021**. [CrossRef]
91. GRI Standard. GRI 103 Management Approach. 2016. Available online: www.globalreporting.org/standards/download-the-standards/ (accessed on 30 November 2021).
92. Jayarathna, C.P.; Agdas, D.; Dawes, L.; Miska, M. Exploring sector-specific sustainability indicators: A content analysis of sustainability reports in the logistics sector. *Eur. Bus. Review.* **2021**. ahead-of-print. [CrossRef]
93. Ahmed, W.; Sarkar, B. Management of next-generation energy using a triple bottom line approach under a supply chain framework. *Resour. Conserv. Recycl.* **2019**, *150*, 104431. [CrossRef]
94. Balaman, Ş.Y. Investment planning and strategic management of sustainable systems for clean power generation: An ε-constraint based multi objective modeling approach. *J. Clean. Prod.* **2016**, *137*, 1179–1190. [CrossRef]
95. Banasik, A.; Kanellopoulos, A.; Claassen, G.D.H.; Bloemhof-Ruwaard, J.M.; van der Vorst, J.G.A.J. Closing loops in agricultural supply chains using multi-objective optimization: A case study of an industrial mushroom supply chain. *Int. J. Prod. Econ.* **2017**, *183*, 409–420. [CrossRef]
96. Bortolini, M.; Faccio, M.; Ferrari, E.; Gamberi, M.; Pilati, F. Fresh food sustainable distribution: Cost, delivery time and carbon footprint three-objective optimization. *J. Food Eng.* **2016**, *174*, 56–67. [CrossRef]
97. Devika, K.; Jafarian, A.; Nourbakhsh, V. Designing a sustainable closed-loop supply chain network based on triple bottom line approach: A comparison of metaheuristics hybridization techniques. *Eur. J. Oper. Res.* **2014**, *235*, 594–615. [CrossRef]
98. Eskandarpour, M.; Dejax, P.; Péton, O. Multi-directional local search for sustainable supply chain network design. *Int. J. Prod. Res.* **2019**, 1–17. [CrossRef]
99. Govindan, K.; Jafarian, A.; Nourbakhsh, V. Bi-objective integrating sustainable order allocation and sustainable supply chain network strategic design with stochastic demand using a novel robust hybrid multi-objective metaheuristic. *Comput. Operat. Res.* **2015**, *62*, 112–130. [CrossRef]
100. Govindan, K.; Jafarian, A.; Khodaverdi, R.; Devika, K. Two-echelon multiple-vehicle location–routing problem with time windows for optimization of sustainable supply chain network of perishable food. *Int. J. Prod. Econ.* **2014**, *152*, 9–28. [CrossRef]
101. Jabbarzadeh, A.; Fahimnia, B.; Sabouhi, F. Resilient and sustainable supply chain design: Sustainability analysis under disruption risks. *Int. J. Prod. Res.* **2018**, *56*, 5945–5968. [CrossRef]
102. Kadambala, D.K.; Subramanian, N.; Tiwari, M.K.; Abdulrahman, M.; Liu, C. Closed loop supply chain networks: Designs for energy and time value efficiency. *Int. J. Prod. Econ.* **2017**, *183*, 382–393. [CrossRef]
103. Kostin, A.; Guillén-Gosálbez, G.; Jiménez, L. Dimensionality reduction applied to the simultaneous optimization of the economic and life cycle environmental performance of supply chains. *Int. J. Prod. Econ.* **2015**, *159*, 223–232. [CrossRef]
104. Kumar, D.; Rahman, Z.; Chan, F.T.S. A fuzzy AHP and fuzzy multi-objective linear programming model for order allocation in a sustainable supply chain: A case study. *Int. J. Comput. Integr. Manuf.* **2017**, *30*, 535–551. [CrossRef]
105. Li, Y.; Soleimani, H.; Zohal, M. An improved ant colony optimization algorithm for the multi-depot green vehicle routing problem with multiple objectives. *J. Clean. Prod.* **2019**, *227*, 1161–1172. [CrossRef]
106. Lin, C.; Choy, K.L.; Ho, G.T.S.; Ng, T.W. A Genetic Algorithm-based optimization model for supporting green transportation operations. *Expert Syst. Appl.* **2014**, *41*, 3284–3296. [CrossRef]
107. Liotta, G.; Stecca, G.; Kaihara, T. Optimization of freight flows and sourcing in sustainable production and transportation networks. *Int. J. Prod. Econ.* **2015**, *164*, 351–365. [CrossRef]
108. Liu, Z.; Qiu, T.; Chen, B. A study of the LCA based biofuel supply chain multi-objective optimization model with multi-conversion paths in China. *Appl. Energy* **2014**, *126*, 221–234. [CrossRef]
109. Mahjoub, N.; Sahebi, H. The water-energy nexus at the hybrid bioenergy supply chain: A sustainable network design model. *Ecol. Indic.* **2020**, *119*, 106799. [CrossRef]
110. Martins, C.L.; Melo, M.T.; Pato, M.V. Redesigning a food bank supply chain network in a triple bottom line context. *Int. J. Prod. Econ.* **2019**, *214*, 234–247. [CrossRef]
111. Mohebalizadeh, M.; Hafezalkotob, A. Modeling sustainable supply chain management problem with fuzzy demand based on multi-criteria decision-making methods. *Int. J. Ind. Syst. Eng.* **2018**, *30*, 267–297. [CrossRef]

112. Musavi, M.; Bozorgi-Amiri, A. A multi-objective sustainable hub location-scheduling problem for perishable food supply chain. *Comput. Ind. Eng.* **2017**, *113*, 766–778. [CrossRef]
113. Park, K.; Okudan Kremer, G.E.; Ma, J. A regional information-based multi-attribute and multi-objective decision-making approach for sustainable supplier selection and order allocation. *J. Clean. Prod.* **2018**, *187*, 590–604. [CrossRef]
114. Pourjavad, E.; Mayorga, R.V. Optimization of a sustainable closed loop supply chain network design under uncertainty using multi-objective evolutionary algorithms. *Adv. Prod. Eng. Manag.* **2018**, *13*, 216–228. [CrossRef]
115. Rabbani, M.; Saravi, N.A.; Farrokhi-Asl, H.; Lim, S.F.W.T.; Tahaei, Z. Developing a sustainable supply chain optimization model for switchgrass-based bioenergy production: A case study. *J. Clean. Prod.* **2018**, *200*, 827–843. [CrossRef]
116. Resat, H.G.; Turkay, M. A discrete-continuous optimization approach for the design and operation of synchromodal transportation networks. *Comput. Ind. Eng.* **2019**, *130*, 512–525. [CrossRef]
117. Reza, E.R.; Sohanian, M. A multi-objective optimization model for sustainable supply chain network with using genetic algorithm. *J. Model. Manag.* **2021**, *16*, 714–727. [CrossRef]
118. Rohmer, S.U.K.; Gerdessen, J.C.; Claassen, G.D.H. Sustainable supply chain design in the food system with dietary considerations: A multi-objective analysis. *Eur. J. Oper. Res.* **2019**, *273*, 1149–1164. [CrossRef]
119. Sahebjamnia, N.; Fathollahi-Fard, A.M.; Hajiaghaei-Keshteli, M. Sustainable tire closed-loop supply chain network design: Hybrid metaheuristic algorithms for large-scale networks. *J. Clean. Prod.* **2018**, *196*, 273–296. [CrossRef]
120. Samadi, A.; Mehranfar, N.; Fathollahi Fard, A.M.; Hajiaghaei-Keshteli, M. Heuristic-based metaheuristics to address a sustainable supply chain network design problem. *J. Ind. Prod. Eng.* **2018**, *35*, 102–117. [CrossRef]
121. Sepehri, M.; Sazvar, Z. Multi-objective sustainable supply chain with deteriorating products and transportation options under uncertain demand and backorder. *Sci. Iran.* **2016**, *23*, 2977–2994. [CrossRef]
122. Souza, V.D.; Bloemhof-Ruwaard, J.; Borsato, M. Exploring ecosystem network analysis to balance resilience and performance in sustainable supply chain design. *Int. J. Adv. Oper. Manag.* **2019**, *11*, 26–45. [CrossRef]
123. Taheri-Moghadam, A.; Razmi, J.; Baki, M.F. Designing and planning a sustainable supply chain network considering economic aspects, environmental impact, fixed job opportunities and customer service level. *Int. J. Process Manag. Benchmark.* **2019**, *9*, 73–100. [CrossRef]
124. Tautenhain, C.P.S.; Barbosa-Povoa, A.P.; Nascimento, M.C.V. A multi-objective matheuristic for designing and planning sustainable supply chains. *Comput. Ind. Eng.* **2019**, *135*, 1203–1223. [CrossRef]
125. Tirkolaee, E.B.; Goli, A.; Faridnia, A.; Soltani, M.; Weber, G.-W. Multi-objective optimization for the reliable pollution-routing problem with cross-dock selection using Pareto-based algorithms. *J. Clean. Prod.* **2020**, *276*, 122927. [CrossRef]
126. Tsao, Y.-C.; Thanh, V.-V.; Lu, J.-C.; Yu, V. Designing sustainable supply chain networks under uncertain environments: Fuzzy multi-objective programming. *J. Clean. Prod.* **2018**, *174*, 1550–1565. [CrossRef]
127. Vafaeenezhad, T.; Tavakkoli-Moghaddam, R.; Cheikhrouhou, N. Multi-objective mathematical modeling for sustainable supply chain management in the paper industry. *Comput. Ind. Eng.* **2019**, *135*, 1092–1102. [CrossRef]
128. Validi, S.; Bhattacharya, A.; Byrne, P.J. Sustainable distribution system design: A two-phase DoE-guided meta-heuristic solution approach for a three-echelon bi-objective AHP-integrated location-routing model. *Ann. Oper. Res.* **2018**, *290*, 191–222. [CrossRef]
129. Validi, S.; Bhattacharya, A.; Byrne, P.J. A case analysis of a sustainable food supply chain distribution system—A multi-objective approach. *Int. J. Prod. Econ.* **2014**, *152*, 71–87. [CrossRef]
130. Wang, F.; Lai, X.; Shi, N. A multi-objective optimization for green supply chain network design. *Decis. Support Syst.* **2011**, *51*, 262–269. [CrossRef]
131. Xifeng, T.; Ji, Z.; Peng, X. A multi-objective optimization model for sustainable logistics facility location. *Transp. Res. Part D Transp. Environ.* **2013**, *22*, 45–48. [CrossRef]
132. Yeh, W.-C.; Chuang, M.-C. Using multi-objective genetic algorithm for partner selection in green supply chain problems. *Expert Syst. Appl.* **2011**, *38*, 4244–4253. [CrossRef]
133. You, F.; Tao, L.; Graziano, D.J.; Snyder, S.W. Optimal design of sustainable cellulosic biofuel supply chains: Multi-objective optimization coupled with life cycle assessment and input–output analysis. *AIChE J.* **2012**, *58*, 1157–1180. [CrossRef]
134. Zarei, J.; Amin-Naseri, M.R.; Fakehi Khorasani, A.H.; Kashan, A.H. A sustainable multi-objective framework for designing and planning the supply chain of natural gas components. *J. Clean. Prod.* **2020**, *259*, 120649. [CrossRef]
135. Zhalechian, M.; Tavakkoli-Moghaddam, R.; Rahimi, Y.; Jolai, F. An interactive possibilistic programming approach for a multi-objective hub location problem: Economic and environmental design. *Appl. Soft Comput.* **2017**, *52*, 699–713. [CrossRef]
136. Zhalechian, M.; Tavakkoli-Moghaddam, R.; Zahiri, B.; Mohammadi, M. Sustainable design of a closed-loop location-routing-inventory supply chain network under mixed uncertainty. *Transp. Res. Part E Logist. Transp. Rev.* **2016**, *89*, 182–214. [CrossRef]
137. Zhang, S.; Lee, C.K.M.; Wu, K.; Choy, K.L. Multi-objective optimization for sustainable supply chain network design considering multiple distribution channels. *Expert Syst. Appl.* **2016**, *65*, 87–99. [CrossRef]
138. Zhang, Q.; Shah, N.; Wassick, J.; Helling, R.; van Egerschot, P. Sustainable supply chain optimisation: An industrial case study. *Comput. Ind. Eng.* **2014**, *74*, 68–83. [CrossRef]