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A Perspective on Supplier Selection and Order Allocation: Literature Review

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Abstract: Purchasing and procurement managers should make informed decisions in selecting materials at the right time, in sufficient quantities, and at affordable prices. Supplier selection and order allocation (SSOA) is a vital aspect of purchasing and procurement processes. In this research, the techniques and decision-making methods used in SSOA from peer-reviewed journals published from 2021 to 2023 are examined. This research explores the publications through three major categories, including literature reviews (LR), deterministic optimization (DO) models, and uncertain optimization (UO) models. The related operations research techniques are also discussed. Furthermore, observations, conclusions, and suggestions for future studies are provided with details.

Keywords: supply chain management; multi-objective programming; supplier selection and order allocation; operations research



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1. Introduction

All around the world, companies rely on procurement, logistics, and supplier selection and order allocation (SSOA) to help their organizations run successfully. As such, many research studies have been conducted on various ways to best utilize the resources in a supply chain. While many papers have been published on supplier selection or order allocation individually, few research papers conjointly cover SSOA. The main research question in this paper is: What are the recent techniques and trends in the supplier selection and order allocation field? This unique literature review summarizes 43 papers published from 2021 to 2023 covering SSOA and its applications. This period was chosen because other literature reviews have covered the papers in this field up to 2020. The small volume of papers found further emphasizes the need for increased research, as there is a deficit in the number of papers incorporating quantitative and qualitative criteria in the evaluation of supply chain suppliers and their uncertain environments (Hu et al. 2022). The papers in this literature review paper have been retrieved using databases and websites such as Taylor and Francis, Google Scholar, ScienceDirect, Scopus, and Web of Science. ‘Supplier selection and order allocation’ is the main keyword used to find the related papers in this study. SSOA involves optimization models that help influence decisions in an organization, usually for maximizing profit, minimizing costs, and increasing efficiency (Bai et al. 2022).

Various multi-criteria decision-making (MCDM) methods like data envelopment analysis (DEA), fuzzy analytical hierarchy process (FAHP), and best–worst method (BWM) are used to determine the priority and usefulness of a decision in the supply chain. These techniques can be applied in various industries, such as agriculture, food and beverage, green supply chain, textile, manufacturing, and automotive. Common sources of uncertainty in SSOA may include demand, cost, supplier, availability, delivery, and quality (defect rate).

Given the ongoing climate change crisis, individuals, industries, and countries around the world are committed to achieving carbon neutrality and lessening the effects of an-

thropogenic activities (Bai et al. 2022). The focus of more recent SSOA papers has been on green supply chains, with multi-objective models including equations for reducing carbon emissions. In a constantly changing environment, many companies feel pressure to transition their strategies to incorporate a circular economy (CE) in their supply chains (Mirzaee et al. 2023). Due to this, procurement of resources focuses on the ability to recycle, refurbish, and remanufacture. In addition, recent socio-economic, political, and environmental factors have incentivized more research on the effects of natural calamities on uncertain parameters; the effects of COVID-19, and the higher occurrence of natural disasters like floods and earthquakes affect delivery rates and supplier availability (Ali and Zhang 2023). Natural disasters, bankruptcies, and equipment failures are also external factors affecting the supply chain and the related SSOA (Hosseini et al. 2022).

This paper will continue to discuss these fundamental ideas and will further elaborate on the types of models and solution methods to tackle SSOA problems. This paper has several research contributions. Unlike other literature review papers in this field, new papers (2021 to 2023) are considered and analyzed in this study. In addition, the related operations research techniques are categorized and discussed in detail. Another research contribution of this paper is providing unique observations and future research directions in the field of supplier selection and order allocation. Section 2 contains the taxonomy and classification, such as literature reviews and deterministic and uncertain optimization models. Then, Section 3 discusses key observations. Section 4 provides conclusions and suggestions for future avenues of research.

2. Organization of the Related Literature

In this research, papers about supplier selection and order allocation have been collected using databases and websites such as Taylor and Francis, Google Scholar, ScienceDirect, Scopus, and Web of Science. Two components are used to classify the publications. The initial component is the problem category, and the secondary component is the operations research techniques. This classification is helpful for analyzing SSOA problems based on qualitative and quantitative aspects.

2.1. Problem Category

The problem categories include the following: deterministic optimization (DO) models, uncertain optimization (UO) models, and literature reviews (LR). In Table 1, the classified papers are shown.

Table 1. References for each problem category.

Problem Category	References
Literature Reviews (LR) (6)	Araújo et al. (2023); Hu et al. (2022); Jamalnia et al. (2022); Masudin et al. (2022); de Oliveira et al. (2023); Spyridonidou and Vagiona (2023)
Deterministic Optimization (DO) models (13)	Ahmad et al. (2022); Alejo-Reyes et al. (2021); Bai et al. (2022); Beiki et al. (2021); Chauhan et al. (2023); Dobos and Vörösmarty (2021); Esmaili-Najafabadi et al. (2021); Estes et al. (2023); Mohammed et al. (2021); Sun et al. (2022); Ventura et al. (2021); Yousefi et al. (2021); Zarelab et al. (2022)
Uncertain Optimization UO) models (24)	Ali and Zhang (2023); Arabsheybani and Arshadi (2021); Ebrahim Qazvini et al. (2021); Feng et al. (2022); Firouzi and Jadidi (2021); Goodarzi et al. (2022); Hamdi et al. (2023); Hosseini et al. (2022); Islam et al. (2023); Islam et al. (2022); Islam et al. (2021); Kaur and Singh (2021); Liaqait et al. (2022); Liu and Li (2021); Mirzaee et al. (2023); Mohammed et al. (2023); Nasr et al. (2021); Nayeri et al. (2023); Nguyen (2023); Sarfaraz et al. (2022); Sharifi et al. (2023); Wu et al. (2022); Yang and Peng (2023); Zhang et al. (2023)

2.1.1. Literature Reviews

Within the ScienceDirect (Elsevier) and Taylor and Francis databases, using the search term ‘supplier selection and order allocation’, there were 6 literature review papers published after 2020 that were found to be relevant to SSOA. The review from [de Oliveira et al. \(2023\)](#) combined multi-criteria decision analysis (MCDA), cluster analysis (CA), and data envelopment analysis (DEA) methods to see future trends and existing applications. They pulled publications from Scopus, ScienceDirect, and Web of Science to find the publications that were the most impactful. It was found that 490 articles (approximately 44%) combined DEA and MCDA methods. The review also stated that there was a growing trend in hybrid decision-making techniques in the banking, energy, and operations industries.

The review from [Araújo et al. \(2023\)](#) found a total of 29 articles that emphasized decision-making methodologies for rating technologies, such as using artificial intelligence, decision theory, and mathematical programming in the oil and gas industry. The paper reviewed a total of 29 articles with new findings of machine learning (ML) methods. For future research, the paper recommends exploring different collections of selection and ranking methods. An example can be merging different heuristic methods like using decision theory methods and fuzzy sets together to show their effectiveness.

[Spyridonidou and Vagiona \(2023\)](#) conducted a direct analysis and assessment of current location-scouting procedures for photovoltaics and other solar technologies. A total of 152 studies were identified based on the following criteria: (1) site selection methods, (2) exclusion criteria, (3) assessment criteria, (4) optimization modules, (5) geographic areas, (6) spatial analysis, (8) UV radiation estimation and analytics, (9) sensitivity analysis (and how it relates to location selection procedure), (10) community engagement planning approaches, (12) regulations and policies, (13) suitability records (linguistic or/and numeric), and rating procedures. The conclusions were that there was a high tendency to use the analytical hierarchy process (AHP) at the assessment stage. A suggestion was made to apply the entropy method more often at the assessment stage since it was more objective than AHP for determining the assessment criteria weights.

[Jamalnia et al. \(2022\)](#) reviewed the sustainability management of multi-tier supply chains. A total of 37 contingency variables were used to measure the effectiveness of sustainable supply chain approaches. The paper evaluated quantitative techniques such as mathematical optimization, simulation, and multi-criteria decision-making (MCDM) techniques. The techniques included case studies, surveys, hypothesis testing, and the Delphi method. The review focused on motivations for non-compliance to sustainability and the risks of ignoring sub-suppliers’ non-compliance to sustainability. It was found that suppliers’ non-compliance to sustainability is due to a lack of visibility and transparency from lower tiers of supply chains, and a lack of sustainable procedures, capabilities, and tools. Their conclusions stated that an in-depth analysis of the contingency variables showed that the variation in the contingency variables influences the effectiveness of each sustainable supply chain management strategy.

The review by [Hu et al. \(2022\)](#) summarizes past work on supplier selection as it relates to supplier selection in a disaster context. The review finds papers focusing on disaster operations management. It analyzed articles between 2010 and 2020. In this field, there was a significant research gap that showed a lack of qualitative standards and assessment of suppliers. They concluded that the models the authors proposed should incorporate more aspects related to the supply, demand, and transportation processes in uncertain environments. In addition, they should be tailored toward specific types of disasters. This is so that effective cooperation between aid organizations and suppliers can occur. The paper also emphasized focusing not only on the economic costs but on humanitarian-related operations as well.

[Masudin et al. \(2022\)](#) performed a bibliometric review on green purchasing using supplier selection from papers published from 1992 to 2022. A total of 220 articles were studied, and it was found that green purchasing increased in frequency around 1994. The most noticeable instances of green procurement involve an effective SSOA strategy that is

sustainable, increases efficiency, and saves costs. In recent years, these factors have played a role in corporate competition and the overall role of green supply chain management. It has been increasingly attracting researcher's interest, given the peak of 27 articles published in 2021. There is specific interest in countries like China where a large part of the industry is in manufacturing, followed by India and then Iran.

2.1.2. Deterministic Optimization Models

This section covers DO models in SSOA. Various publications are discussed regarding the different types of applications, techniques, and common topics.

[Bai et al. \(2022\)](#) tested SSOA policies for the procurement of electric power supplies in China by building a multi-objective model. The paper aimed to set up an SSOA model that supported carbon neutrality and optimized cost and quality goals. The model was applied empirically and analyzed with case study information using a trading platform that gives access to joint supplier selection. With this model, various sourcing policies were able to be evaluated, but the trading platform considered was a simple one-sided market situation. In various real-life scenarios, a larger two-sided market scenario is likely to be involved. The future recommendations from this study suggest including more complex and detailed models alongside economic valuations and decision-support tools.

[Ahmad et al. \(2022\)](#) studied a two-echelon make-to-order SSOA problem from an Indian belt conveyor company. They looked at the bills of materials to determine the short-list of suppliers in each echelon and formulated a mixed-integer nonlinear programming (MINLP) model to determine how many manufacturers and part suppliers in the first and second echelons are required to meet the periodic demand. To ensure the robustness of the model, the Taguchi method of tolerance design (TMTD) was used. When the MINLP and TMTD were applied, the coefficient of variation of the objective function increased by 51%.

[Sun et al. \(2022\)](#) used a numerical experiment and created a MINLP and order-splitting model. This model was solved with a Knitro commercial package in MATLAB. The order-splitting model was designed based on chosen suppliers to maximize profit, and MINLP was used to determine the top suppliers and to find the reorder point and order-split quantities for each supply chain group. The findings showed how the models allowed for simultaneous consideration of decisions, future suppliers, and inventory management policies in a warehouse and N number of identical retailers.

[Esmaeili-Najafabadi et al. \(2021\)](#) used MINLP to create risk-neutral and risk-averse decision-making models. Value-at-risk (VaR), conditional value-at-risk (CVaR), and particle swarm optimization (PSO) were the risk assessment tools that were used to determine the models. The MINLP models considered local and regional disruption risks. Local disruption risks occur internally with the supplier (i.e., machine breakdown), while regional disruption risks happen in the same geographical region (natural hazard).

2.1.3. Uncertain Optimization Models

In this part, some papers that used UO models and applied related techniques are mentioned and the key ideas are highlighted. Each paper and its type of uncertainty variables are shown in Table 2.

The latest literature review by [Zhang et al. \(2023\)](#) focused on the disruption of collaborative manufacturing supply chains due to cyber attacks. SSOA is used to mitigate risks that may cause disruptions. The researchers collected indicators of cyber risk from suppliers and used the fuzzy analytical hierarchy process (FAHP) to calculate their risk level, followed by the technique for order preference by similarity to ideal solution (TOPSIS) to evaluate the cyber risk and determine their rankings by risk. A two-stage hybrid mixed-integer programming (MIP) was created to support decisions on the suppliers' order allocation and minimize supply chain costs. The first stage of decisions was based on predicted circumstances and no emergencies, while the second stage was based on unforeseen circumstances and emergencies. The conclusions of the application showed

that this model helped mitigate risks by offering a quantitative and theoretical basis for cyber risk evaluation, making a significant impact on supply chain management.

Table 2. The references and uncertainty sources.

Source of Uncertainty	References
Availability/Selection	Firouzi and Jadidi (2021) ; Feng et al. (2022)
Cost	Mirzaee et al. (2023) ; Mohammed et al. (2023)
Supplier	Hosseini et al. (2022) ; Nasr et al. (2021)
Decision-makers	Wu et al. (2022)
Delivery time	Mirzaee et al. (2023) ; Nguyen (2023)
Demand	Arabsheybani and Arshadi (2021) ; Ebrahim Qazvini et al. (2021) ; Hamdi et al. (2023) ; Hosseini et al. (2022) ; Islam et al. (2022) ; Islam et al. (2023) ; Islam et al. (2021) ; Kaur and Singh (2021) ; Liaqait et al. (2022) ; Mirzaee et al. (2023) ; Goodarzi et al. (2022) ; Mohammed et al. (2023) ; Sharifi et al. (2023) ; Zhang et al. (2023)
	Liu and Li (2021) ; Nayeri et al. (2023) ; Yang and Peng (2023) ; Zhang et al. (2023)
Disruptions/Event-based	Arabsheybani and Arshadi (2021)
Processing time	Nguyen (2023)
Quality (defect rate)	Sharifi et al. (2023)
Prices	Ali and Zhang (2023)
Quantity discount	Mirzaee et al. (2023)
Resource utilization	

[Islam et al. \(2022\)](#) conducted a study on juice consumption from the Canadian juice industry. They developed a long-short-term memory (LSTM) network to form accurate predictions on juice consumption choices and help managers determine future demand. A fuzzy strengths, weaknesses, opportunities, threats (SWOT) analysis was done on the qualitative and quantitative factors of selecting suppliers. The results from the LSTM network and the fuzzy SWOT analysis were combined to develop a multi-objective model to help managers restructure their SSOA in their organization.

[Islam et al. \(2021\)](#) published another paper applying machine learning and optimization models to data from a Canadian food grain company. They looked at the demand for flour, rye flour, wheat, and rice from 11 different suppliers and geographic locations. The parameter of uncertainty for this model was the demand, which can negatively impact results if the data are not accurate. Two methods for measuring demand were implemented. The relational regressor chain (RRC) method was used to predict future demand and form comparisons with the auto-regressive integrated moving average technique and Holt's linear trend. The results show that RRC was more precise in forecasting demand. Then, a multi-objective programming model (MOPM) was formulated to determine the distributors and the order quantities for each distributor.

In the paper published by [Ali and Zhang \(2023\)](#), a real-life Pakistani textile industry was analyzed to verify the techniques and to determine the best SSOA based on neutral and risk-averse decision-making options. They considered quantity discounts with respect to foreign transportation risks (e.g., natural disasters and global pandemics). FAHP calculated the relative rates of the criteria, and then a multi-objective linear programming model (MOLPM) was created to reduce the delivery lateness rate, quality rejection rate, total procurement cost, foreign transportation risks, and carbon emissions from product procurement. Afterward, the model was converted using the fuzzy compromise programming technique to find SSOA companies that provided quantity discounts. The findings show that the suggested model and methodology are effective for managing data uncertainties compared to other existing SSOA approaches.

[Hosseini et al. \(2022\)](#) analyzed a composite products company within the aerospace industry. They used the BWM-evidential reasoning method to evaluate distributors under uncertainty and calculated their weights. A multi-objective mathematical model (MOMM) was used to measure the trade-off between the financial costs and the sustainability of the supply chain. The uncertainty being measured was the demand and availability of the supply. They mentioned equipment failures, natural disasters, and bankruptcies as the

factors affecting the availability of supply. These uncertainties were studied with a set of scenarios classified under three states: optimistic, pessimistic, and probabilistic. The second part used stochastic and dynamic programming to solve the MOMM. These results were measured against the results found from the Epsilon constraint method and the revised multi-choice goal programming technique. The findings showed that the proposed MOMM delivered faster and more accurate results.

2.2. Operations Research Techniques

The references in Table 3 are divided based on the operations research (optimization) techniques. Multiple authors adopted hybrid techniques in this area of study. Table 4 includes various types of objective functions that were collected from different publications.

Table 3. Sorting papers according to their operations research techniques.

Techniques	References
Analytical Hierarchical Process (AHP)	Mohammed et al. (2021) ; Nasr et al. (2021)
Analytical Network Process (ANP)	Nasr et al. (2021)
Backtracking Algorithm	Liu and Li (2021)
Bargaining Game	Yousefi et al. (2021)
Best–Worst Method (BWM)	Wu et al. (2022)
BWM-ER (Best–Worst Method-Evidential Reasoning)	Hosseini et al. (2022)
Bi-level Programming Model	Liu and Li (2021)
Bi-objective Mixed-Integer Programming	Yang and Peng (2023)
Chebyshev Multi-Choice Goal Programming with Utility Function (CMCGP-UF)	Nayeri et al. (2023)
Common Weights Model	Dobos and Vörösmarty (2021)
Conditional Value-at-Risk (CVaR)	Esmaeili-Najafabadi et al. (2021)
Differential Evolution	Alejo-Reyes et al. (2021)
Data Envelopment Analysis (DEA)	Dobos and Vörösmarty (2021) ; Kaur and Singh (2021) ; Yousefi et al. (2021)
Dynamic Programming	Hosseini et al. (2022) ; Nguyen (2023)
Economic Order Quantity (EOQ)	Ventura et al. (2021)
Fuzzy Analytical Hierarchy Process (FAHP)	Arabsheybani and Arshadi (2021) ; Ali and Zhang (2023) ; Ebrahim Qazvini et al. (2021) ; Kaur and Singh (2021) ; Zhang et al. (2023)
Fuzzy BWM	Goodarzi et al. (2022) ; Nasr et al. (2021)
Fuzzy Compromise Programming	Ali and Zhang (2023) ; Nguyen (2023)
Fuzzy-Delphi	Goodarzi et al. (2022)
Fuzzy Goal Programming	Nasr et al. (2021)
Fuzzy Multi-Objective Mixed-Integer Linear Programming	Liaqait et al. (2022) ; Mohammed et al. (2023)
Fuzzy Multi-Objective Optimization based on Ratio Analysis (MOORA)	Arabsheybani and Arshadi (2021)
Fuzzy Robust Stochastic (FRS) Optimization	Nayeri et al. (2023)
Fuzzy Sets Theory	Firouzi and Jadidi (2021) ; Sarfaraz et al. (2022)
Fuzzy Stochastic BWM	Nayeri et al. (2023)
Fuzzy Stochastic Goal Programming	Hamdi et al. (2023)
Fuzzy SWOT (Strengths, Weaknesses, Opportunities, Threats)	Islam et al. (2022)
Genetic Algorithm (GA)	Chauhan et al. (2023) ; Liu and Li (2021)

Table 3. Cont.

Techniques	References
Global Criterion Method (GCM)	Yousefi et al. (2021)
Gray Correlation TOPSIS (GC-TOPSIS)	Goodarzi et al. (2022)
Language Entropy Weight Method	Beiki et al. (2021)
Light-Gradient Boosted Machine (LGBM)	Islam et al. (2023)
Long-Short-Term Memory (LSTM)	Islam et al. (2022) ; Islam et al. (2023)
Mixed-Integer Linear Programming (MILP)	Feng et al. (2022) ; Islam et al. (2023) ; Nguyen (2023)
Mixed-Integer Nonlinear Programming (MINLP)	Ahmad et al. (2022) ; Alejo-Reyes et al. (2021) ; Esmaeili-Najafabadi et al. (2021) ; Sun et al. (2022) ; Ventura et al. (2021)
Mixed Integer Programming (MIP)	Chauhan et al. (2023) ; Firouzi and Jadidi (2021) ; Kaur and Singh (2021) ; Zhang et al. (2023)
Multi-Criteria Decision Making (MCDM)	Goodarzi et al. (2022)
Multi-Objective Evolutionary Algorithm based on Decomposition (MOEA/D)	Zaretalab et al. (2022)
Multi-Objective Linear Programming (MOLP)	Ali and Zhang (2023)
Multi-Objective Mixed-Integer Linear Programming (MOMILP)	Bai et al. (2022) ; Ebrahim Qazvini et al. (2021) ; Goodarzi et al. (2022) ; Islam et al. (2022) ; Nasr et al. (2021)
Multi-Objective Mixed-Integer Nonlinear Programming (MOMILP)	Yousefi et al. (2021)
Multi-Objective Optimization	Esteso et al. (2023)
Multi-Objective Programming (MOP)	Beiki et al. (2021) ; Islam et al. (2021) ; Mohammed et al. (2021)
Multi-Stage Decision-Making Framework	Nayeri et al. (2023)
Non-Dominated Sorting Genetic Algorithm Type II	Zaretalab et al. (2022)
Order Splitting	Sun et al. (2022)
Particle Swarm Optimisation (PSO)	Alejo-Reyes et al. (2021) ; Esmaeili-Najafabadi et al. (2021) ; Wu et al. (2022)
Polyhedral and Box Ambiguity Sets	Feng et al. (2022)
Principal Component Analysis (PCA)	Islam et al. (2023)
Product Family Configuration and Order Allocation (PCOA)	Liu and Li (2021)
Relational Regressor Chain	Islam et al. (2021)
Seasonal Autoregressive Integrated Moving Average (SARIMA)	Islam et al. (2023) ; Nayeri et al. (2023)
Shannon Entropy	Sarfaraz et al. (2022)
Stochastic Mixed-Integer Linear Programming	Islam et al. (2021)
Stochastic Programming	Hosseini et al. (2022) ; Sharifi et al. (2023)
Taguchi Loss Function (TLF)	Wu et al. (2022)
Taguchi Method of Tolerance Design (TMTD)	Ahmad et al. (2022)
Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)	Mohammed et al. (2021) ; Wu et al. (2022) ; Zhang et al. (2023)
Trapezoidal Fuzzy BWM	Sharifi et al. (2023)
Trapezoidal Fuzzy Numbers	Wu et al. (2022)
Two-stage Distributionally Robust (DR) Mean-CVaR model	Feng et al. (2022)
Value-at-Risk (VaR)	Esmaeili-Najafabadi et al. (2021)
Weight additive function	Firouzi and Jadidi (2021)

Table 4. Single-objective and multi-objective models.

Objective Functions	References
Single-objective	Min total cost for first and second echelon
	Ahmad et al. (2022)
	Min total cost per time unit (ordering, purchasing, inventory, transportation costs)
	Alejo-Reyes et al. (2021)
	Min cost of machining parts as per requirements (proportion and supplier)
	Chauhan et al. (2023)
	Max sum of inequalities
Multi-objective	Dobos and Vörösmarty (2021)
	Max expected total profit
	Sun et al. (2022)
	Max supply chain profit (cost per time unit, purchasing, ordering, inventory holding, and supplier managerial costs)
	Ventura et al. (2021)
	Min supply chain costs
	Zhang et al. (2023)
	(5) Min overall procurement costs, min number of defective items, min delivery lateness rate (from supplier location to buyer destination), min total greenhouse gas emissions, min overall foreign transportation risks
	Ali and Zhang (2023)
	(2) Max profit, max total value of supply chain resiliency
	Arabsheybani and Arshadi (2021)
	(4) Max purchasing quantity, min purchasing cost, min investment cost, carbon neutrality
	Bai et al. (2022)
	(3) Min total cost, min carbon emissions, max procurement value
	Beiki et al. (2021)
	(2) Min total costs of chain, max value of purchases from qualified suppliers
	Ebrahim Qazvini et al. (2021)
	(2) Min total annual expected supply chain costs (including annual expected costs of the buyer and annual expected cost of the suppliers), min CVaR
	Esmaeili-Najafabadi et al. (2021)
	(5) Max economic profits, min waste, unsatisfied demand, max sold crops and their freshness, min farmers' perception of economic injustice
	Esteso et al. (2023)
	(4) Cost of contracting main suppliers, cost of contracting backup suppliers, min sum of purchasing and transportation cost, worst-case mean-CVaR value of the second-stage cost
	Feng et al. (2022)
	(4) Min cost and late delivery, total monetary cost, number of defective units, number of units delivered late
	Firouzi and Jadidi (2021)
	(2) Max order value based on selected supplier's weights, max total value of purchase, min total cost (variable purchase cost, transport costs, order fixed costs, inventory control cost, and penalty costs)
	Goodarzi et al. (2022)
	Min cost (fixed cost, purchasing cost, and shortage cost), max sum of membership functions
	Hamdi et al. (2023)
	(2) Max total value of purchase (TVP), min total cost of purchase (TCP)
	Hosseini et al. (2022)
	(2) Min total cost (cost of different meat types, requisition costs, holding costs), max on-time delivery of meat
	Islam et al. (2023)
	(5) Min total cost (purchasing, holding, and ordering costs), max weight of suppliers, min supplier carbon footprint, max supplier rates of on-time delivery, min supplier defect rates
	Islam et al. (2022)
	(5) Min total cost, max on-time delivery, min damage rates, min carbon emissions
	Islam et al. (2021)

Table 4. Cont.

Objective Functions	References
(5) Max total output, min total cost of procurement (unit price, ordering cost, transportation, total risk, holding cost)	Kaur and Singh (2021)
(2) Max total value of purchase (TVP), min total cost of purchase (TCP)	Hosseini et al. (2022)
(2) Min total cost (cost of different meat types, requisition costs, holding costs), max on-time delivery of meat	Islam et al. (2023)
(5) Min total cost (purchasing, holding, and ordering costs), max weight of suppliers, min supplier carbon footprint, max supplier rates of on-time delivery, min supplier defect rates	Islam et al. (2022)
(5) Min total cost, max on-time delivery, min damage rates, min carbon emissions	Islam et al. (2021)
(5) Max total output, min total cost of procurement (unit price, ordering cost, transportation, total risk, holding cost)	Kaur and Singh (2021)
(5) Min cost (purchasing, ordering, inventory holding, transportation, transfer, and customs clearance cost), min total travel time, min carbon emission (i.e., from ship, rail, road), min noise pollution, max total value of sustainable purchasing	Liaqait et al. (2022)
(2) Min cost module instance, max lowest quantity of module instance	Liu and Li (2021)
(3) Min related costs (purchasing, transportation, operating costs), min transportation time, max g-resilient performance (purchasing value)	Mohammed et al. (2023)
(3) Min related costs, min environmental impact, max of resilience purchasing	Mohammed et al. (2021)
(4) Min total cost of chain, min undesired environmental effect, max employment created, min lost sales, max procurement value from sustainable suppliers	Nasr et al. (2021)
(4) Min total costs (fixed cost of supplier contract making, fixed cost for building manufacturing sites, fixed cost of using manufacturing technologies, procurement costs, production costs, shortage costs, extra capacity costs, transport costs), min greenhouse gas emissions from production and transport activities, max created jobs, max scores of suppliers	Nayeri et al. (2023)
(3) Min total cost (procurement cost, requisition cost, and holding cost), min total rejected material, min total raw material quantity from late delivery	Nguyen (2023)
(2) Min operator, max operator	Sarfaraz et al. (2022)
(4) Max total profit, max job opportunities, max supplier's sustainability, min carbon emissions	Sharifi et al. (2023)
(5) Min total cost, min total carbon emissions, min total social value, min total defect rate, min total supplier value	Wu et al. (2022)
(3) Max production capacity, max and min estimated cost and estimated service level	Yang and Peng (2023)
(2) Min total supply chain annual cost, max overall supplier efficiency	Yousefi et al. (2021)
(2) Min total cost (technical activities, planning activities, procurement costs), max system availabilities	Zaretalab et al. (2022)

3. Observations

In this section, recommendations and observations are made based on the 43 collected publications.

3.1. The Most Popular Category

Three elements were categorized for optimization models in the papers related to SSOA: LR, DO, and UO. Based on Figure 1, the most popular domain was UO, taking up 56% of the distribution of papers, followed by DO and LR at 30% and 14%, respectively.

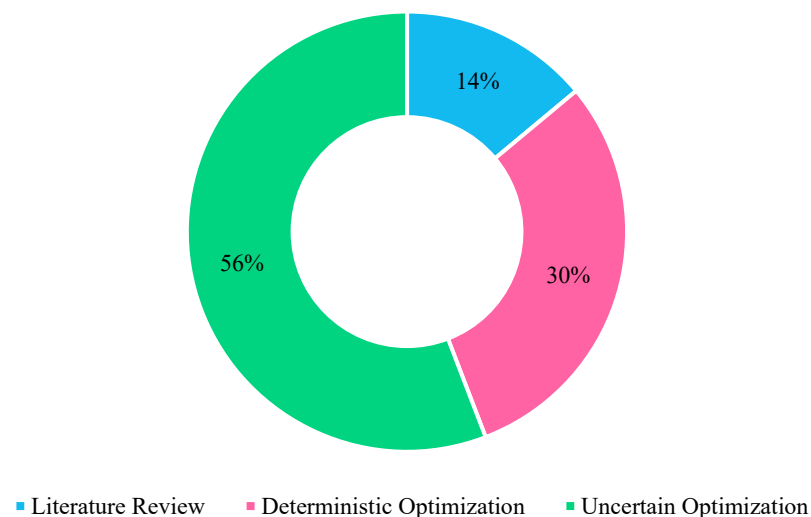


Figure 1. Distribution of domain categories.

3.2. The Most Popular Source of Uncertainty

Based on the results, the greatest source of uncertainty was demand. A total of 32% of the selected papers considered demand as an uncertainty source. This parameter was commonly used to determine the demand of customers to procure supplies. A few examples include the demand for juice beverages (Islam et al. 2022), part suppliers in the manufacturing industry (Ahmad et al. 2022), demand for food produce (Islam et al. 2021), and demand for supplier parts in the aerospace industry (Hosseini et al. 2022).

3.3. Common Objective Functions

Referring to Table 4, the most popular single-objective functions involve models related to minimizing costs and maximizing profit, while multi-objective models have many objectives related to minimizing costs and reducing carbon emissions or negative environmental impacts.

3.4. Most and Least Popular Techniques

Based on Table 3, the commonly used methods for solving optimization models were various types of mixed-integer linear programming (MILP) and mixed-integer nonlinear programming (MINLP). A common linear programming technique was data envelopment analysis (DEA), which evaluates suppliers based on selected criteria (Kaur and Singh 2021). Multiple papers also employed the techniques of the analytical hierarchy process (AHP) or fuzzy analytical hierarchy process (FAHP) to calculate weights, assign importance to supplier selection criteria, and analyze factors for decision-making attitudes (Ali and Zhang 2023). TOPSIS was used in conjunction with AHP/FAHP to verify and reinforce the criteria defined in that method. Another popular MCDM was the fuzzy and non-fuzzy best-worst method (BWM) mentioned in papers by Nayeri et al. (2023) and Wu et al. (2022). Nasr et al. (2021) used BWM to select suppliers based on factors such as environmental, social, economic, and circular criteria. Another used technique is particle swarm optimization

(PSO), employed by [Wu et al. \(2022\)](#), [Esmaeili-Najafabadi et al. \(2021\)](#), and [Alejo-Reyes et al. \(2021\)](#). Less popular methods included by [Nayeri et al. \(2023\)](#) used the seasonal autoregressive integrated moving average (SARIMA) and the utility function (CMCGP-UF) technique with Chebyshev multi-choice goal programming.

3.5. Popular Applications

Table 5 classifies the papers based on the applications of the techniques. Most papers applied their objective functions to a general SSOA application, but the second-highest applications were both in the green supply chain industry and the material/equipment manufacturing industry. The green supply chain industry included applications of models that incorporated reducing carbon footprint in their supply chain. The material/equipment manufacturing industry includes papers that cover manufacturing industries such as steel, medical equipment, and AC units.

Table 5. Industry applications of the models.

Applications	References
Aerospace industry	Hosseini et al. (2022)
Agriculture industry	Esteso et al. (2023) ; Islam et al. (2023) ; Sharifi et al. (2023)
Automotive industry	Beiki et al. (2021) ; Kaur and Singh (2021) ; Chauhan et al. (2023)
Energy industry	Bai et al. (2022) ; Spyridonidou and Vagiona (2023)
Food and beverage industry	Arabsheybani and Arshadi (2021) ; Islam et al. (2022) ; Islam et al. (2021) ; Mohammed et al. (2023)
General supply chain industry	Alejo-Reyes et al. (2021) ; Araújo et al. (2023) ; Esmaeili-Najafabadi et al. (2021) ; Feng et al. (2022) ; Firouzi and Jadidi (2021) ; Goodarzi et al. (2022) ; Hamdi et al. (2023) ; Nayeri et al. (2023) ; de Oliveira et al. (2023) ; Ventura et al. (2021) ; Yousefi et al. (2021) ; Zaretab et al. (2022)
Green/environmental supply chain management	Dobos and Vörösmarty (2021) ; Ebrahim Qazvini et al. (2021) ; Hu et al. (2022) ; Jamalnia et al. (2022) ; Mirzaee et al. (2023)
Material/equipment manufacturing industry	Ahmad et al. (2022) ; Liaqait et al. (2022) ; Liu and Li (2021) ; Mohammed et al. (2021) ; Nguyen (2023) ; Wu et al. (2022) ; Yang and Peng (2023) ; Zhang et al. (2023)
Oil industry	Sarfaraz et al. (2022)
Textile industry	Ali and Zhang (2023) ; Nasr et al. (2021)

3.6. The List of Publications

Table 6 includes the list of publications and the names of their respective journals. Some common journals include Computers & Industrial Engineering, International Journal of Production Economics, and Expert Systems with Applications.

Table 6. The publications list.

Journal	Number of Papers			
	LR	DO	UO	Total
Applied Mathematical Modelling		1		1
Annals of Operations Research		1		1
Computers & Industrial Engineering		3	2	5
Computers & Operations Research		1		1
Cogent Engineering	1			1
Decision Analytics Journal	1		1	2
Energy Reports	1			1
Engineering Applications of Artificial Intelligence			1	1
Engineering Optimization			1	1
Expert Systems with Applications		1	4	5
Geoenergy Science and Engineering	1			1
Information Systems and Operational Research			1	1
International Journal of Management Science and Engineering Management			1	1
International Journal of Production Economics	1	1	2	4
International Journal of Production Research			3	3
International Journal of Systems Science			1	1
Journal of Cleaner Production			1	1
Journal of Decision Systems		1	1	2
Journal of Engineering Design			1	1
Journal of Industrial and Production Engineering		1	2	3
Managerial and Decision Economics		1		1
Operational Research		1		1
Reliability Engineering and System Safety		1		1
Scientia Iranica			1	1
Socio-Economic Planning Sciences	1			1
Sustainable Production and Consumption			1	1
Total	6	13	24	43

3.7. Classification of the Articles Based on Year

Table 7 presents the grouping of the publications by the year of publication and their respective domain. For this review, papers published after 2020 were included. The number of articles reviewed is based on the number of articles collected at the time of this publication.

Table 7. Grouping of the papers by the year.

Number of Articles				
Year	LR	DO	UO	Total
2021	0	7	7	14
2022	3	4	7	14
2023	3	2	10	15
Total	6	13	24	43

4. Discussion and Conclusions

Overall, this paper addresses LR, DO, and UO models related to supplier selection and order allocation. A total of 43 papers published from 2021 to 2023 were collected. The papers were classified based on their operation research methods. This paper has several research contributions. New papers were considered and analyzed in this study. In addition, the related operations research techniques were categorized and discussed in detail.

Observations on the most popular methods show the use of MILP and MINLP to solve DO and UO models. FAHP/AHP were the common decision-making techniques for determining specific criteria for SSOA. Recent publications have significantly modeled more multi-objective functions than single-objective ones; many of the multi-objective models include functions that maximize profit, minimize costs, and minimize carbon emissions. This can be due to a rise in company interest to save costs and government incentives, policies, and attitudes to reduce carbon footprint (Bai et al. 2022). This point also becomes evident when there was a significant prevalence of green supply chain applications followed by an expected high number of SSOA application uses in the manufacturing industry. For future study, a few recommendations on the topics that should be explored are as follows:

- (i) Simultaneously consider multiple sources of uncertainty in the objective function. Many papers focused on one factor for uncertainty and used that as a basis to help determine their fuzzy or stochastic model. In real cases, multiple factors should be measured under uncertainty and incorporated into the optimization models.
- (ii) Increased research on SSOA in the healthcare industry other than how it relates to manufacturing equipment. Sudden events like COVID-19 show how disruptive events can significantly impact the supply of medical supplies and staff to meet in-hospital care. SSOA can be used to improve existing hospital systems that can prevent short staffing and insufficient medical supply in predictable and unpredictable situations.
- (iii) Overall, more research should be conducted in the field of supplier selection and as a result, extra literature reviews can be written. Many papers cover the topics on solely supplier selection or order allocation. Increasing studies on SSOA can provide a more comprehensive view of the topic of SSOA and the implementation of its techniques in real-world situations.
- (iv) There are several future opportunities to explore the applications of data science techniques, such as machine learning methods in SSOA. For instance, neural networks can be combined (e.g., Yang et al. (2008a, 2008b); Zhang et al. 2005).

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