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ORIGINAL ARTICLE

Supplier selection and order allocation: a literature review

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Abstract

The goals of procurement managers in every industry usually are acquiring the right materials at the right time, at the right prices and quantities. To achieve these goals, the best suppliers should be selected. Supplier selection and order allocation have been studied extensively in the past. In this paper, we review the peer-reviewed journal publications in this area. The taxonomy in this research includes problem domain and operations research techniques. The problem domain is examined in three subcategories including Literature Reviews (LR), Deterministic Optimization (DO) models, and Uncertain Optimization (UO) models. Then, observations, recommendations, and future research directions in the field of supplier selection and order allocation are discussed.

Keywords Supplier selection · Supply chain management · Order allocation · Optimization · Decision-making

1 Introduction

Purchasing and procurements are important activities in every organization. Supplier Selection and Order Allocation (SSOA) are prominent elements of purchasing and procurement (Bohner and Minner 2017). Both qualitative and quantitative factors such as quality, cost, and delivery time should be considered in the supplier selection problem (Arabsheybani et al. 2018). Therefore, supplier selection is a Multi-Criteria Decision-Making (MCDM) problem (Cheraghalipour and Farsad 2018; Moheb-Alizadeh and Handfield 2019).

Cost saving and minimization of risks can be achieved by using suitable supplier selection methods (Çebi and Otay 2016; Arabsheybani et al. 2018). Some authors have combined supplier selection and order allocation together to solve these two problems simultaneously (e.g., Babbar and Amin 2018). Supplier selection and order allocation are very important in green supply chain management considering sustainability and environmental factors (Hamdan and Cheaitou 2017a). Sustainable supplier selection encompasses cost, environmental, and social criteria and supplier's performance history (Hamdan and Cheaitou 2017b; Ghadimi et al. 2018).

Supplier selection is a strategic process in organizations, and plays a critical role in the success of them (Razaei et al. 2020). Offering quantity discount is an important feature in the selection of the best suppliers. Therefore, each company can achieve low cost while allocating large volume orders to the suppliers (Alegoz and Yapicioglu 2019).

In this paper, the related peer-reviewed journal papers have been found and reviewed via search in globally recognised databases such as ScienceDirect (Elsevier), Taylor and Francis, and Google Scholar. The main keyword is "supplier selection and order allocation" which is used to search related papers published between 2015 and 2020. As a result, 92 articles are analysed. The majority of other literature review papers in this field just have focused on supplier selection, and order allocation has been ignored. In addition, they have been written some years ago, and there is a need to have an updated literature review paper about supplier selection and order allocation. The structure of our paper is new among those literature review papers. Considering uncertainty in the reviewed papers and reviewing the applied operations research techniques are other main characteristics of our paper.

The other parts of this paper are as follows. The taxonomy and classification of the literature are provided in Section 2. Then, some observations and discussions are mentioned in Section 3. In addition, the related conclusions and future research avenues are provided in Section 4.

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2 Taxonomy

Two dimensions are utilized in this review paper to categorize the papers. The first one is the problem domain. Besides, the second one is the operations research (optimization) methods. This classification is useful to analyze the supplier selection and order allocation problem based on both conceptual and mathematical viewpoints.

2.1 Problem domain

The problem domain comprises three subsections: Literature Reviews (LR), Deterministic Optimization (DO) models, and Uncertain Optimization (UO) models. Table 1 includes the related papers.

2.1.1 Literature reviews

Some authors have published literature review papers in the field of supplier selection and order allocation. Govindan et al. (2015) reviewed green purchasing and green supplier selection process of some articles published between 1997 and 2011. They found that Analytic Hierarchy Process (AHP) is the most popular MCDM method for assessing green suppliers. In addition, Fuzzy AHP is very popular in the environmental management systems. Yildiz and Yayla (2015) reviewed 91 articles that have been published between 2001 and 2014 about supplier selection. They stated that quality and cost are the most significant criteria in the supplier selection problem.

Wetzstein et al. (2016) reviewed several papers in the supplier selection field published between 1990 and 2015. They mentioned that there are future research avenues in considering green and sustainable factors. Karsak and Dursun (2016) reviewed 149 articles published between 2001 and 2013 concentrating nondeterministic analytical methods (i.e., stochastic/fuzzy) under imprecise data.

Simić et al. (2017) examined the last 50 years (50th anniversary of fuzzy sets theory established by Lotfiali Askar Zadeh in 1965) of articles in supplier selection and evaluation that are based on fuzzy sets theory, fuzzy models, and fuzzy hybridization. The authors combined individual and integrated approaches to effectively review the fuzzy supplier selection methods. The authors selected 54 papers published in the reputable journals.

Alkahtani and Kaid (2018) studied some journal papers published between 1995 and 2018 focusing on supplier selection. They provided information about the trends, the research gaps, and the selection criteria in the supplier selection field. Ocampo et al. (2018) reviewed 240 articles from peer-reviewed journals published between 2006 and 2016 focusing on the applications of different approaches for supplier selection and evaluation which include individual and hybrid methods. The authors indicated that the novel methods in the literature include uncertainty, risk analysis, and sustainability factors.

Aouadni et al. (2019) reviewed 270 articles published between 2000 and 2017 about supplier selection and order allocation. In their paper, about 17 %, 9 %, and 7 % of the reviewed papers were about AHP, TOPSIS, and ANP methods, respectively. They mentioned that

Table 1 Problem domain and related references

Problem domain	References
Literature reviews (LR) (9)	Aouadni et al. (2019), Alkahtani and Kaid (2018), Chai and Ngai (2019), Govidan et al. (2015), Karsak and Dursun (2016), Ocampo et al. (2018), Simić et al. (2017), Yildiz and Yayla (2015), Wetzstein et al. (2016)
Deterministic optimization models (DO) (16)	Arabzad et al. (2015), Bohner and Minner (2017), Cheraghalipour and Farsad (2018), Rao and Rao (2018) Hamdan and Jarndal (2017); Hamdan and Cheaitou (2017a); Jadidi et al. (2015); Jain et al. (2015); Mohammaditabar and Ghodsypour (2016); Esmaeili-Najafabadi et al. (2019); Nazeri et al. (2019); Park et al. (2018); Scott et al. (2015), Nourmohamadi Shalke et al. (2018), Sodenkamp et al. (2016), Wang et al. (2020)
Uncertain optimization models (UO) (67)	Alegoz and Yapicioglu (2019), Moheb-Alizadeh and Handfield (2019), Arabsheybani et al. (2018), Aggarwal et al. (2018), Ahmadi and Amin (2019), Moheb-Alizadeh et al. (2017), Almasi et al. (2019), Azadnia and Ghadimi (2018), Azadnia (2016), Moheb-Alizadeh and Handfield (2018), Azadnia et al. (2015), Babbar and Amin (2018), Beauchamp et al. (2015), Bektur (2020), Bodaghi et al. (2018) , Cui et al. (2015) , Çebi and Otay (2016); Dotoli et al. (2015); Duan et al. (2019); Feng and Gong (2020); Fu et al. (2016); Ghadimi et al. (2018); Ghorabaee et al. (2017); Gören (2018); Govindan and Sivakumar (2016); Govindan et al. (2020); Gupta et al. (2016); Hajikhani et al. (2018); Hamdan and Cheaitou (2015, 2017b); Hamdi et al. (2016); Hasan et al. (2020)), Hosseini and Nezhad (2019), Hosseini et al. (2019), Hu et al. (2016), Hu et al. (2018), Jia et al. (2020), Kaur and Singh (2020), Kazemi et al. (2015), Kellner and Utz (2019), Khoshfetrat et al. (2019), Kilici and Yalcin (2020) Kumar et al. (2017); Kuo et al. (2015); Lee et al. (2015); Lo et al. (2018); Meena and Sarmah (2016); Memon et al. (2015); Mirzaee et al. (2018); Moghaddam (2015a, b); Mohammed et al. (2018, 2019); Noori-Daryan et al. (2019); Pazhani et al. (2016), Razaei et al. (2020), Rosyidi et al. (2016), Sawik (2016), Shadkam and Bijari (2017), Suprasongsin et al. (2019), Talebi and Jafari (2015), Tirkolaee et al. (2020), Torabi et al. (2015), Tsai (2015), Vahidi et al. (2018), Prasanna Venkatesan and Goh (2016), Wong (2020)

Table 2 Deterministic optimization models according to multiple elements

Multiple elements	References
Parts	Arabzad et al. (2015), Cheraghalipour and Farsad (2018), Jain et al. (2015), Park et al. (2018), Nourmohamadi Shalke et al. (2018)
Products	Bohner and Minner (2017), Hamdan and Jarndal (2017), Jadidi et al. (2015), Esmaeili-Najafabadi et al. (2019), Nazeri et al. (2019), Scott et al. (2015), Wang et al. (2020).
Periods	Cheraghalipour and Farsad (2018); Hamdan and Jarndal (2017); Hamdan and Cheaitou (2017a); Jain et al. (2015); Nazeri et al. (2019), Nourmohamadi Shalke et al. (2018)
Suppliers	Arabzad et al. (2015), Bohner and Minner (2017), Cheraghalipour and Farsad (2018), Rao and Rao (2018) Hamdan and Jarndal (2017); Hamdan and Cheaitou (2017a); Jadidi et al. (2015); Jain et al. (2015); Mohammaditabar and Ghodsypour (2016); Esmaeili-Najafabadi et al. (2019); Nazeri et al. (2019); Park et al. (2018); Scott et al. (2015), Nourmohamadi Shalke et al. (2018), Sodenkamp et al. (2016), Wang et al. (2020)
Scenarios	Cheraghalipour and Farsad (2018); Hamdan and Cheaitou (2017a); Esmaeili-Najafabadi et al. (2019); Wang et al. (2020)

fuzzy multiple-objective programming is a popular method in this area. In addition, some papers have used genetic algorithm to determine the orders. Chai and Ngai (2019) reviewed SSOA papers published among 2013 and 2018. They brought to light that MCDM methods and optimization are the most popular techniques for supplier selection and order allocation.

2.1.2 Deterministic optimization models

In this part, deterministic optimization methods for supplier selection and order allocation are discussed. We provide some information about the publications that have received several citations. Other publications are written and mentioned in the following table.

Sodenkamp et al. (2016) used a novel approach (trade-off mechanism) because the current multi-objective methods were not capable to create positive and negative performance synergies. Bohner and Minner (2017) disscussed a mixed-integer linear programming model for solving the intricate issue of supplier selection by having a backup supplier who is not cost effective. However, it minimizes the risk related to the stock out condition. Nourmohamadi Shalke et al. (2018) studied purchasing decision-making through a TOPSIS method and a multi-choice goal programming model. In addition, they developed rough set theory and grey system. Moheb-Alizadeh and Handfield (2019) constructed a multi-objective optimization model for a manufacturer of automobile transmission systems for order allocation considering minimization of the CO_2 emissions.

Nazeri et al. (2019) proposed a multi-objective model to test effective ranking in military's SSOA for outsourcing of hazardous materials. Wang et al. (2020) implemented carbon emission trading schemes using analytic network process-integer programming model and stipulated approach. They minimized cost and carbon emissions. The deterministic optimization models of supplier selection and order allocation are classified in Table 2 according to the multiple elements (sets) including parts, products, periods, suppliers, and scenarios. In some papers, it has been assumed that the parts can be assembled to make a product. Products usually represent the final products that can be sold in the markets. In addition, some papers have considered different periods such as months in their mathematical models. Besides, multiple potential suppliers have been considered by some authors. Furthermore, some authors have assumed different scenarios to analyze the problem under uncertainty.

2.1.3 Uncertain optimization models

In this part, we mention some important publications that have developed uncertain optimization models and have received several citations. Other papers are mentioned in the following two tables.

The paper of Azadnia et al. (2015) has been cited by more than 200 papers in Google Scholar. In this article, the authors introduced sustainable supplier selection by adding occupational health and safety management system. Those sub-criteria are important components in sustainable supplier criteria. The authors utilized a fuzzy AHP and a rule based weighted fuzzy approach. They selected a sustainable supplier using a multi-product lot sizing order model. Çebi and Otay (2016) proposed a two-stage fuzzy method including fuzzy MULTIMOORA and fuzzy goal programming for the supplier selection and order allocation problem. They considered green supplier selection in the beverage industry. Govindan and Sivakumar (2016) studied the selection of the best supplier by minimizing the greenhouse gas emissions

Table 3 Uncertain optimization models according to multiple elements

Multiple elements	References
Parts (item)	Arabsheybani et al. (2018), Moheb-Alizadeh et al. (2017), Beauchamp et al. (2015), Bodaghi et al. (2018), Dotoli et al. (2015), Gupta et al. (2016), Hu et al. (2018), Kazemi et al. (2015), Kilici and Yalcin (2020) Moghaddam (2015a, b), Rosyidi et al. (2016), Sawik (2016), Talebi and Jafari (2015), Torabi et al. (2015), Tsai (2015), Vahidi et al. (2018)
Periods	Ahmadi and Amin (2019), Moheb-Alizadeh and Handfield (2019), Arabsheybani et al. (2018), Aggarwal et al. (2018), Moheb-Alizadeh et al. (2017), Almasi et al. (2019), Azadnia and Ghadimi (2018), Azadnia (2016), Moheb-Alizadeh and Handfield (2018) Azadnia et al. (2015); Babbar and Amin (2018); Bektur (2020); Bodaghi et al. (2018); Cui et al. (2015); Çebi and Otay (2016); Feng and Gong (2020); Gören (2018); Hajikhani et al. (2018); Hamdan and Cheaitou (2015, 2017b); Hasan et al. (2020), Hosseini and Nezhad (2019), Hosseini et al. (2019), Hu et al. (2016), Hu et al. (2018), Kaur and Singh (2020), Kazemi et al. (2015), Kellner and Utz (2019), Khoshfetrat et al. (2019), Kilici and Yalcin (2020), Lee et al. (2015), Mirzaee et al. (2018), Sawik (2016), Shadkam and Bijari (2017), Tirkolaee et al. (2020), Tsai (2015), Wong (2020)
Products	Ahmadi and Amin (2019), Alegoz and Yapicioglu (2019), Moheb-Alizadeh and Handfield (2019), Arabsheybani et al. (2018), Aggarwal et al. (2018), Almasi et al. (2019), Azadnia and Ghadimi (2018), Azadnia (2016), Moheb-Alizadeh and Handfield (2018) Azadnia et al. (2015); Babbar and Amin (2018); Bektur (2020); Bodaghi et al. (2018); Cui et al. (2015); Çebi and Otay (2016); Duan et al. (2019); Feng and Gong (2020); Fu et al. (2016); Ghadimi et al. (2018); Ghorabaee et al. (2017); Gören (2018); Govindan and Sivakumar (2016); Govindan et al. (2020); Hajikhani et al. (2018); Hamdan and Cheaitou (2015, 2017b); Hu et al. (2016); Jia et al. (2020); Kaur and Singh (2020); Khoshfetrat et al. (2019); Kuo et al. (2015); Lo et al. (2018); Mirzaee et al. (2018), Moghaddam et al. (2015a, b), Noori-Daryan et al. (2019), Shadkam and Bijari (2017), Suprasongsin et al. (2019), Tirkolaee et al. (2020)
Scenarios	Arabsheybani et al. (2018), Babbar and Amin (2018), Bektur (2020), Ghadimi et al. (2018), Gupta et al. (2016), Hamdi et al. (2016), Hosseini and Nezhad (2019), Hosseini et al. (2019), Hu et al. (2018), Jia et al. (2020), Kaur and Singh (2020), Sawik (2016), Suprasongsin et al. (2019), Torabi et al. (2015), Vahidi et al. (2018)
Suppliers	Ahmadi and Amin (2019), Alegoz and Yapicioglu (2019), Moheb-Alizadeh and Handfield (2019), Arabsheybani et al. (2018), Aggarwal et al. (2018), Moheb-Alizadeh et al. (2017), Almasi et al. (2019), Azadnia and Ghadimi (2018), Azadnia (2016), Moheb-Alizadeh and Handfield (2018) Azadnia et al. (2015); Babbar and Amin (2018); Beauchamp et al. (2015); Bektur (2020); Bodaghi et al. (2018); Cui et al. (2015); Çebi and Otay (2016); Dotoli et al. (2015); Duan et al. (2019); Feng and Gong (2020); Fu et al. (2016); Ghadimi et al. (2018); Ghorabaee et al. (2017); Gören (2018); Govindan and Sivakumar (2016); Govindan et al. (2020); Gupta et al. (2016); Hajikhani et al. (2018); Hamdan and Cheaitou (2015, 2017b); Hamdi et al. (2016); Hasan et al. (2020), Hosseini and Nezhad (2019), Hosseini et al. (2019), Hu et al. (2016), Hu et al. (2018), Jia et al. (2020), Kaur and Singh (2020), Kazemi et al. (2015), Kellner and Utz (2019), Khoshfetrat et al. (2019), Kilici and Yalcin (2020) Kumar et al. (2017); Kuo et al. (2015); Lo et al. (2018); Meena and Sarmah (2016); Memon et al. (2015); Mirzaee et al. (2018); Moghaddam (2015a, b); Mohammed et al. (2018, 2019); Noori-Daryan et al. (2019); Pazhani et al. (2016), Rosyidi et al. (2016), Sawik (2016), Shadkam and Bijari (2017), Suprasongsin et al. (2019), Talebi and Jafari (2015), Torabi et al. (2015), Tirkolaee et al. (2020), Tsai (2015), Vahidi et al. (2018), Prasanna Venkatesan and Goh (2016), Wong (2020)
Customers	Ahmadi and Amin (2019), Razaei et al. (2020), Sawik (2016)

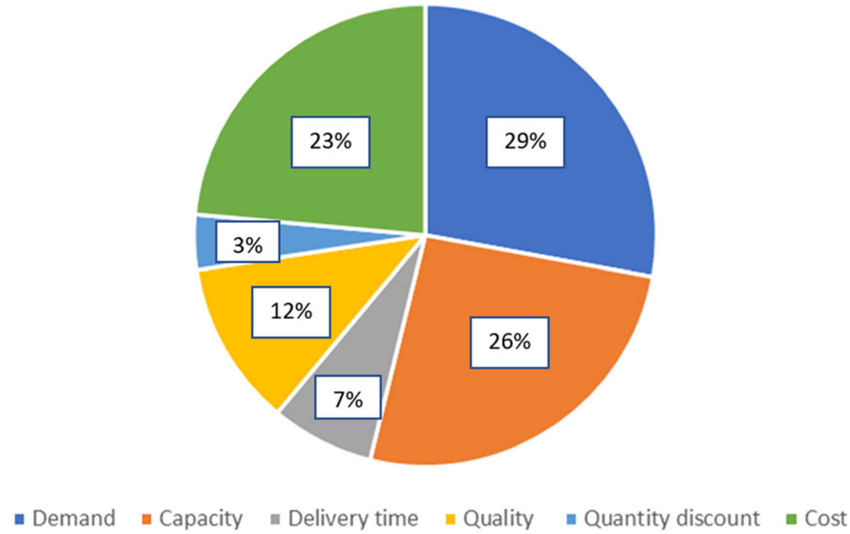
using a fuzzy TOPSIS and a multi-objective method. They determined the ranks of the green suppliers, and they classified the potential suppliers. Pazhani et al. (2016) proposed a mathematical model to find the optimal inventory level and showed that cost could be minimized if the transportation cost is considered in the objective. They also discussed the benefits of the integrated inventory management system approach comparing the sequential approach for solving the supplier selection problem.

Ghorabaee et al. (2017) stated that a novel EDAS technique and interval type-2 fuzzy sets lead to a good multi-criteria green supplier selection model. Hamdan and Cheaitou

Table 4 The references and uncertainty sources

Source of uncertainty	References
Demand	Ahmadi and Amin (2019), Alegoz and Yapicioglu (2019), Moheb-Alizadeh and Handfield (2019), Arabsheybani et al. (2018), Aggarwal et al. (2018), Moheb-Alizadeh et al. (2017), Almasi et al. (2019), Azadnia and Ghadimi (2018), Azadnia (2016), Moheb-Alizadeh and Handfield (2018), Azadnia et al. (2015), Babbar and Amin (2018); Beauchamp et al. (2015); Bektur (2020); Bodaghi et al. (2018); Cui et al. (2015); Çebi and Otay (2016); Dotoli et al. (2015); Duan et al. (2019); Fu et al. (2016); Ghadimi et al. (2018); Ghorabaee et al. (2017); Gören (2018); Govindan et al. (2020); Gupta et al. (2016); Hajikhani et al. (2018); Hamdan and Cheaitou (2015, 2017b), Hamidi et al. (2016), Hosseini and Nezhad (2019) Hosseini et al. (2019); Jia et al. (2020); Kaur and Singh (2020); Kazemi et al. (2015); Kellner and Utz (2019); Khoshfetrat et al. (2019); Kumar et al. (2017); Kuo et al. (2015); Lee et al. (2015); Lo et al. (2018); Meena and Sarmah (2016); Memon et al. (2015); Mirzaee et al. (2018); Moghaddam (2015a); Mohammed et al. (2019); Noori-Daryan et al. (2019); Pazhani et al. (2016), Razaei et al. (2020), Rosyidi et al. (2016), Sawik (2016), Shadkam and Bijari (2017), Suprasongsin et al. (2019), Talebi and Jafari (2015), Torabi et al. (2015), Tirkolaee et al. (2020), Tsai (2015), Vahidi et al. (2018), Prasanna Venkatesan and Goh (2016), Wong (2020)
Capacity	Alegoz and Yapicioglu (2019), Moheb-Alizadeh and Handfield (2019), Arabsheybani et al. (2018), Aggarwal et al. (2018), Moheb-Alizadeh et al. (2017), Almasi et al. (2019), Azadnia and Ghadimi (2018), Azadnia (2016), Moheb-Alizadeh and Handfield (2018), Azadnia et al. (2015), Beauchamp et al. (2015), Bektur (2020), Bodaghi et al. (2018), Cui et al. (2015), Çebi and Otay (2016), Duan et al. (2019), Ghadimi et al. (2018), Ghorabaee et al. (2017), Gören (2018), Govindan and Sivakumar (2016), Govindan et al. (2020), Gupta et al. (2016), Hajikhani et al. (2018), Hamdan and Cheaitou (2015), Hamdi et al. (2016), Hosseini and Nezhad (2019), Hasan et al. (2020), Hosseini et al. (2019), Hu et al. (2018), Jia et al. (2020), Kaur and Singh (2020), Kazemi et al. (2015), Kellner and Utz (2019), Khoshfetrat et al. (2019), Kilici and Yalcin (2020) Lo et al. (2018); Meena and Sarmah (2016); Memon et al. (2015); Mirzaee et al. (2018); Moghaddam (2015a, b); Mohammed et al. (2018, 2019); Noori-Daryan et al. (2019); Pazhani et al. (2016), Razaei et al. (2020), Rosyidi et al. (2016), Sawik (2016), Suprasongsin et al. (2019), Torabi et al. (2015), Tsai (2015), Vahidi et al. (2018), Prasanna Venkatesan and Goh (2016)
Cost	Alegoz and Yapicioglu (2019), Moheb-Alizadeh and Handfield (2019), Arabsheybani et al. (2018), Aggarwal et al. (2018), Almasi et al. (2019), Azadnia and Ghadimi (2018), Azadnia (2016), Azadnia (2015) Babbar and Amin (2018); Bektur (2020); Bodaghi et al. (2018); Cui et al. (2015); Dotoli et al. (2015); Duan et al. (2019); Ghorabaee et al. (2017); Gören (2018); Govindan and Sivakumar (2016); Govindan et al. (2020); Gupta et al. (2016); Hajikhani et al. (2018); Hamdan and Cheaitou (2015, 2017b); Hamdi et al. (2016), Hosseini and Nezhad (2019), Hosseini et al. (2019), Hu et al. (2016), Kaur and Singh (2020), Kellner and Utz (2019), Khoshfetrat et al. (2019), Kilici and Yalcin (2020) Kuo et al. (2015); Lo et al. (2018); Meena and Sarmah (2016); Mirzaee et al. (2018); Moghaddam (2015b; Mohammed et al. (2018, (2019; Noori-Daryan et al. (2019); Pazhani et al. (2016), Razaei et al., (2020), Shadkam and Bijari (2017), Suprasongsin et al. (2019), Talebi and Jafari (2015), Torabi et al. (2015), Tsai (2015), Vahidi et al. (2018), Prasanna Venkatesan and Goh (2016), Wong (2020)
Delivery time	Alegoz and Yapicioglu (2019), Moheb-Alizadeh and Handfield (2019), Dotoli et al. (2015), Ghadimi et al. (2018), Ghorabaee et al. (2017), Govindan and Sivakumar (2016), Gupta et al. (2016), Hajikhani et al. (2018), Hamdan and Cheaitou (2015), Kaur and Singh (2020), Kilici and Yalcin (2020), Mirzaee et al. (2018), Noori-Daryan et al. (2019), Shadkam and Bijari (2017), Talebi and Jafari (2015)
Quality (defect rate)	Alegoz and Yapicioglu (2019), Çebi and Otay (2016), Duan et al. (2019), Ghadimi et al. (2018), Ghorabaee et al. (2017), Govindan and Sivakumar (2016), Gupta et al. (2016), Hamdan and Cheaitou (2015), Hu et al. (2016), Jia et al. (2020), Kazemi et al. (2015), Kuo et al. (2015), Kilici and Yalcin (2020), Lo et al. (2018), Memon et al. (2015), Mirzaee et al. (2018), Razaei et al. (2020), Rosyidi et al. (2016), Shadkam and Bijari (2017), Suprasongsin et al. (2019), Talebi and Jafari (2015), Torabi et al. (2015), Tsai (2015) Vahidi et al. (2018)
Quantity discount	Alegoz and Yapicioglu (2019), Arabsheybani et al. (2018), Aggarwal et al. (2018), Bektur (2020), Lo et al. (2018), Mirzaee et al. (2018), Tsai (2015)

Fig. 1 Sources of uncertainty



(2017b) proposed a model to choose a green supplier and allocate the orders using a multi-objective optimization model. For solving the problem, the authors utilized AHP, Fuzzy TOPSIS, and multi-objective optimization techniques. Arabsheybani et al. (2108) considered some risk factors and enhanced FMEA method to determine the risk and price criteria.

Babbar and Amin (2018) proposed a novel two-stage QFD model and an optimization model for SSOA. They solved the optimization model using GAMS software. Their method can handle the vagueness and uncertainty considering qualitative and quantitative criteria. Ahmadi and Amin (2019) introduced the supplier selection and order allocation in closed-loop network of cellular phone industry in Toronto Canada. They developed a fuzzy based solution approach using IBM ILOG CPLEX 12.7.1.0 software. Hosseini et al. (2019) developed a bi-objective mixed-integer programming model (stochastic) for the SSOA problem. They illustrated the application of the model in the automotive industry. Bektur (2020) introduced F-AHP and F-PROMETHEE to study uncertainty in the decision-making environment. Govindan et al. (2020) described sustainability through incorporating circular supplier selection and order allocation. They combined all activities such as waste reduction in transportation. Hasan et al. (2020) developed a Decision Support System (DSS) for companies operating under logistics industry 4.0.

Jia et al. (2020) developed a robust optimization goal programming model for a steel company. They solved the problem by CPLEX, and optimized it considering the total cost, CO_2 emission, and environmental objectives. Kaur and Singh (2020) proposed a model with consideration of risks and disruption (both natural and man made), suitable for industry 4.0 environment. The uncertain optimization models are categorized in Table 3 according to the multiple elements. In addition, the uncertainty sources are shown in Table 4; Fig. 1. Demand, capacity, and cost are the major sources of uncertainty in the reviewed papers.

2.2 Operations research techniques

We divide the references according to the operations research (optimization) techniques in Table 5. Several authors have utilized hybrid techniques in this field. Table 6 includes the types of the objective functions in different papers. In addition, single objective and multi-objective functions are illustrated in Fig. 2.

3 Observations and related recommendations

In this part, observations and recommendations according to the reviewed papers are provided.

3.1 The most popular domain

In this paper, we discussed three domains of supplier selection and order allocation including literature reviews, deterministic optimization models, and uncertain optimization models. The most popular domain is the uncertain optimization models (73 % of the papers). Deterministic optimization models (17 % of the papers), and Literature reviews (10 % of the papers) domains have the next ranks.

3.2 The most popular uncertainty source

According to Table 4; Fig. 1, the most popular sources of uncertainty are demand, capacity, and cost, respectively. Among them, demand has been considered more than the other factors (29 % of the papers). This parameter usually

Table 5 Arrangement of the papers according to the operations research methods

Techniques	References
Analytic Hierarchy Process (AHP)	Hamdan and Cheaitou (2015, 2017a, b); Hamdan and Jarndal (2017), Hosseini and Nezhad (2019), Khoshfetrat et al. (2019), Razaei et al., (2020)
AHP-QFD, Chance-constrained optimization, Chance Constrained Programming	Moheb-Alizadeh and Handfield (2018), Scott et al. (2015)
Analytical Model-heuristics	Meena and Sarmah (2016)
Analytic Network Process - Integer Programming (ANP-IP)	Wang et al. (2020)
Best worst method	Cheraghalipour and Farsad (2018), Lo et al. (2018)
Branch and cut algorithm	Hamdan and Cheaitou (2017b)
Combination of Grey System and Uncertainty Theory	Memon et al. (2015)
Comprehensive Criterion Method (CCM), Weighted Comprehensive criterion Method (WCM)	Hamdan and Cheaitou (2015, 2017b)
Correlated AHP, Linear physical programming	Rao and Rao (2018)
Constrained Programming – Simulated Annealing (CP-SA)	Cui et al. (2015)
Cuckoo Optimization Algorithm (COA), Discrete Event Simulation (DES), Supply Chain Model (SCM), and Generalized Data Envelopment Analysis (GDEA)	Shadkam and Bijari et al. (2017)
DEA, Fuzzy sets theory, Fuzzy ILP	Arabzad et al. (2015), Dotoli et al. (2015), Kaur and Singh (2020), Moheb-Alizadeh and Handfield (2018), Moheb-Alizadeh and Handfield (2019)
Dependant chance programming, Minimum deviation method	Moheb-Alizadeh et al. (2017)
Evaluation based on Distance from Average Solution (EDAS), Type 2 Fuzzy sets	Ghorabaee et al. (2017)
ε-constraint	Ahmadi and Amin (2019), Moheb-Alizadeh and Handfield (2019), Almasi et al. (2019), Azadnia et al. (2015), Babbar and Amin (2018), Bektur (2020), Hosseini et al. (2019), Kellner and Utz (2019), Mohammed et al. (2018), Mohammed et al. (2019), Rezaei et al. (2020), Torabi et al. (2015), Vahidi et al. (2018), Moheb-Alizadeh and Handfield (2019), Almasi et al. (2019), Kellner and Utz (2019)
Fuzzy AHP-Fuzzy TOPSIS	Kaur and Singh (2020), Mohammed et al. (2019)
Fuzzy Multi-Attribute Decision-Making	Hasan et al. (2020)
Fuzzy AHP	Azadnia et al. (2015), Bektur (2020), Hu et al. (2016), Kumar et al. (2017), Lee et al. (2015), Mohammed et al. (2018), Mohammed et al. (2019), Razaei et al. (2020)
Fuzzy ANP	Bodaghi et al. (2018), Tirkolaee et al. (2020)
Fuzzy DEMATEL	Gören (2018), Govindan et al. (2020), Tirkolaee et al. (2020)
Fuzzy Multi-objective Linear Programming	Gupta et al. (2016), Kumar et al. (2017)
Fuzzy Multi-objective Programming	Lo et al. (2018)
Fuzzy MOORA, Failure Mode and Effect Analysis (FMEA)	Arabsheybani et al. (2018)
Fuzzy MULTIMOORA	Çebi and Otay (2016)
Fuzzy multi-objective	Bektur (2020); Moghaddam (2015a); Talebi and Jafari (2015); Mohammed et al. (2019)
Fuzzy multi-objective, Fuzzy QFD	Azadnia and Ghadimi (2018), Babbar and Amin (2018)
Fuzzy Quality Loss	Rosyidi et al. (2016)
Fuzzy TOPSIS, SWOT Analysis	Arabzad et al. (2015); Govindan and Sivakumar (2016); Hamdan and Cheaitou (2015, 2017a, b); Hasan et al. (2020); Lee et al. (2015); Lo et al. (2018); Mohammed et al. (2018)
Fuzzy-PROMETHEE	Bektur (2020)
Genetic Algorithm, Artificial Bee Colony, Chaotic Bee Colony	Moheb-Alizadeh et al. (2017), Hamdan and Jarndal (2017), Hu et al. (2018), Jain et al. (2015)
Hybrid FAHP-FPROMETHEE	Prasanna Venkatesan and Goh (2016)
Hybrid Monte Carlo Simulation, Fuzzy Goal Programming	Çebi and Otay (2016); Moghaddam (2015a, b); Wong (2020),
Hybrid optimization, Association rule mining	Kuo et al. (2015)
Hybrid SWOT-QFD	Vahidi et al. (2018), Prasanna Venkatesan and Goh (2016)
Interactive Fuzzy MOLP, IFGP, Fuzzy programming	Kazemi et al. (2015)
Intuitionistic Fuzzy -TOPSIS (IF-TOPSIS), two-phase Fuzzy GP	Kilic and Yalcin (2020)
Linear Programming	Beauchamp et al. (2015), Rao and Rao (2018), Sodenkamp et al. (2016)
Linguistic Entropy Weight Method (LEWM)	Feng and Gong (2020)
Linguistic Z numbers, Alternative Queuing Method (AQM)	Duan et al. (2019)
MILP, Pre-emptive Fuzzy GP	Ahmadi and Amin (2019), Arabzad et al. (2015), Bohner and Minner (2017), Govindan et al. (2020), Khoshfetrat et al. (2019), Mirzaee et al. (2018), Moheb-Alizadeh and Handfield (2019)
Mixed-Integer Nonlinear Programming (MINLP)	

Table 5 (continued)

Techniques	References
	Esmaeili-Najafabadi et al. (2019), Hu et al. (2018), Jain et al. (2015), Moheb-Alizadeh and Handfield (2018), Pazhani et al. (2016), Tsai (2015)
Mixed-Integer Programming (MIP), Two MIP	Cui et al. (2015), Hamdi et al. (2016), Kaur and Singh (2020)
MOPSO, NSGA-II	Hajikhani et al. (2018), Prasanna Venkatesan and Goh (2016)
Multi Agent System (MAS)	Ghadimi et al. (2018)
Multi Attribute Utility Theory (MAUT), Multi-objective Integer Linear Programming (MOILP)	Hamdan and Cheaitou (2017a); Park et al. (2018)
Multi-objective programming	Almasi et al. (2019), Azadnia et al. (2015), Azadnia (2016), Duan et al. (2019), Feng and Gong (2020), Govindan and Sivakumar (2016), Kellner and Utz (2019), Nazeri et al. (2019), Nourmohamadi Shalke et al. (2018), Razaei et al. (2020)
Multi-choice Goal Programming (MCGP), Revised MCGP	Cheraghalipour and Farsad (2018), Hasan et al. (2020), Jadidi et al. (2015), Nourmohamadi Shalke et al. (2018)
Non-linear optimization	Noori-Daryan et al. (2019)
Non-Pre-emptive Goal Programming, Weighted-sum Aggregate Objective Function (AOF)	Aggarwal et al. (2018); Moghaddam (2015b)
Possibilistic programming, two-stage stochastic programming	Torabi et al. (2015)
Robust optimization, GP	Jia et al. (2020), Fu et al. (2016)
Rule-based weighted fuzzy method	Azadnia et al. (2015)
Simulated Annealing	Mohammaditabar and Ghodsypour (2016)
Stochastic MIP	Sawik (2016)
Stochastic programming, Stochastic multi-objective programming, Dynamic programming	Babbar and Amin (2018), Fu et al. (2016), Hosseini and Nezhad (2019), Hosseini et al. (2019), Vahidi et al. (2018)
TOPSIS	Alegoz and Yapicioglu (2019), Bektur (2020), Tirkolaee et al. (2020)
Trapezoidal Type 2 FAHP	Alegoz and Yapicioglu (2019)
Weight-consistent constraint, Maximin aggregation operator	Suprasongsin et al. (2019)
Weighted possibilistic programming	Gupta et al. (2016)

affects the order allocation significantly, and it is considered as one of the constraints of the optimization models.

3.3 The most popular technique

Based on the information in Table 5, Fuzzy TOPSIS, Fuzzy-multi objective programming, Stochastic programming, and Mixed-integer linear programming are the most popular techniques in the literature of SSOA. Fuzzy TOPSIS is a useful technique to determine the weights (importance) of the suppliers. Fuzzy sets theory enables researchers to consider uncertainty in the parameters. Fuzzy multi-objective programming considers uncertainty and the effects of some objectives on the problem. There are several stochastic programing models in the literature which are based on the probabilities in the SSOA problem. Mixed-integer linear programming also have been utilized in the literature because it can handle both non-negative and 0–1 variables.

3.4 The most popular multi-objective method

There are several techniques for solving multi-objective problems. Based on our observation, weighted-sums method is the most popular one. Several authors also have utilized goal programming and ε-constraints method to solve multi-objective SSOA problems.

3.5 The most popular applications

The applications of the models have been categorized in Table 7. Several authors have considered case studies. “Automotive industry” is a popular application in the supplier selection and order allocation field.

3.6 The list of publications

Table 8 includes the information related to the names of the journals. These journals have published papers related to SSOA. “Journal of Cleaner Production”, “Computers & Industrial Engineering”, “International Journal of Production Research”, “International Journal of Production Economics”, and “Expert Systems with Applications” have published several papers in this field.

3.7 Classification of the articles based on year

Table 9 includes the classification of the papers based on year and the mentioned three domains. The journal papers from 2015 to 2020 have been examined in this research. It is noticeable that

Table 6 Single objective and multi-objective models

	Objective functions	References
Single objective		
	Max value of cooperation between supplier and customer	Arabzad et al. (2015)
	Max total stake-holder satisfaction score	Scott et al. (2015)
	Min total cost	Bohner and Minner (2017)
	Max total profit	Cui et al. (2015)
	Min outsourcing cost	Fu et al. (2016)
	Max total score	Beauchamp et al. (2015)
	Max over all performance of the system	Hu et al. (2018)
	Min deviation (cost, CO_2, emission, society and supplier's value)	Jia et al. (2020)
	Min cost	Esmaeili-Najafabadi et al. (2019), Jain et al. (2015), Kuo et al. (2015), Meena and Sarmah (2016), Mohammaditabar and Ghodsypour (2016), Pazhani et al. (2016), Torabi et al. (2015), Wang et al. (2020)
	Max conditional service at risk	Sawik (2016)
	Max efficiency of the proposed system	Shadkam and Bijari (2017)
	Max satisfaction level of cost, quality and delivery lateness	Suprasongsin et al. (2019)
	Min penalties	Hasan et al. (2020)
Multi-objective	(3) Min total cost, quality and lead time	Aggarwal et al. (2018), Alegoz and Yapicioglu (2019)
	(2) Max profit, Max weights of suppliers	Ahmadi and Amin (2019)
	(4) Min cost, time, Max efficiency, Max environmental objective	Moheb-Alizadeh and Handfield (2018)
	(3) Min cost, time, Max environmental objectives	Moheb-Alizadeh and Handfield (2019)
	(3) Min cost, rate of rejection, delay	Moheb-Alizadeh et al. (2017)
	(6) Min cost, price, inflation, Max quantity, environmental objectives and social score	Almasi et al. (2019)
	(3) Max profit, Min loss in sale and discount risk	Arabsheybani et al. (2018)
	(4) Min cost, Max environmental objectives	Azadnia et al. (2015), Azadnia and Ghadimi (2018)
	(5) Min total cost, defect rate, carbon emission, Max of weights of suppliers, on-time delivery	Babar and Amin (2018)
	(5) Min cost, delivery, rate of defects, Max flexibility and total weighted quantity of purchase	Bodaghi et al. (2018)
	(4) Min cost, late delivery, rate of defects, Max total utility of the system	Çebi and Otay (2016)
	(2) Min cost, Max total score	Cheraghalipour and Farsad (2018)
	(2) Max efficiency of supplier, Max order quantity	Dotoli et al. (2015)
	(2) Min total cost, Max green value	Duan et al. (2019)
	(3) Min total cost, carbon emission, Max total purchasing value	Feng and Gong (2020)
	(2) Min cost, Max supplier's performance	Ghadimi et al. (2018)
	(3) Max positive score of supplied material, Min negative score of supplied material and cost	Ghorabaee et al. (2017)
	(2) Min total cost, Max total value purchasing	Bektur (2020), Gören (2018), Razaei et al., (2020)
	(5) Min total cost, total quality rejection, late delivery, waste, total carbon emission	Govindan and Sivakumar (2016)
	(4) Min cost, defective items, delay in delivery, Max vendor performance	Gupta et al. (2016)
	(4) Min price, delay, Max coverage of customer's suppliers, supplier evaluation more realistic	Hajikhani et al. (2018)
	(2) Max total preference, Min total cost	Hamdan and Cheaitou (2015)
	(2) Max total performance, Min total cost	Kaur and Singh (2020); Hamdan and Cheaitou (2017a, b)
	(3) Max green purchasing, Min cost, Min defects	Hamdan and Jarndal (2017)
	(2) Max profit, Min loss	Hamdi et al. (2016)

Table 6 (continued)

Objective functions	References
(2) Max total value of purchase, total profit	Hosseini and Nezhad (2019)
(2) Max distance between all pairs of supplier locations, Min cost	Hosseini et al. (2019)
(3) Min rejection, late delivery, purchasing cost	Hu et al. (2016)
(3) Min cost, rejects, late deliveries	Jadidi et al. (2015)
(3) Min cost, Max quality, and delivery reliability	Kazemi et al. (2015)
(3) Min cost, supply risk, Max sustainability	Kellner and Utz (2019)
(6) Min cost, risk, inflation effect, Max economic score, environmental score, social score	Khoshfetrat et al. (2019)
(2) Max satisfaction degree of the goal, Max total weighted satisfaction degree	Kilici and Yalcin (2020)
(7) Min carbon emission, waste, order cost, percentage of rejection, percentage of late delivery, Max percentage of profit	Kumar et al. (2017)
(4) Min cost, delay, defect rate, Max organizational utility	Lo et al. (2018)
(2) Min cost, Min lead time	Memon et al. (2015)
(3) Min total cost, Max total value of purchase and total achievement degree	Mirzaee et al. (2018)
(4) Max profit, Min defective parts, late deliveries, risk	Moghaddam (2015a)
(4) Max total profit, Min defective parts, late delivery, risks	Moghaddam (2015b)
(5) Min cost, carbon emission, travel time, Max social impact and total purchase value	Mohammed et al. (2018)
(4) Min cost, carbon emission, Max social impact, purchasing value	Mohammed et al. (2019)
(5) Max supply priority, Min cost, delay, defects, risk	Nazeri et al. (2019)
(4) Min cost, defects, total delay, total carbon footprint	Park et al. (2018)
(2) Min cost and fuzzy quality loss	Rosyidi et al. (2016)
(4) Min total cost, Max total economic score, total environmental score, total social score	Nourmohamadi Shalke et al. (2018)
(3) Max TVP, Max strategic effectiveness between customer and supplier	Sodenkamp et al. (2016)
(3) Min cost, failure rate, delivery	Talebi and Jafari (2015)
(3) Min total cost, Max weights of value of different products, Max reliability of system	Tirkolaee et al. (2020)
(2) Min rejects, late delivery	Tsai (2015)
(2) Max total sustainability, Min total cost	Vahidi et al. (2018)
(2) Min total cost, and Min total purchase value	Prasanna Venkatesan and Goh (2016)
(7) Max trend value, average value, green consensus, market bonus, Min risk, cost, market penalty	Wong (2020)
(2) Min total cost and shortages	Govindan et al. (2020)

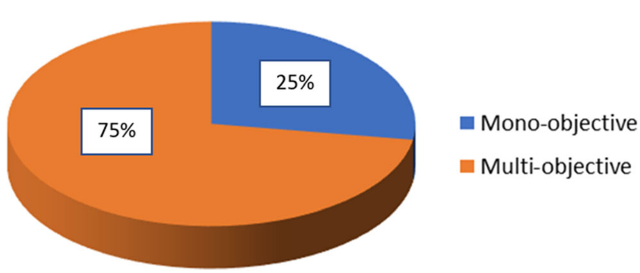


Fig. 2 Mono-objective and multi-objective models

our paper has been written in 2020. Therefore, the number of the published journal papers in 2020 are limited in Table 9.

4 Conclusions

In this research, three problem domains including literature reviews, deterministic optimization models, and uncertain optimization models have been considered, and the related papers have

Table 7 Applications of the models

Applications	References
Agriculture industry	Hajikhani et al. (2018), Sodenkamp et al. (2016)
Automotive industry	Moheb-Alizadeh and Handfield (2019), Almasi et al. (2019), Azadnia and Ghadimi (2018), Feng and Gong (2020), Govindan et al. (2020), Gupta et al. (2016), Jain et al. (2015), Kaur and Singh (2020), Kellner and Utz (2019), Khoshfetrat et al. (2019), Kumar et al. (2017), Lee et al. (2015), Razaei et al. (2020), Tsai (2015), Vahidi et al. (2018)
Air filter industry	Kilici and Yalcin (2020)
Beverage industry	Babbar and Amin (2018), Çebi and Otay (2016)
Bicycle manufacturing	Park et al. (2018)
Camera manufacturer	Kuo et al. (2015)
Coffee bean importer	Wong (2020)
Computer/electronic manufacturer	Ahmadi and Amin (2019), Lo et al. (2018), Tirkolaee et al. (2020), Wang et al. (2020)
Food industry	Azadnia et al. (2015), Azadnia (2016), Cui et al. (2015), Hu et al. (2018)
Gas industry	Arabzad et al. (2015)
Healthcare industry/medical devices	Bektur (2020), Noori-Daryan et al. (2019)
Home appliances industry	Arabsheybani et al. (2018)
Logistics	Hasan et al. (2020)
Manufacturer of hydraulic plants	Dotoli et al. (2015)
Meat industry	Mohammed et al. (2018)
Medical device industry	Ghadimi et al. (2018)
Military logistics	Nazeri et al. (2019)
Online sales	Gören (2018)
Plastic industry	Cheraghalipour and Farsad (2018)
Plastic and textile industry	Hu et al. (2016)
Steel industry/metal factory	Jia et al. (2020), Mohammed et al. (2019)
Test problems	Aggarwal et al. (2018), Alegoz and Yapicioglu (2019), Esmaeili-Najafabadi et al. (2019), Moheb-Alizadeh et al., (2017), Moheb-Alizadeh and Handfield (2018) Beauchamp et al. (2015); Bodaghi et al. (2018); Bohner and Minner (2017); Duan et al. (2019); Fu et al. (2016); Ghorabaee et al. (2017); Hamdan and Cheaitou (2015, 2017a, b); Hamdi et al. (2016), Hosseini and Nezhad (2019) Hosseini et al. (2019); Hu et al. (2018); Jadidi et al. (2015); Kazemi et al. (2015); Meena and Sarmah (2016); Memon et al. (2015); Mirzaee et al. (2018); Moghaddam (2015a, b); Mohammaditabar and Ghodsypour (2016); Pazhani et al. (2016), Rao and Rao (2018), Rosyidi et al. (2016), Sawik (2016), Scott et al. (2015), Shadkam and Bijari (2017), Suprasongsin et al. (2019), Talebi and Jafari (2015), Torabi et al. (2015), Prasanna Venkatesan and Goh (2016)

been gathered and analyzed. In addition, these papers (92 publications between 2015 and 2020) have been classified according to the operations research methods. Furthermore, observations have been provided and discussed. We have observed that most of the mathematical models in SSOA belong to the uncertain optimization models category. Supplier selection and order allocation methods may create competitive advantages for companies, and at the same time, poor selection of the suppliers may result in the failure of the companies. The basic criteria for supplier selection include cost, quality, and time. Recently, more green and environmental factors such as minimization of carbon emissions have been considered in the SSOA process. There are numerous directions for future research in the SSOA problem. Some of them are as follow:

Table 8 The publications list

Journal	Number of papers LR	DO	UO	Total
Applied Mathematical Modelling		1	1	2
Annals of Operations Research			2	2
Applied Mathematics and Computation			1	1
Applied Soft Computing			1	1
Benchmarking: An International Journal			1	1
Computers & Industrial Engineering		4	4	8
Computers & Operations Research			1	1
Conference papers		1	2	3
Cogent Engineering			1	1
Decision Science Letters			1	1
Engineering Management Journal			1	1
Engineering Optimization			1	1
Expert Systems with Applications	1		5	6
European Journal of Operational Research		1	1	2
IFAC-PapersOnLine			1	1
IEEE Transactions			1	1
Information Sciences			1	1
International Journal of Business Performance and Supply Chain Modelling	1			1
International Journal of Computer Integrated Manufacturing,	1		2	3
International Journal of Engineering			1	1
International Journal of Environmental Research and Public Health		1		1
International Journal of Fuzzy Systems			1	1
International Journal of Integrated Supply Management	1		1	2
International Journal of Logistics Research and Applications			1	1
International Journal of Management Science and Engineering Management		1		1
International Journal of Operations Research and Information Systems			1	1
International Journal of Procurement Management		1		1
International Journal of Production Economics	1	1	4	6
International Journal of Production Research			5	5
International Journal of Services and Operations Management			1	1
International Journal of Supply and Operations Management			1	1
International Journal of Systems Science		1	1	2
Journal of Applied Logic	1			1
Journal of cleaner production	1	1	11	13
Journal of Optimization in Industrial Engineering			1	1
Journal of Intelligent Manufacturing		1		1
Journal of Industrial Engineering International	1			1
Materials Today: Proceedings		1		1
Scientia Iranica			1	1
Scientific Programming			1	1
South African journal of Industrial Engineering	1			1
Sustainable Production and Consumption			2	2
The International Journal of Advanced Manufacturing Technology		1	3	4
Transportation Research Part E: Logistics and Transportation Review			3	3
Total	9	16	67	92

Table 9 Classification of the papers based on year

Year	Number of articles LR	DO	UO	Total
2015	1	3	14	18
2016	2	2	12	16
2017	1	4	5	10
2018	3	4	14	21
2019	2	2	12	16
2020		1	10	11
Total	9	16	67	92

(i) Usually a few sources of uncertainty have been considered in the optimization models of order It is useful to consider several sources of uncertainty simultaneously using advanced methods such as robust optimization.

(ii) Most of the SSOA papers have focused on manufacturing systems such as automobile It is valuable to consider SSOA in service industry such as healthcare systems (e.g., hospitals).

(iii) Fuzzy sets theory and fuzzy logic have been combined with other techniques to handle However, there are some practical challenges in applying these methods in

More case studies can be considered in this area to show and discuss the applications of these methods.

(iv) Under special circumstances such as COVID-19, the normal supplier selection and order allocation may not lead to excellent Developing new methods for these situations can be an avenue of future research.

(v) There are several parameters such as cost, capacity, and demand in the optimization models of the order These parameters can be estimated using advanced forecasting techniques such as machine learning, deep learning, and neural To our knowledge, this area of research is new, and has not been explored in the SSOA papers.

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