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A comprehensive framework and literature review of supplier selection under different purchasing strategies

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ABSTRACT

Supplier selection has received substantial consideration in the literature since it is considered one of the key levers contributing to a firm's success. Selecting the right suppliers for different product items requires an appropriate problem framing and a suitable approach. Despite the vast literature on this topic, there is not a comprehensive framework underlying the supplier selection process that addresses those concerns. This paper formalizes a framework that provides guidance on how supplier selection should be formulated and approached for different types of items segmented in Kraljic's portfolio matrix and production policies. The framework derives from a thorough literature review, which explores the main dimensions in supplier selection, including sourcing strategy, decision scope and environment, selection criteria, and solution approaches. 326 papers, published from 2000 to 2021, were reviewed for said purpose. The results indicate that supplier selection regarding items with a high purchasing importance should lead to holistic selection criteria. In addition, items comprising a high complexity of supply and production activities should require integrated selection and different sources of uncertainty associated with decision scope and environment, respectively, to solve it, as well as hybrid approaches. There are still many research opportunities in the supplier selection area, particularly in the integrated selection problems and hybrid solution methods, as well as in the risk mitigation, sustainability goals, and new technology adoption.

1. Introduction

Supplier selection is one of the vital purchasing activities that have an integrative role in the firms' strategic planning process, as companies'performance and competitive advantages rely on the collaboration with capable suppliers (Wagner, 2006). More specifically, suppliers contribute to the four main competitive priorities, namely quality, delivery, flexibility, and cost (Olhager and Prajogo, 2012). In general, the cost of materials and components, particularly for high technological products, can range from 60% to 80% of production cost (Dey et al., 2015). Selecting appropriate suppliers and carrying out their involvement to assist strategic supply management activities can reduce material costs and product development time by 20% and improve material quality by 20% (Monczka et al., 2015). Clearly, supplier selection is critical to the overall firm's performance.

However, selecting appropriate suppliers is not a straightforward process. It relies not only on the selection (solution approach) itself but also on the precedent phases, including the problem definition and the criteria identification (de'Boer et al., 2001). Each stage of the supplier selection process requires a framework that should align with the purchasing strategy to achieve goals successfully.

The need to manage the supply of different types of purchased items with differentiated strategies has been recognized due to their contributions and profit impacts, as well as supply complexity. The strategic role of supplier selection becomes important for the purchase of items whose financial impact and supply complexity are high (e.g., chipsets in the electronic industry). By contrast, this decision should not be as critical for low-cost items with abundant sources (e.g., standard screws in the electronic industry). Due to their different degrees of complexity and importance, all purchased materials should not be managed in the same way (Abdollahi et al., 2015; Gelderman and Weele, 2003), and consequently, the supplier selection process also must be specific for different types of items. It requires differentiation and some sort of classification of these purchases (Gelderman and Weele, 2003). Purchasing portfolio models have been developed to provide an approach for differentiating purchasing.

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Kraljic (1983) introduced the first portfolio model for such purpose. The author has identified four classes of items (non-critical, leverage, bottleneck, and strategic), based on two dimensions: supply risk (complexity) and the purchase importance (shown in Fig. 1). The Kraljic Portfolio Matrix (KPM) has been widely used as a diagnostic and prescriptive purchasing tool (Montgomery et al., 2018). For instance, it has been used to classify and position purchased items in areas such as public procurement (Padhi et al., 2012), construction (Ferreira et al., 2015), and manufacturing (Lee and Drake, 2010), as well as to analyze supplier selection methods (de'Boer et al., 2001). It has received considerable attention since the firm's ability to manage supplier relations empirically linking to competitive advantages has been recognized (Montgomery et al., 2018). Furthermore, KPM can also be useful as a starting point for developing a supplier selection framework, particularly in defining the selection problem and identifying criteria according to the supply complexity and purchasing importance.

It is worth of note that various industries differ in the production policy used to meet their demand, such as make-to-stock (MTS), assembly-to-order (ATO), make-to-order (MTO), and engineer-to-order (ETO). Accordingly, their competitive priorities and operational performance outcomes may also differ (Olhager and Prajogo, 2012). For instance, MTS companies typically compete on price and cost efficiency, while MTO companies compete on customization and flexibility. Thus, to sustain strategic competitive priorities, companies should cooperate with the right suppliers. In other words, supplier selection criteria and framework must be in accordance with the competitive priorities of the respective production policy.

A number of literature reviews on supplier selection have been presented. The majority is focused on identifying trends and potential solution approaches for supplier selection (Aouadni et al., 2019; Chai and Ngai, 2020; Chai et al., 2013; Karsak and Dursun, 2016; Rashidi et al., 2020; Simic et al., 2017; Schramm et al., 2020; Zhang et al., 2020). Other reviews have also delved into the selection criteria (Ho et al., 2010; Mukherjee, 2016; Wetzstein et al., 2016), and some focused their analysis on green and environmental contexts (Igarashi et al., 2013; Govindan et al., 2015; Rashidi et al., 2020; Zhang et al., 2020; Zimmer et al., 2016). The discussion of other dimensions in supplier selection, such as sourcing strategy and uncertainty environment, has also been conducted, but in specific contexts or for specific methods (e.g., Aissaoui et al. (2007) considered those two additional dimensions when evaluating mathematical programming approaches). While the aforementioned literature is helpful to provide the principles for identifying supplier selection criteria and methods, as well as to understand the decision environment, analysis of the supply chain activities integrated with supplier selection (decision scope) has not been discussed. Moreover, a framework that integrates these dimensions and links to critical drivers (such as KPM and production policy) has not been presented despite the vast literature on supplier selection.

This paper provides a framework from which we can derive insights into supplier selection problems. Accordingly, this paper aims to contribute to the literature in four important ways. First, we expand the preceding literature by providing an updated and comprehensive review of supplier selection papers deeper and broader than prior reviews.

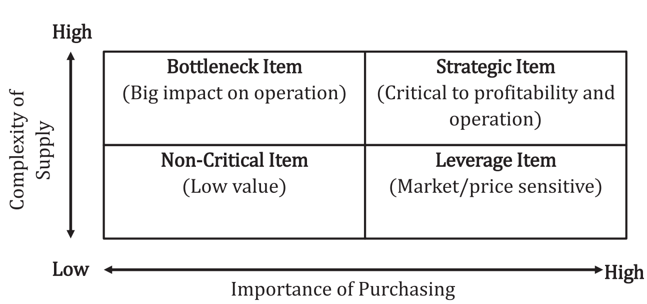

Fig. 1. Purchasing classification (Kraljic, 1983).

Second, we link the reviewed papers to the KPM and production policy to understand how supplier selection should be formulated in different contexts. Third, we connect four different supplier selection dimensions (sourcing strategy, decision environment, scope, and criteria) to identify the right approach to each setting. Fourth, we extract existing research gaps and synthesize research recommendations to direct future avenues of research. We aim at answering three main research questions:

- (**Q1**) How should supplier selection be formulated for different types of items and production policies?
- (**Q2**) How should a given supplier selection problem formulation be approached?
- (**Q3**) What are the research trends and opportunities for supplier selection?

The remainder of the paper is organized as follows. Section 2 presents the methodology used to answer the three research questions, including the novel framework that we extend from the literature to guide the research process. Section 3 provides an exploratory review of each of the main dimensions that characterize this problem. The first two research questions are then explored in Section 4. Finally, we highlight the findings, as well as recommendations for future work in Section 5.

2. Research methodology

A synthesis of supplier selection studies reveals the main dimensions found to influence the diversity and complexity of decision-making in this context. Those dimensions include: sourcing strategy (Aissaoui et al., 2007; de'Boer et al., 2001), decision environment (Chai and Ngai, 2015), decision scope (Nair et al., 2015), supplier selection criteria (Govindan et al., 2015; Ho et al., 2010; Igarashi et al., 2013; Mukherjee, 2016; Wetzstein et al., 2016; Zimmer et al., 2016), and solution approaches (Aouadni et al., 2019; Chai and Ngai, 2020; Chai et al., 2013; de'Boer et al., 2001; Karsak and Dursun, 2016; Schramm et al., 2020; Simic et al., 2017).

To answer the research questions previously presented, we extend de'Boer's framework (de'Boer et al., 2001) of supplier selection by considering the dimensions identified and by connecting them to the KPM and production policy that characterize each type of items. Our framework is depicted in Fig. 2.

According to this framework, this study comprises two fundamental questions (Q1 and Q2) associated with two phases of the supplier selection process, namely problem statement and the evaluation. The focus of Q1 is to represent a thorough problem statement in the context of purchasing management. Thus, we investigate an appropriate sourcing strategy, decision scope and environment, as well as selection criteria associated with the different types of items and production policies. According to these dimensions, Q2 is then addressed to examine a suitable approach to that problem. Finally, and based on all the reviewed papers, driving forces of supplier selection (Q3) are disclosed to explore research opportunities synthesized from the literature.

A literature review is presented to discuss the dimensions of supplier selection addressing the aforementioned research questions. This review covers the studies of supplier selection from 322 articles collected from the scholarly published journal between 2000 and 2021. There is a higher focus on papers published in the last eight years since recently published reviews covered those published until 2012 (Chai et al., 2013; Govindan et al., 2015; Igarashi et al., 2013; Mukherjee, 2016). Therefore, we collected papers published between 2013 and 2021 by performing a systematic literature review. In addition, we consider 50 papers published between 2000 and 2012 that have been included in Chai et al. (2013) and Ho et al. (2010) studies.

The collected papers have been published online and publicly available on Scopus database. To ensure the quality evaluation in identifying the papers, we only consider papers published in an

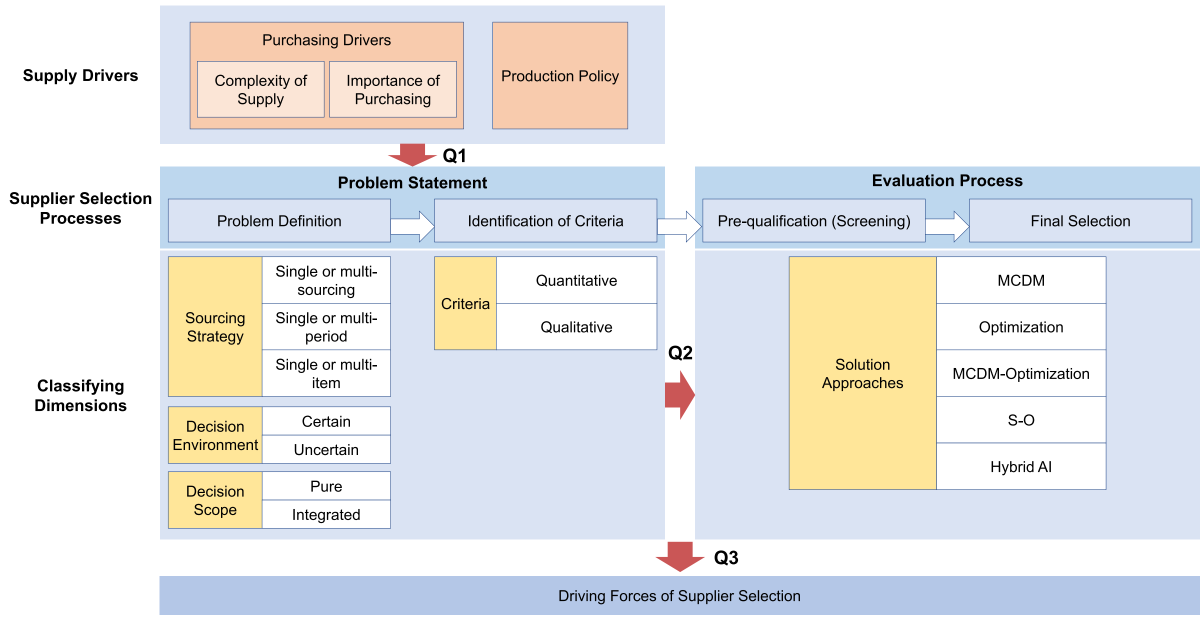

Fig. 2. A framework of supplier selection (adapted from de'Boer et al., 2001; Aissaoui et al., 2007) and conte.xt of the study.

international journal. Book chapters and conference proceedings are not taken into account.

To establish a reproducible and unbiased article search process, the following keywords were used: ("supplier" OR "vendor") AND ("selection" OR "evaluation" OR "integration"). 369 papers in total were found according to specific filtering criteria, including keywords, languages (English), types of source (journal), year of publication (2013–2021), and subject areas (business and management, decision sciences, and mathematics). We ensure the relevancy of the collected papers by reading the abstract and the content and checking the quality of the papers according to the index of Scimago Journal Ranking (SJR). Papers that do not involve decision-making for supplier selection and only focus on a review (qualitative) and survey and whose SJR index is less than 0.9 are excluded. We obtained 276 papers qualified for review after this checking process. Finally, 326 papers (276 + 50) are included in our study. Fig. 3 represents data collection framework.

3. Exploratory review: The dimensions of supplier selection

We present the review according to the dimensions of supplier selection shown in Fig. 2. The review is systematically organized according to the following order. First, we provide an overview of the sourcing strategy that has been implemented in various industries, discussing sourcing strategy associated with the number of selected suppliers (single or multi-sourcing), planning horizon (single or multi-period demand planning), and the number of items (single or multi-item). Second, we discuss the decision scope in supplier selection problems (pure and integrated selection). Third, we analyze the decision environment,

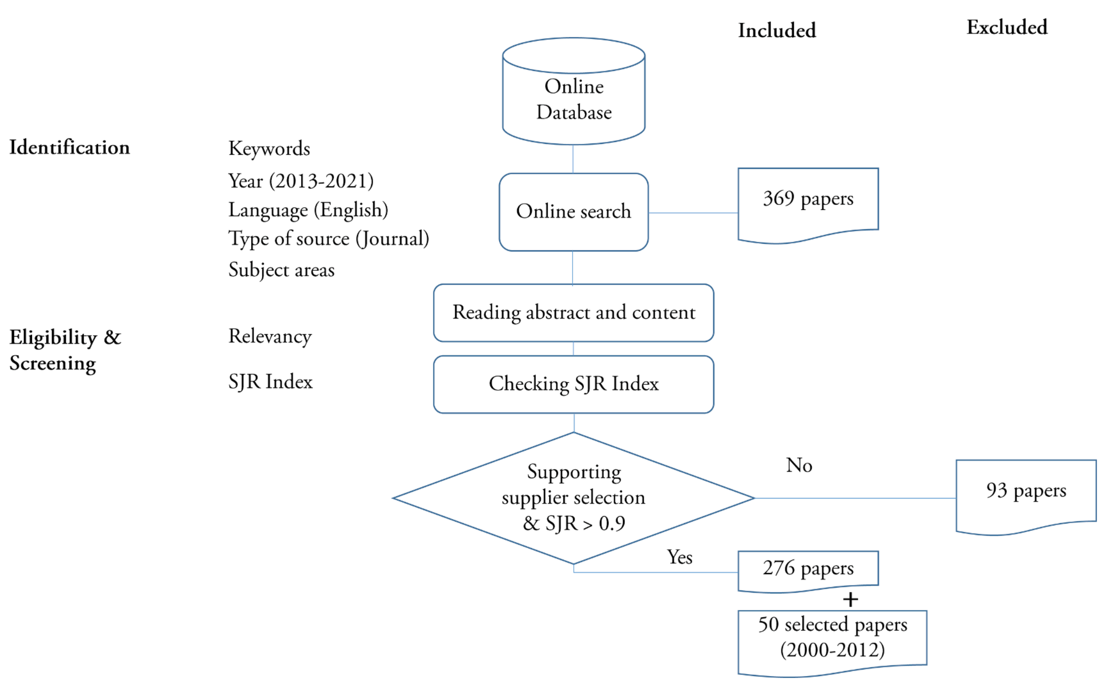

Fig. 3. Papers collection framework.

categorized as certain or uncertain. Fourth, we identify the selection criteria, and, finally, the studies according to the solution approaches are reviewed.

3.1. Sourcing strategy

There are two types of sourcing strategies, namely single and multi-sourcing, and both can be used regarding single or multi-item, as well as single or multi-period. In this review, we discuss sourcing strategies according to the number of suppliers, items, and period, which is illustrated in Fig. 4.

51% of the studies focus on a single sourcing strategy and the remaining 49% deal with a multi-sourcing strategy. According to the number of items, the number of studies addressing single and multi-item are 44% and 56%, respectively. Most of the studies (54%) consider long-term demand planning, which is aggregated into a single-period model. On the other hand, 46% of the studies cover a multi-period model.

According to the planning horizon, a single-period supply indicates that the amount of items to be purchased (order quantity) is constant (non-dynamic), and selected suppliers are identical within the planning period. By contrast, multi-period supply implies a dynamic setting where the number of suppliers and selected suppliers is non-identical, depending on the demand in each period. The order quantity would change over time as a result of dynamic demand. Generally, a multi-period model indicates demand planning with a short time window (i.e., weekly or monthly) (Choudhary and Shankar, 2014; Songhori et al., 2011). Conversely, a single-period model most likely involves demand planning with a large time window (i.e., yearly) (Ghodsypour and O'Brien, 2001; Kull and Talluri, 2008).

In multi-sourcing settings, orders generally need to be adequately allocated to each supplier without omitting its capacity. Managing the supply under multi-sourcing can be complicated in terms of multi-item (Che, 2010a; Rezaei and Davoodi, 2008).

3.2. Decision scope

According to the scope, supplier selection problems can be classified into two categories: pure (48%) and integrated selection (52%). The latter involves not only supplier selection but also other supply chain-related activities such as order allocation, transportation, inventory management, production planning, and closed-loop supply chain or reverse logistics (as shown in Fig. 5). Despite the integrated selection accounting for a high number of papers, 30% of the studies only integrate supplier selection with order allocation. Integrated problems considering transportation (3%), inventory management (11%), production planning (4%), and material flows in reverse logistics (5%) are still scarcely studied.

3.2.1. Pure selection problems

Pure selection involves a single type of decision: selecting or ranking the best supplier. The selection process generally follows a decision-making framework that relies on decision-maker judgment. It typically involves initializing evaluation processes by defining the problem, identifying criteria, and determining the relative criteria importance (criteria weighting). In other words, the final selection output can stem from either a "yes" or "no" decision or a continuous supplier scoring system.

Typically, the scope of pure selection depicts the implementation of a single-sourcing strategy, for a single item, and within a single-period (Bai et al., 2019; Bruno et al., 2012; Chen et al., 2021; Ghoushchi et al., 2020; Gupta and Barua, 2018; Kuo et al., 2016; de Oliveira e Silva et al., 2016). Nevertheless, it is still possible to source from the desired number of suppliers according to the decision-makers perspectives, although the optimal number of the selected suppliers is not guaranteed.

A case study of supplier selection based on the pure selection has been carried out in manufacturing companies engaged in computer, communication, and consumer electronics ("3C") products (Chai and Ngai, 2015), public road and rail transportation (Bruno et al., 2012; Bruno et al., 2016; Dulmin and Mininno, 2003; Xue et al., 2018), electronics (Gao et al., 2020; Rajesh and Ravi, 2015; Kannan et al., 2015; Lee et al., 2009), automobiles (automotive) (Awasthi and Kannan, 2016; Hashemi et al., 2015; Hadian et al., 2020; Memari et al., 2019; R et al., 2017; Sanayei et al., 2010), textiles (Guarnieri and Trojan, 2019; Li et al., 2020), wood & paper (Valipour Parkouhi et al., 2019), energy (Lu et al., 2019), telecommunications (Ahmadi et al., 2017), and constructions (Matic et al., 2019; Shishodia et al., 2019). These studies applied a decision-making process that normally relies on decision-makers judgment. The decision-makers played a key role in identifying supplier selection criteria that meet company strategies and needs, as well as assessing potential suppliers. The strategic decisions were taken by determining the ranking of suppliers according to their performance score and deciding on the number of suppliers to be selected.

3.2.2. Integrated selection problems

In order to improve supply chain management and increase competitiveness, it is crucial to integrate supplier selection with other activities at either tactical or operational levels of a supply chain, including order allocation (Abel et al., 2020; Banaeian et al., 2015; Bohner and Minner, 2017; Choi, 2013; Jain et al., 2015; Kasirian and Yusuff, 2013; Lamba et al., 2019; Lo et al., 2018; Memon et al., 2015; Moheb-Alizadeh and Handfield, 2018; Sanayei et al., 2008; Ruiz-Torres et al., 2013; Sawik, 2017; Sodenkamp et al., 2016; Weber et al., 2000; Wang et al., 2005; Wadhwa and Ravindran, 2007; Ulutas et al., 2016; Yu and Wong, 2015), inventory management (Firouz et al., 2017; Mazdeh et al., 2015; Guo and Li, 2014; Hamdan and Cheaitou, 2017; Keskin et al., 2010; Esmaeili Aliabadi et al., 2013; Alejo-Reyes et al., 2021), transportation (Liao and Rittscher, 2007; Songhori et al., 2011; Choudhary and Shankar, 2014; Choudhary and Shankar, 2013), production planning (Duan and Ventura, 2019; Paydar and Saidi-Mehrabad, 2017; Che and Wang, 2008; Che, 2010a), material flows in a supply chain network design (SCN) (Che and Wang, 2008; Talluri and Baker, 2002; Yeh and Chuang, 2011; Che, 2010b) and reverse logistics (Amin and Zhang, 2012; Tsai and Hung, 2009a; Jahangoshai Rezaee et al., 2017; Moghaddam, 2015a; Rezaee et al., 2017). Unlike the pure selection problems, which typically focus exclusively on one strategic decision, the focus of integrated selection is to determine strategic, tactical, and operational decisions jointly.

Most of the studies in the integrated selection setting include order allocation, which underlies the implementation of a multi-sourcing strategy while aiming to determine strategic and tactical decisions in

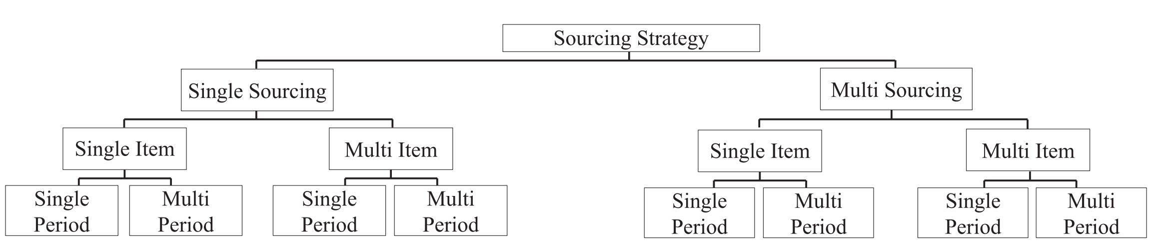

Fig. 4. Categories of sourcing considered in supplier selection problems.

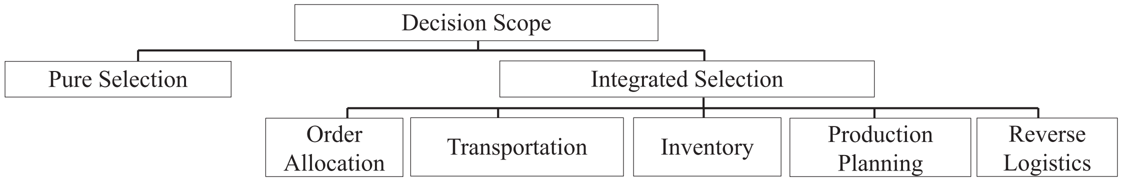

Fig. 5. Categories of decision scope in supplier selection problems.

procurement. Regarding said integration, demand can be fittingly split into partial orders to two or more suppliers without neglecting supplier's capacity (e.g., Mohammaditabar and Ghodsypour (2016) and Ware et al. (2014)). Therefore, costs incurred due to order allocation are taken into account in joint decision-making, such as unit purchasing and contractual costs (see Moghadam et al. (2008), Ware et al. (2014), and Rezaei and Davoodi (2008)).

Other studies consider inbound transportation in the supplier selection process to determine the number of vehicles or carriers. The main objective is reducing inbound transportation costs since a different vehicle or carrier provided by certain suppliers leads to different unit transportation costs. An appropriate vehicle is also selected while evaluating suppliers, according to either the suppliers' shipping distance (Liao and Rittscher, 2007; Choudhary and Shankar, 2014; Choudhary and Shankar, 2013) or unit shipping costs (Ghorbani and Ramezanian, 2020; Kirschstein and Meisel, 2019; Nasiri et al., 2018), as well as the supplier efficiency score (Songhori et al., 2011). In those studies, multi-sourcing was taken into account, holding the extension of order allocation. The order allocation was determined according to transportation costs under full-truck-load (FTL) (Choudhary and Shankar, 2014; Songhori et al., 2011; Choudhary and Shankar, 2013), and less-than-truck-load (LTL) (Liao and Rittscher, 2007).

In addition, several studies incorporate inventory management dealing with decision-making at strategic (supplier selection), tactical (order allocation), and operational levels (inventory management). Inventory decisions, including order quantity and reorder point (in a single period model) (Firouz et al., 2017; Keskin et al., 2010; Pazhani et al., 2016; Zarindast et al., 2017), inventory level (in a multi-period model) (Basnet and Leung, 2005; Mafakheri et al., 2011; Hamdan and Cheaitou, 2017; Turk et al., 2017; Ventura et al., 2013), or backorder level (Niknamfar and Niaki, 2016), were also determined while performing supplier selection. The objective is to minimize both purchasing and inventory costs. Since the costs associated with a given trip represent a significant part, and any order quantity less than or equal to the load capacity of a vehicle can be charged a flat rate, few studies took into account transportation costs combined with inventory costs (Pazhani et al., 2016; Firouz et al., 2017; Keskin et al., 2010).

A cross-functional activity between procurement and production has been integrated to reduce procurement and production/ shop floor-related costs (Paydar and Saidi-Mehrabad, 2017; Du et al., 2015; Ling et al., 2006; Paydar and Saidi-Mehrabad, 2017; Duan and Ventura, 2019; Nguyen and Chen, 2018), as well as to maximize production or project efficiency (Che, 2017; Che and Wang, 2008; Chen et al., 2018). Production costs such as material handling, maintenance, and machine overhead costs have been considered important in supplier selection. Decision-making related to production management at tactical (production planning) (i.e., number of batches or production (Sarvestani et al., 2019; Megahed and Goetschalckx, 2019)) and operational levels (sequencing and job assignment) have been integrated with supplier selection. Considering production management in the earlier stages of supplier selection can contribute to a competitive advantage since selecting appropriate suppliers can help to minimize the cycle time of assembly lines - consequently increasing the total output (Che and Wang, 2008). Besides, it can reduce product delivery time, which, in turn, allows companies to address market demand much faster.

In supply chain network design, supplier selection has been studied to determine decisions associated with plants, distributors, and customers (Che and Wang, 2008; Talluri and Baker, 2002; Yeh and Chuang, 2011; Govindan et al., 2020; Ahmadi and Amin, 2019; Ghayebloo et al., 2015; Shakourloo et al., 2016). The decision-making aims to select appropriate suppliers and distributors by considering their capacity. Accordingly, the order and shipping quantities to the selected suppliers and distributors, respectively, were also determined.

Finally, supplier selection has been addressed to optimize material flows in reverse logistics (e.g., the amount of material in each supply chain party). This problem generally underlies broader horizontal activities across supply chain parties, such as suppliers, plants, disassembly, disposal, and refurbishing sites. This type of decision scope typically aims to maximize profit by taking into account purchasing, production, disassembly, refurbishing, and disposal costs (Amin and Zhang, 2012; Jahangoshai Rezaee et al., 2017; Moghaddam, 2015a; Zouadi et al., 2018; Huang et al., 2016).

3.3. Decision environment

The decision environment in supplier selection problems can be classified into two categories: certain and uncertain (as shown in Fig. 6). We found that most of the studies (55%) focus on uncertain decision environments.

Supplier selection under a certain decision environment involves deterministic parameters and precise information. By contrast, non-deterministic (stochastic) parameters and vague or imprecise information generally represent the characteristics of an uncertain decision environment. According to these characteristics, we categorize the source of uncertainty in supplier selection problems into decision-makers judgment, supplier–buyer parameters, and managerial goals (target).

Supplier selection is considered a strategic decision, typically employing decision-makers or stakeholders' opinions or judgment. In this context, decision-makers take a huge part in defining and prioritizing supplier selection criteria and assessing suppliers' performance. Uncertainty triggering imprecise judgment in the evaluation of suppliers can occur due to an external factor, such as unquantifiable (intangible), incomplete or insufficient, or non-obtainable information related to suppliers (Amin and Zhang, 2012; Lee et al., 2009; Awasthi and Kannan, 2016; Kannan et al., 2015; Liu et al., 2019a; Büyüközkan and Göçer, 2017; Wen et al., 2020; Deng et al., 2014b; Aggarwal, 2019).

Moreover, uncertainty can also emerge due to the variability of demand from buyers (Guo and Li, 2014; Arikan, 2013; Wu and Olson, 2008; Ahmadi and Amin, 2019; liang Zhang and Chen, 2013; Manerba and Perboli, 2019; Balcik and Ak, 2014), as well as the unreliability of quality and delivery, decreased supply capacity, and price fluctuation from suppliers (Xu and Yan, 2011; Arikan, 2013; Haleh and Hamidi, 2011; Razmi and Maghool, 2010; Moghaddam, 2015a; Li and Zabinsky, 2011; Mohammed et al., 2018; Aghai et al., 2014; Aggarwal and Singh, 2015; Hammami et al., 2014). In practice, supply uncertainty usually occurs due to these parameters. If this uncertainty is not taken into account, selection and purchasing decisions will be sub-optimal (Zarindast et al., 2017; Hammami et al., 2014).

Since supplier selection typically involves multi-criteria evaluation, managers in charge of purchasing may need to meet important goals that need to be achieved. In terms of supplier selection, minimizing

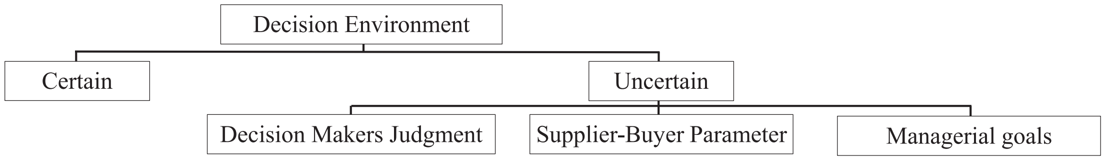

Fig. 6. Categories of decision environment in supplier selection problems.

procurement costs, net rejected items, the total rejection rate of a product, the total amount of defective units, the net late delivered items or delivery lateness frequency, and the number of late items are some of the most considered goals (Choudhary and Shankar, 2014; Arikan, 2013; Memon et al., 2015). In this context, achieving each goal (objective) relies on a target level and specified priority of decision-makers on achieving the target as the goals may not be equally important. In some cases, decision-makers do not have exact and complete information related to objective targets. Hence, it could lead to the uncertainty associated with subjectivity in human decision-making. Furthermore, supplier selection as a strategic decision might involve a shared interest from different business managers in order to meet enterprise strategy and requirements -particularly considering strategic items (Monczka et al., 2015). The interest can differ among a group of decision-makers due to differences in understanding of requirements, information asymmetry, relevance of objectives, and other subjective reasons (Kar, 2015); these factors could potentially raise uncertainty and prevent decision-makers from reaching a consensus regarding supplier selection.

Different techniques can be used to incorporate uncertainty in model parameters. The latter can be represented as fuzzy numbers (e.g., triangular (Arikan, 2013; Haleh and Hamidi, 2011; Razmi and Maghool, 2010; Moghaddam, 2015a; Beikkhakhian et al., 2015; Ghorbani et al., 2013; Pang and Bai, 2013), trapezoidal (Xu and Yan, 2011)), interval (Heidarzade et al., 2016; Wan et al., 2017; Garcez et al., 2021), and stochastic distributions (e.g., gamma (Razmi and Maghool, 2010), exponential (Amorim et al., 2016)).

3.4. Selection criteria

According to the studies, suppliers are assessed based on multi-criteria, which typically involve qualitative and/or quantitative (as shown in Fig. 7). Of all reviewed studies, 2% only take into account qualitative criteria, while 52% consider quantitative criteria, and the remaining 46% incorporate both criteria.

As critical factors for business competitiveness, selection criteria regarding costs, quality, and delivery are strongly taken into account. Typically, these criteria are considered quantitative measures. Concerning the costs criterion, cost components such as unit purchasing, contractual, inventory, fixed, and variable transportation costs have been addressed in the literature. However, only a few studies consider all those aspects (Kannan et al., 2013; Keskin et al., 2010; Firouz et al., 2017; Liao and Rittscher, 2007; Choudhary and Shankar, 2014; Duan and Ventura, 2019; Rezaei and Davoodi, 2012; Lee et al., 2013; Zarindast et al., 2017). A supplier's quality can be assessed according to product specification, number of defects, defect rate, and product reliability. For assessing a supplier's delivery performance, criteria such as delivery time, lead time, order fulfillment rate, on-time delivery, and distance have been considered.

Besides the aforementioned criteria, important intangible criteria that can only be assessed through DM's judgment have also been considered in supplier selection. In this category, qualitative criteria that have been widely used in supplier selection can be classified into technology, services, relationship, and flexibility. Examples of criteria related to technology assessment are the capability of design, innovation, production capability, and technological compatibility (Perçin, 2006; Kannan et al., 2013; Wu et al., 2016; Rajesh and Ravi, 2015). Nevertheless, technology can also be assessed based on tangible criteria, such as productivity, production time, and production capacity (Yeh and Chuang, 2011; Guarnieri and Trojan, 2019). With the evolution of technology, in the context of Industry 4.0, new criteria for supplier selection have been considered, including the level of smart contracts (blockchain), data visibility, traceability (GIS/GPS enabled logistics), and digitalization (cloud computing for resource efficiency and shared platforms) (Kaur and Prakash Singh, 2020; Chen et al., 2020; Hasan et al., 2020). Services from suppliers can be evaluated based on warranty, complaint handling, repair & maintenance services, response to changes, ease of transaction (payment), quality assurance, quality certifications (ISO), and the penalty for delay (Kannan et al., 2015; Yadav and Sharma, 2016; Demirtas and Üstün, 2008; Ustun and Demirtas, 2008; Bruno et al., 2012; Kar, 2015). Concerning the relationship, criteria including managers' attitude, financial position, mutual trust, honesty, communication, management commitment, information sharing, and geographical location have been used to evaluate suppliers (Kar, 2015; Perçin, 2006; Yadav and Sharma, 2016; Lee et al., 2009; Hashemi et al., 2015; Bruno et al., 2012; Lee et al., 2009; Abdollahi et al., 2015). Criteria such as flexibility in purchase quantity, service, process, and product mix have been used to evaluate suppliers with respect to the flexibility (Parkouhi and Ghadikolaei, 2017; Kar, 2015; Yadav and Sharma, 2016; Demirtas and Üstün, 2008; Demirtas and Ustun, 2009; Kannan et al., 2015; Rezaei et al., 2014). We found that these four categories of criteria indicate a buyer's intention in establishing a long-term contract or relationship.

Furthermore, other criteria have been considered to grasp resilience. These criteria are taken into account to mitigate the impact of global supply chains' vulnerability, namely when dealing with unexpected events or disruptions (Meena and Sarmah, 2016; Sawik, 2013; Sawik, 2014; Hu and Dong, 2019). We classified these criteria in supplier selection as a risk category. In this category, it is worth mentioning risk awareness, vulnerability, disruption management, financial instability, currency volatility, political instability, terrorism, labor strikes, supply capacity instability, machine breakdown, IT infrastructure failure, and order delays (Chen and Wu, 2013; Rajesh and Ravi, 2015; Parkouhi and Ghadikolaei, 2017; Wu et al., 2016; Dupont et al., 2018; Kull and Talluri, 2008; Yoon et al., 2018; Liou et al., 2014; Viswanadham and Samvedi,

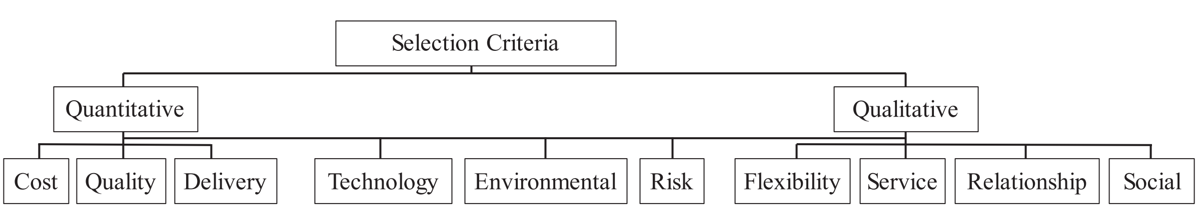

Fig. 7. Categories of selection criteria (adapted from Yadav and Sharma (2016),Perçin (2006), Hashemi et al. (2015),?)).

2013; Rao et al., 2017; Pamucar et al., 2020; Fang et al., 2016).

More recently, sustainability has become a central issue in supplier selection imposing sustainable supply chain initiatives. Green and environmental-related criteria have been addressed in the literature (Jain et al., 2016; Awasthi and Kannan, 2016; Hashemi et al., 2015; Banaeian et al., 2018; Mohammed et al., 2018; Hamdan and Cheaitou, 2017; KhanMohammadi et al., 2018; Dobos and Vörösmarty, 2019; Krishankumar et al., 2020; Qin et al., 2017; Demir et al., 2018; Wu et al., 2019; Mohammadi et al., 2017; Jia et al., 2020). In this category, criteria such as environmental regulation, sustainability assurance certificate, product recycling, pollution, waste production and treatment, resource consumption, and eco-design have been taken into account in supplier selection. Furthermore, social aspects have also been included as a critical aspect of sustainability (Bai et al., 2019; Alikhani et al., 2019; Chen et al., 2020; Gören, 2018; Sarkar et al., 2018; Li et al., 2019; Hendiani et al., 2020b; Ecer and Pamucar, 2020; Jain and Singh, 2020a; Zhou et al., 2016; Orji and Wei, 2015; Azadi et al., 2015; Hendiani et al., 2020a; Xu and Yan, 2011; Zarbakhshnia and Jaghdani, 2018; Fallahpour et al., 2017; Gupta et al., 2016; Bakeshlou et al., 2017). Criteria including health & safety at work, information disclosure, supportive activities, and the workers' interests and rights are commonly considered.

Sustainability criteria are not easily accessible, certifiable, and audited (Foerstl et al., 2018). In order to avoid this information barrier, distributed ledger technology (such as blockchain) can support the credibility and accessibility of information regarding the whole supply chain across multi-tiers and suppliers (Kouhizadeh and Sarkis, 2018; Ghadimi et al., 2019). Although it is still at an early stage, distributed ledger technology shows potential in different issues related to operations management (Babich and Hilary, 2019; Kouhizadeh and Sarkis, 2018; Saberi et al., 2019; Babich and Hilary, 2020). More specifically, in green supplier selection, distributed ledger technology facilitates a trustworthy and free environment between a buyer and supplier through a smart contract, thus reducing opportunistic behaviors between them (Kouhizadeh and Sarkis, 2018; Saberi et al., 2019). The secure and accurate data regarding suppliers' environmental performance made available on a blockchain can help companies to improve supplier selection or evaluation processes. This higher perceptibility also applies to the ability to track items through the entire supply chain or to access information regarding suppliers' capacity at any given time. Chen et al. (2020) and Kaur and Prakash Singh (2020) considered smart technologies as supplier selection criteria for an intelligent, sustainable, and resilient supply chain, respectively.

3.5. Solution approach

There are different approaches used to solve supplier selection problems. We classify them into three major categories: multi-criteria decision-making (MCDM), optimization, and hybrid approaches. Fig. 8 shows the classification of the approaches.

3.5.1. MCDM approach

In general, MCDM approaches are used to tackle pure selection. Typically, a unique optimal solution does not exist in this problem. Therefore, the decision maker's preferences play an important role in differentiating between solutions (Kahraman, 2008). The main selection tasks tackled with this approach involve sorting, ranking, and selection, as well as determining criteria weight (Hashemi et al., 2015; Lee et al., 2009; Awasthi and Kannan, 2016).

In the supplier selection problems, we classify MCDM approach according to the type of performance, including deterministic and uncertain (Cinelli et al., 2020). Deterministic evaluation is applied to deal with complete and precise information. A crisp value represents the value of certain information. Based on the crisp value, an MCDM approach like analytical hierarchy process (AHP) (Matic et al., 2019; Parthiban and Zubar, 2013), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Azimifard et al., 2018; Rodríguez et al., 2013; Hague et al., 2015), VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) (Abdel-Baset et al., 2019), analytic network process (ANP) (Jiang et al., 2018; Govindan et al., 2018; Li et al., 2020), Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) (Dulmin and Mininno, 2003; Abdullah et al., 2019), ELimination Et Choice Translating REality (ELECTRE) (Guarnieri and Trojan, 2019), Measurement of Alternatives and Ranking according to COmpromise Solution (MARCOS) (Stevic et al., 2020), and believable rough set (BRS) (Chai and Liu, 2014) have been employed to tackle supplier selection problems.

Uncertain MCDM relates to decision-makers ambiguities, uncertainties, and imprecision, which cannot be addressed by using a crisp value. MCDM approaches under uncertainty generally transform a value of information into a fuzzy or interval (grey) number. The use of fuzzy set theory enables decision-makers to incorporate unquantifiable, incomplete, and/or non-obtainable information into the decision model, as well as facts that are not fully justified (Kahraman, 2008). The fuzzy set theory has been widely adopted in MCDM approach to solve supplier selection problems, including fuzzy ELETRE (F-ELECTRE) (Zhong and Yao, 2017), fuzzy PROMETHEE (F-PROMETHEE) (Hashemian et al., 2014), fuzzy ANP (F-ANP) (Ayag and Samanlioglu, 2016), fuzzy AHP (F-AHP) (Lee et al., 2009; Zimmer et al., 2017; Lima Junior et al., 2014), fuzzy VIKOR (F-VIKOR) (Sanayei et al., 2010; Awasthi et al., 2018; You et al., 2015), fuzzy TOPSIS (F-TOPSIS) (Gupta and Barua, 2018; Rashidi and Cullinane, 2019; Dowlatshahi et al., 2015; Yu and Wong, 2014; Jang et al., 2017), IVPFS (interval-valued Pythagorean fuzzy set) TOPSIS (Wang et al., 2019), IT2F (interval type-2 fuzzy) TOPSIS (Görener et al., 2017), fuzzy nominal group technique (F-NGT) (Awasthi and Kannan, 2016), fuzzy weighted aggregated sum-product assessment (F-WASPAS) & fuzzy multi-attributive border approximation area comparison (F-MABAC) (Gupta et al., 2019), fuzzy COmbinative Distance-based Assessment (F-CODAS) (Bolturk, 2018), and Fuzzy Combined Compromise Solution (F-CoCoSo) (Ecer and Pamucar, 2020). Other MCDM methods have also been proposed to address uncertainty, including Interval-COmplex PRoportional ASsessment (I-COPRAS) (Matic et al., 2019; Ghorabaee et al., 2014), Grey-Simple Additive Weighting technique (G-SAW) (Valipour Parkouhi et al., 2019), fuzzy multiattribute border approximation area comparison (MABAC) (Pamucar et al., 2020), multiple comparisons with the best (MCB) (Wang and Tamirat, 2016), grey TOmada de Decisão Interativa e Multicritério (G-TODIM) (Bai et al., 2019), and grey additive-veto model (GAVM) (Garcez et al., 2021).

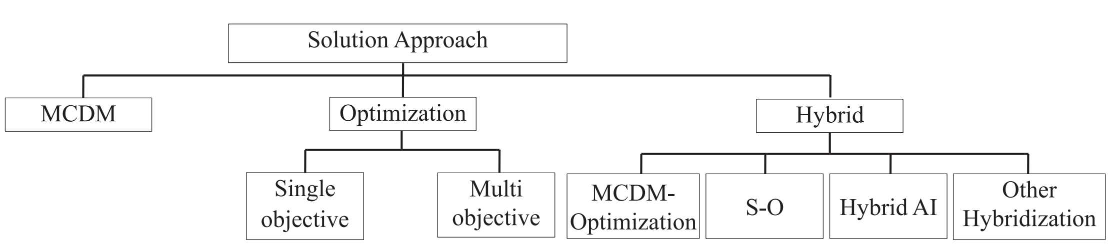

Fig. 8. Categories of solution approaches for supplier selection.

3.5.2. Optimization approach

The studies applying optimization approaches usually address an integrated selection problem, including the integration of supplier selection and order allocation (Arikan, 2013; Kazemi et al., 2015; Jadidi et al., 2015), inventory management (Rezaei and Davoodi, 2008; Rezaei and Davoodi, 2012), transportation (Choudhary and Shankar, 2014; Pazhani et al., 2016; Liao and Rittscher, 2007), and production planning (Paydar and Saidi-Mehrabad, 2017; Duan and Ventura, 2019; Du et al., 2015). Nevertheless, few studies applied an optimization approach to deal with pure selection (Ng, 2008; Jain et al., 2015; Ghoushchi et al., 2020; Dobos and Vörösmarty, 2019).

According to the optimization approaches, the supplier selection problem is formulated into a mathematical model and solved according to a different optimization technique. Using these techniques, it is possible to find an optimal or nearly optimal solution. We classify optimization approaches according to the number of objective functions into single-objective and multi-objective.

Single-objective programming with a linear objective function has been proposed to solve supplier selection problems (Ng, 2008; Rezaei and Davoodi, 2008; Basnet and Leung, 2005; Lee et al., 2013; Jain et al., 2015; Amorim et al., 2016; Nguyen and Chen, 2018; Zouadi et al., 2018; Kanagaraj et al., 2016; Emirhüseyinoglu and Ekici, 2019). Furthermore, several studies applied single-objective programming with a non-linear cost function (Guo and Li, 2014; Ghodsypour and O'Brien, 2001; Pazhani et al., 2016; Soto et al., 2017; Ware et al., 2014). Jain et al. (2016) implemented chance-constrained data envelopment analysis (CC-DEA) to select suppliers so that maximum profit can be achieved. Ng (2008) tackled supplier selection based on the suppliers' score by using a transformation technique that enables the weighted linear program to be solved without the need for an optimizer. Rezaei and Davoodi (2008), Lee et al. (2013), Zouadi et al. (2018) and Alfares and Turnadi (2018) solved mathematical programming using a genetic algorithm (GA) and Kanagaraj et al. (2016),Sadigh et al. (2013) applied integrated GA and cuckoo search. Other metaheuristics, namely a hybrid artificial immune network and particle swarm optimization (aiNet-PSO) (Kuo et al., 2015) and a progressive hedging-based heuristic approach and a benders algorithm (Manerba and Perboli, 2019) also have been proposed. A heuristic algorithm, namely, the Wagner-Within algorithm (W-W algorithm) (Basnet and Leung, 2005), a reduce optimize approach (ROA) (Cárdenas-Barrón et al., 2015), and fixed and optimized heuristics (Sahling and Kayser, 2016), has been used to solve solved mixed integer programming (MIP) model. Nguyen and Chen (2018) and Amorim et al. (2016) solved two-phase stochastic programming by using a multi-cut Benders decomposition technique, as well as Olanrewaju et al. (2020) using a solver. A supplier selection model with a non-linear constraint (Soto et al., 2017) and a non-linear objective function (Yang et al., 2011) has been introduced to achieve minimum total costs. GA guided with local search was used to find a near-optimal solution to solve this model. Instead of using heuristics or metaheuristics, a solver package such as GAMS, CPLEX, GINO, and LINGO have been effectively used to solve mixed-integer non-linear programming (MINLP) (Ghodsypour and O'Brien, 2001; Guo and Li, 2014; Pazhani et al., 2016; Ware et al., 2014; Esmaeili-Najafabadi et al., 2019). Nevertheless, the model solution should not take too long.

A multi-objective setting, with regards to a goal programming variant, has been widely adopted to solve multi-objective programming with a linear function such as preemptive goal programming (PGP), non-preemptive goal programming (non-PGP), weighted fuzzy goal programming (WF-GP) (Choudhary and Shankar, 2014), fuzzy relaxed normalized goal programming (F-RNGP) (Jadidi et al., 2014), improved multi-choice goal programming (MCGP) (Jadidi et al., 2015), weighted and min–max MCGP (Ho, 2019), revised multi-segment goal programming (Karimi and Rezaeinia, 2014), and (interactive) fuzzy goal programming ((I) F-GP) (Kazemi et al., 2015; Wong, 2020; Sheikhalishahi and Torabi, 2014), fuzzy multi-objective linear programming (F-MOLP) (Erginel and Gecer, 2016; Nazari-Shirkouhi et al., 2013), MOMILP (Kellner and Utz, 2019; Toffano et al., 2021), bi-objective DEA (Goswami and Ghadge, 2020), and PSO (Assadipour and Razmi, 2013). Furthermore, several studies considered multi-objective (goal) programming with non-linear cost functions. Evolutionary algorithms have been widely applied to solve multi-objective non-linear programming, namely GA (Liao and Rittscher, 2007), non-dominated sorting genetic algorithms II (NSGA II) (Rezaei and Davoodi, 2012; Deng et al., 2014a; Cao et al., 2014), and multi-objective genetic algorithms (MOGA) (Yeh and Chuang, 2011).

3.5.3. Hybrid approach

Instead of using a single approach, some studies applied a hybrid approach to address supplier selection. We classify the hybrid approaches into four major categories: MCDM-Optimization, simulation–optimization, hybrid Artificial Intelligence (hybrid AI), and other hybrids. In accordance with the literature, MCDM-optimization is most widely used to solve supplier selection problems. Similarly to the optimization approach, the studies employing hybrid approaches also address an integrated supplier selection model, which incorporates order allocation (Scott et al., 2015; Ayhan and Kilic, 2015; Banaeian et al., 2015; Azadnia et al., 2015; Wang and Liang, 2004; Che and Wang, 2008; Perçin, 2006; Kokangul and Susuz, 2009; Narasimhan et al., 2006; Xia and Wu, 2007; Hamdan and Cheaitou, 2017; Hamdan and Jarndal, 2017), inventory management (Ustun and Demirtas, 2008; Razmi and Rafiei, 2010; Mafakheri et al., 2011; Jolai et al., 2011; Hasan et al., 2020; Keskin et al., 2010; Firouz et al., 2017; Hlioui et al., 2017), transportation (Songhori et al., 2011) and material flows in the reverse logistics or closed-loop supply chain (Amin and Zhang, 2012; Moghaddam, 2015a; Moghaddam, 2015b). Moreover, hybrid approaches have also been applied to pure selection problems (Chen and Wu, 2013; Karsak and Dursun, 2014; Kar, 2014; Abdollahi et al., 2015; Kar, 2015; Igoulalene et al., 2015; Kellner et al., 2019).

3.5.3.1. MCDM-Optimization. An MCDM-Optimization approach incorporating qualitative and quantitative criteria relies on two-phase decision-making. Basically, MCDM is employed to determine the value of purchasing representing a score of supplier performance, which involves qualitative and quantitative criteria. The optimization considers a different approach and it is undertaken in the second phase of the process.

Mathematical programming has been widely combined with MCDM, including data envelopment analysis and multi-objective mixed-integer linear programming (DEA-MOMILP) (Songhori et al., 2011), ANP-MOMILP (Ustun and Demirtas, 2008; Razmi and Rafiei, 2010; Bodaghi et al., 2018), AHP-MOMILP (Kokangul and Susuz, 2009; Narasimhan et al., 2006; Xia and Wu, 2007; Mafakheri et al., 2011), TOPSIS-MOMILP (Kannan et al., 2013; Mohammed et al., 2018; Lo et al., 2018; Mohammed et al., 2019; Tirkolaee et al., 2020), multi-attribute utility theory and linear programming (MAUT-LP) (Sanayei et al., 2008), TOPSIS-LP (Li and Zabinsky, 2011; Kilic, 2013; Singh, 2014), AHP-GP (Wang and Liang, 2004; Che and Wang, 2008; Perçin, 2006), AHP-MCGP (Liao and Kao, 2011), TOPSIS-GP (Jolai et al., 2011; Hasan et al., 2020; Kasirian and Yusuff, 2013), TOPSIS-MCGP (Hasan et al., 2020; Sharma and Balan, 2013), multi-objective optimization model based on the ratio analysis and GP (MOORA-GP) (Arabsheybani et al., 2018), linguistic entropy weight method and GP (LEWM-GP) (Feng and Gong, 2020), PROMETHEE-MOMILP (Bektur, 2020), MAUT and integer programming (Wong, 2020), best-worst method and MCGP (BWM-MCGP) (Cheraghalipour and Farsad, 2018), EDAS (Evaluation based on Distance from Average Solution) and F-MOLP (Keshavarz Ghorabaee et al., 2017), WSM and F-MOLP (Babic and Peric, 2014), and fuzzy MULTIMOORA-GP (spsacctoremoveAPAÇebi and Otay, 2016).

Furthermore, metaheuristics, such as particle swarm optimization (PSO) and GA, have also been hybridized with MCDM methods in the literature. Some of them include AHP-PSO (Che, 2010a) and AHP-GA

(Hamdan and Cheaitou, 2017; Hamdan and Jarndal, 2017).

3.5.3.2. Simulation–Optimization. Based on the simulation purpose within this hybridization suggested by Figueira and Almada-Lobo (2014), simulation–optimization can be divided into evaluation function (EF), surrogate model construction (SMC), analytical model enhancement (AME), and solution generation (SG). In supplier selection, simulation–optimization is usually developed using EF. Keskin et al. (2010) and Firouz et al. (2017) proposed hybrid scatter search and simulation. Supplier selection decisions were optimized by scatter search, considering the costs obtained from the simulation. Hlioui et al. (2017) applied a hybrid simulation and response surface methodology. The simulation was used for the construction of a surrogate model (SMC). The Response Surface Methodology was used to determine the relationship between supplier and inventory decisions, which become the simulation inputs, interactions, and the total cost. Moghaddam (2015b) proposed a hybrid Monte Carlo simulation and goal programming, generating goals for each objective function and weights of the goals' deviations. Park et al. (2018) and Dotoli et al. (2016) applied discrete-event and Monte Carlo simulation respectively integrated with DEA. Shadkam and Bijari (2017) developed a hybrid cuckoo algorithm and discrete event simulation.

3.5.3.3. Hybrid artificial intelligence. One can use this approach to address pure and integrated selection problems. Artificial Intelligence tools and approaches, including: *(i) fuzzy set theory*, used to address the imprecision and uncertainty inherent to human judgment in decision-making processes (i.e., fuzzy consensus-based neat OWA (ordered weighted average) and goal programming (Igoulalene et al., 2015); interval and hesitant fuzzy technique (IHF) (Chai and Ngai, 2015); generalized intuitionistic fuzzy soft set (GIFSS) and GRA (Chen and Zou, 2017), interval-valued intuitionistic uncertain linguistic (IVIUL) (Liu et al., 2019a); fuzzy group graph theory and matrix approach (FGGTMA) (KhanMohammadi et al., 2018); fuzzy axiomatic design (F-AD) (Kannan et al., 2015), FIS (fuzzy interface system) and assurance region DEA method (AR-DEA) (Amindoust, 2018), multi-agent system and FIS (Ghadimi et al., 2019), FIS and fuzzy rule-based (Lima et al., 2013; Paul, 2015), q-rung orthopair fuzzy set (Krishankumar et al., 2020), fuzzy Kano model-based FIS (Jain and Singh, 2020; Jain et al., 2016)), fuzzy decision support system (García et al., 2013), and fuzzy support vector domain description (SVDD)-cooperative coevolution algorithm (Guo et al., 2014); *(ii) grey system theory*, which is applied to imprecise information in the form of interval values (i.e., GRA (grey relational analysis) (Rajesh and Ravi, 2015); F-GRA (Haeri and Rezaei, 2019); F-GRA and MILP (Banaeian et al., 2015); GRA and chance-constrained goal programming (CCGP) (Memon et al., 2015); GRA and principal component analysis (PCA) (Pitchipoo et al., 2015)); *(iii) expert systems*, applied to incorporate the experts' opinion and knowledge in the field through a series of IF-THEN rules (i.e., hybrid knowledge base and bi-objective mathematical programming (Ghadimi et al., 2018)), *(iv) Bayesian network*, which uses probabilistic graphical models to represent uncertainty (i.e., DEMATEL-Bayesian Network (Kaya and Yet, 2019)), *(v) Dempster-Shafer theory (DST)*, which is used to combine unexpected empirical evidence regarding the evaluation of judgement and consequently organize a coherent picture of reality (i.e., Dempster-Shafer VIKOR (DS-VIKOR) (Fei et al., 2019); Dempster-Shafer ELECTRE (DS-ELECTRE) (Fei et al., 2019)); and *(vi) neural network (NN)*, which helps the network predicting the correct class label for the input objects based on the weight associated to the connection of an input–output in the learning phase (i.e., F-AHP and Fuzzy Neural Network (F-NN) (Kar, 2015); adaptive neuro fuzzy inference system (ANFIS) and artificial neural network (ANN) (Tavana et al., 2016)), have been extended to solve supplier selection.

3.5.3.4. Other hybridizations. Some studies in the literature applied a hybrid approach, which is not included in the three main categories discussed before, such as quality function deployment (QFD), statistical models, failure mode and effect analysis (FMEA), strengths-weakness-opportunities-threats analysis (SWOT), cluster analysis, and game theory. In this classification, the majority of the studies applied QFD and statistical models for supplier selection.

For studies employing QFD for supplier selection, inner dependence among supplier evaluation criteria is assessed by creating a house of quality (HOQ). This method has been improved with fuzzy (Lima-Junior and Carpinetti, 2016) and combined with SAW (Dursun and Karsak, 2013), DEA (Karsak and Dursun, 2014), OWA (Karsak and Dursun, 2015), ANP (Asadabadi, 2017), MOMILP Bevilacqua et al. (2006), F-AHP (Alinezad et al., 2013), AHP and chance-constrained programming (CCP) (Scott et al., 2015), and fuzzy partitioned Bonferroni mean (Liu et al., 2019b).

The hybrid statistical models, such as fuzzy six sigma and the statistical analysis (Chen et al., 2019) and six sigma-euclidean distance Yang and Chen (2019) were used for supplier selection concerning the quality of final products. Another statistical model proposed by Davoudabadi et al. (2020), namely PCA, has been integrated with DEA to reduce the dimensions and the correlation between the criteria in supplier selection. Talluri and Narasimhan (2003) used hybrid DEA and Kruskall-Wallis test for suppliers clusterization. Cheng et al. (2020) developed support vector regression (SVR) integrated with DEA-TOPSIS.

The remaining approaches are found to be less explored. Jahangoshai Rezaee et al. (2017) and Wang and Li (2014) applied an integrated DEA and Nash bargaining game to create a competitive environment between suppliers, namely when the buyer defines a minimum efficiency level. Amin et al. (2011) proposed a hybrid approach using fuzzy SWOT and fuzzy LP, enabling decision-makers to evaluate suppliers under imprecise judgment and to identify suppliers' portfolios based on internal and external factors. Parthiban et al. (2013) integrated fuzzy SWOT with DEA. Chen and Wu (2013) and Foroozesh et al. (2018) proposed a hybrid FMEA for supplier selection. Hybrid cluster analysis, namely fuzzy C means, was applied for pure supplier selection problem integrated with fuzzy DEMATEL (Keskin, 2015) and rough set (Omurca, 2013).

4. Supplier selection framework

4.1. Formulating supplier selection problems for different types of items and production policies

The problem statement in supplier selection needs to be appropriately addressed, including determining the sourcing strategy, incorporating related supply chain activities (decision scope), and uncertainty (decision environment) while identifying supplier selection criteria. Supplier selection needs to be appropriately formulated since the characteristics of items and industrial settings associated with the production policy are different. From the reviewed studies, we extract the appropriate problem setting for each combination of production policy and type of item, which is summarized in Table 1.

Concerning the types of items, we found that the reviewed studies focus on the supplier selection for strategic, bottleneck, and leverage items. None of the studies deal with non-critical items due to their low complexity and importance. Their acquisition process should be simplified, and the final selection for its supplier should be more straightforward. Direct purchase or day-to-day purchases can be performed through an online vendor catalog to reduce time and effort (Monczka et al., 2015).

In supplier selection problems, the sourcing strategy varies depending on the complexity of supply and other factors associated with the production policy. Sourcing strategy for strategic and bottleneck items typically follows multi-sourcing with a single period model for all production policies (Scott et al., 2015; Kull and Talluri, 2008; Kokangul and Susuz, 2009; Jain et al., 2015; Ayhan and Kilic, 2015; Amin et al., 2011).

Table 1
Sourcing strategy, criteria, decision scope and environment based on the KPM and production policy

Production Policy	Types of item	Dimensions				
		Sourcing	Period	Criteria	Scope	Decision Environment
ETO	**Strategic, Bottleneck**	Multi	Single	**Winner:** technology capability (Ql)(technical capability, product innovation capability, technological compatibility); lead time (Qn) (design, manufacturing & delivery); Quantity flexibility (Qn); risk factors (Qn, Ql); **Qualifier:** purchasing costs (Qn)	OA	Supplier–buyer parameters, Decision-makers judgment
	Leverage	Single	Single	**Winner:** purchasing costs; **Qualifier:**: technology capability (Ql) (technical capability, product innovation capability, technological compatibility); lead time (Qn) (design, manufacturing & delivery); Quantity flexibility (Qn)	PS	Supplier–buyer parameters
MTO	**Strategic, Bottleneck**	Multi	Single	**Winner:** technology capability (Ql)(technical capability, product innovation capability, technological compatibility); lead time (Qn) (design, manufacturing & delivery); Quantity flexibility (Qn); risk factors (Qn, Ql); **Qualifier:** purchasing costs (Qn)	OA, PP	Decision-makers judgment; Supplier–buyer parameters
	Leverage	Single	Single	**Winner:** purchasing costs (Qn); transportation costs (Qn); **Qualifier:** technology capability (Ql)(technical capability, product innovation capability, technological compatibility); lead time (Qn) (design, manufacturing & delivery); Quantity flexibility (Qn)	PS	Supplier–buyer parameters
ATO/MTS	**Strategic**	Multi	Single	**Winner:** contractual costs (Qn); purchasing costs; inventory costs (Qn); transportation costs (Qn); supply capacity (Qn); relationship (Ql)(management commitment, honesty, reputation, communication); risk factors (Qn, Ql)	OA, PP, I	Supplier–buyer parameters; Decision-makers judgment; Managerial goals
	Bottleneck	Multi	Single	**Winner:** supply capacity (Qn); relationship (Ql)(management commitment, honesty, reputation, communication); risk factor (Qn) **Qualifier:** contractual costs (Qn); purchasing costs; inventory costs (Qn); transportation costs (Qn)	OA, PP, I	Supplier–buyer parameters; Decision-makers judgment; Managerial goals
	Leverage	Single	Multi	**Winner:** purchasing costs; inventory costs; transportation costs; **Qualifier:** supply capacity (Qn)	PS, I	Supplier–buyer parameters

Ql: Qualitative criteria — Qn: Quantitative criteria — OA: Order allocation — PS: Pure selection — I: Inventory management — PP: Production planning.

Multi-sourcing can be applied to mitigate the high risks of supply, particularly for strategic and bottleneck items. For instance, a disruptive event can trigger a significant loss to buyers due to the unreliability of suppliers to perform their operation or even due to their absence. A multi-sourcing strategy enables buyers to split and rely on other suppliers, who can then compensate for the disruptions of the former. A single-period model in ATO and MTS typically indicates a medium-to-long-term demand plan. It also implies the intention to develop good supplier relationships in order to ease the communication, consolidation, and coordination, as well as to maintain the continuity of supply and mitigate the risk of supply. Meanwhile, the application of a single period in ETO and MTO holds a different principle depending on the customization, the so-called versatile manufacturing company (VMC) (see Stevenson et al. (2005) for more detail). In VMC, where the purchase volume is low and the customization is high, the demand fulfillment is typically based on a single period under short-term planning. A long-term supplier relationship is not necessary in these cases. Contrary to the strategic and bottleneck items, leverage items apply single-sourcing due to low risk of supply (Soto et al., 2017). Nevertheless, multi-sourcing may also be applied since this type of items constitutes high volume demand while suppliers' capacity is limited in practice (Azadnia et al., 2015; Kilic and Yalcin, 2020). For leverage items, with a high number of suppliers and source availability, buyers may focus on selecting suppliers based on a multi-period under a short-term contract (Soto et al., 2017; Azadnia et al., 2015; Mohammed et al., 2018; Babbar and Amin, 2018). However, since this type of items substantially impacts profit, buyers can also consider selecting suppliers under a medium-term contract to maintain a high level of quality and reduce the total costs to the business.

The appropriateness of supplier selection criteria depends on the importance of purchasing and the issues that raise the challenges of the production policy. For instance, ETO and MTO production policies in which the purchasing and production activities are only done after receiving customer orders and products are manufactured to meet specific customers' needs, require reliability in manufacturing lead time and product requirements. Therefore, incorporating these concerns into supplier selection criteria is essential to the implementation of the production policy. Supplier selection criteria, including suppliers' product design, innovation, production capabilities, and technological compatibility, are taken into account as means to meet customer's requirements in ETO and MTO production policies (Kannan et al., 2013; Rajesh and Ravi, 2015; Perçin, 2006; Wu et al., 2016; Dulmin and Mininno, 2003; Yousefi et al., 2017). In addition, suppliers' production (design) and delivery time are also considered critical criteria in supplier selection for ETO and MTO (Awasthi and Kannan, 2016; Jain et al., 2015; Rajesh and Ravi, 2015; Dulmin and Mininno, 2003; Kuo et al., 2016). Criterion such as flexibility of purchase quantity is also essential to consider (Xu and Ding, 2011; Chen et al., 2020), since the demand volume in these production policies is unique for each customer order. In MTS and ATO, where a customer's order is met from stock, inventory management becomes the main issue. Criteria such as inventory cost are taken into account in this case (Ayhan and Kilic, 2015; Lee et al., 2013; Soto et al., 2017; Yin et al., 2015).

Furthermore, the order winners and qualifiers related to the supplier selection vary depending on the importance of purchasing. For items with a high impact on profit, such as strategic and leverage, the criteria should focus on the monetary base orientation to reduce total cost. For leverage items, order winners can be determined based on monetary criteria (Lee et al., 2013; Soto et al., 2017; Jain et al., 2015; Moghadam et al., 2008), since the number of suppliers and substitution possibilities are large. Therefore, a buyer has more power in a negotiation, and a monopoly on the pricing does not exist among suppliers. For strategic items, due to a high volume of purchases (except in ETO and MTO), a buyer can approach suppliers to negotiate pricing options for specific purchase volumes. This negotiation enables a buyer to reduce costs through different pricing strategies (Jain et al., 2015). However, it requires an effort to pursue negotiations with suppliers since the number of suppliers is small. In addition, suppliers are usually in control in said negotiations, and very little competition exists among them. Buyers also need to maintain a high quality since these types of items are important to the business. Competitive bidding can be very useful in maintaining a reduced price and a high level of quality (Gelderman and Weele, 2003).

With the increase of the items' importance on the operations, such as strategic items, non-monetary based oriented criteria (i.e., technology, relationship, flexibility) are also important (Azadnia et al., 2015; Ustun and Demirtas, 2008; Demirtas and Ustun, 2009; Kokangul and Susuz, 2009). Bottleneck items indicate a low impact on profits but a high impact on operations. The main focus of managing this type of item is to ensure supply continuity. Criteria for selecting bottleneck items' suppliers can be more focused on achieving a non-monetary added-value (Che, 2017; Wang and Liang, 2004; Amin et al., 2011; Lin et al., 2011). Reducing total costs for bottleneck items is not straightforward because buyers encounter high switching costs and lack negotiating power due to small purchase volume. Besides, suppliers have more power due to their ability to provide inputs that are important to the operation. However, buyers might make an effort to negotiate with suppliers through competitive bidding to obtain a lower purchasing price.

The supply complexity also brings specific supplier selection criteria. Considering long-term relationships in supplier selection is beneficial in reducing the impact of risk factors triggering supply complexity. Concerning this kind of relationship, criteria such as management commitment, honesty, reputation, communication, and disruption management have been taken into account in the selection of bottleneck and strategic items, particularly in ATO and MTS (Lin et al., 2011; Hashemi et al., 2015; Amin et al., 2011).

The factors, including supply complexity (i.e., the implementation of sourcing strategy), importance of purchasing (i.e., the incorporation of the criteria), and production policy, play a role in the integration of activities in supplier selection. For instance, the decision scope of order allocation becomes larger when implementing a multi-sourcing strategy for bottleneck and strategic items (Scott et al., 2015; Kilic, 2013; Xu and Ding, 2011). In addition, the decision scope remains large, even for leverage items, whenever the pivotal criteria affecting the success of a production policy implementation are incorporated. Regarding the decision scope, inventory management is often integrated with supplier selection, particularly in ATO and MTS (Soto et al., 2017; Lee et al., 2013). Exceptionally, in ETO, the decision scope for leverage items only deals with pure selection due to the characteristics of its customization (Dulmin and Mininno, 2003; Wu et al., 2016).

The source of uncertainty in supplier selection problems becomes diverse with the increase of supply and production complexities and the increase of purchasing importance. For instance, the source of uncertainty, including supplier–buyer parameters and decision maker's judgment, exists for strategic and bottleneck items due to high supply complexity (Scott et al., 2015; Du et al., 2015; Amin et al., 2011). The diversity of the source of uncertainty related to the supplier–buyer parameters also varies. For example, demand is typically known and certain in ETO and MTO. However, other parameters related to suppliers such as quality, lead time, and price are often uncertain due to the supply complexity (Zimmer et al., 2017; Wu et al., 2016; Awasthi et al., 2018). For the items that have a significant impact on profit and operations, such as strategic items, setting up precise managerial targets (goals) appears to be difficult since it requires careful consideration within enterprise strategy and requirements. Typically, in ATO and MTS, to relax the preferences, decision-makers usually define their targets or goals as imprecise values (Kannan et al., 2013; Tsai and Hung, 2009b). In ETO and MTO, managerial targets are known precisely (Lee et al., 2009; Kull and Talluri, 2008; Perçin, 2006), since customers typically specify the product or purchase requirements in advance.

4.2. Approaching different supplier selection problems

Once the problem statement is determined appropriately, a suitable solution approach is demanded to solve it. As not all the approaches are equally useful in every possible purchasing situation (de'Boer et al., 2001), we seek to analyze the suitability of the approaches in dealing with the dimensions according to the problem statements discussed earlier. Table 2 shows the suitability of the approaches to address said different problems.

Based on the analysis, one can observe hybrid approaches prevail both in tackling a broader scope of supplier selection problems, as well as in incorporating criteria holistically and uncertainty. MCDM-Optimization is noticeably the most widely used hybridization. Indeed, this combination has several benefits. First, both qualitative (flexibility, service, environment management, green image) and quantitative criteria (quality, price, order fulfill rate) can be well incorporated in the supplier selection (Azadnia et al., 2015; Kull and Talluri, 2008; Perçin, 2006; Ustun and Demirtas, 2008; Demirtas and Ustun, 2009; Singh, 2014). This would be difficult using standalone mathematical optimization models. Second, multiple phases, such as criteria weighting, supplier evaluation (performance assessment), and constraint assurance, can be used to accommodate decision-makers preferences while seeking the optimal solution (Azadnia et al., 2015; Kull and Talluri, 2008; Perçin, 2006; Ustun and Demirtas, 2008; Demirtas and Ustun, 2009; Singh, 2014). Third, interrelated decisions (e.g., order allocation, transportation, and inventory replenishment), which may involve a large number of alternatives, can be properly evaluated. Therefore, steps such as pre-qualification may not necessarily be performed as they can be jointly optimized. MCDM-Optimization appears to be applicable for solving supplier selection problems that fit almost all the characteristics of the dimensions. For instance, it can accommodate various types of sources of uncertainty, including supplier–buyer parameters (Govindan et al., 2020; Haleh and Hamidi, 2011), DMs' judgment (Kilic, 2013; Azadnia et al., 2015; Che, 2010b; Ayhan and Kilic, 2015), and managerial target (Kannan et al., 2013; Tsai and Hung, 2009b; Mohammed et al., 2018).

However, not all the hybrid approaches are equally useful and applicable in dealing with the different criteria, decision scopes, and environments. Simulation–optimization is more suitable to incorporate quantitative criteria and is very useful for tackling integrated problems and representing some particular sources of uncertainty, such as supplier–buyer parameter (Firouz et al., 2017; Keskin et al., 2010; Hlioui et al., 2017) and managerial targets or goals (Moghaddam, 2015a). Hybrid AI is limited to the incorporation of uncertainty into decision-

Table 2
Approaches for the different supplier selection problems

Criteria	Decision Environment		Scope: Pure Selection Single sourcing-Single period	Scope: Integrated Selection All sourcing strategies
Qualitative	**Certain**		MCDM, MCDM-Optimization, Hybrid AI	MCDM-Optimization
	Uncertain	**DM's judgement**		
		Supplier–Buyer parameter	N/A	
		Managerial target (goals)	MCDM-Optimization, Hybrid AI	MCDM-Optimization, Hybrid AI
Quantitative	**Certain**		Optimization, MCDM-Optimization, Hybrid AI	Optimization, MCDM-Optimization
	Uncertain	**DM's judgement**	MCDM-Optimization, Hybrid AI	MCDM-Optimization
		Supplier–Buyer parameter	Optimization, S-O	Optimization, MCDM-Optimization, S-O
		Managerial target (goals)	Optimization, MCDM-Optimization, Hybrid AI	

AI: Artificial Intelligent — S-O: Simulation–optimization makers judgment (Kar, 2015; Kaya and Yet, 2019). However, the applicability of this approach to the decision scope is large, including pure and integrated selection (Ghadimi et al., 2018).

Single-based approaches are useful for specific problem statements dealing with criteria, decision scope, or decision environment. For the type of items and production policy that follow the pure selection, the problems generally incorporate supplier selection criteria, including both qualitative and qualitative criteria. In these cases, a pure MCDM is sufficient to accommodate the criteria and obtain a solution that satisfies the decision maker's preferences (Yadav and Sharma, 2016; Dulmin and Mininno, 2003; Azimifard et al., 2018). In addition, MCDM can also be applied to incorporate uncertainty, mainly dealing with DMs' judgment (Banaeian et al., 2018; Zimmer et al., 2017; Lee et al., 2009). However, MCDM can appropriately perform when the number of alternatives is relatively small due to the consistency assurance in supplier evaluation (Saputro et al., 2015). This indicates that it is necessary to perform pre-qualification to reduce the number of possible alternatives when solely employing MCDM. Thus, the inconsistency of human judgment can be avoided. On the other hand, pure selection can also be effectively tackled using pure optimization, considering that all selection criteria are measurable (quantitative). Furthermore, optimization is useful in tackling a complex problem and incorporating decisions (i.e., strategic and tactical), that are solved simultaneously, such as order allocation, inventory management, and production planning.

All the approaches (hybrids and optimization) are helpful to address single and multi-sourcing strategies, as well as single and multi-period (Scott et al., 2015; Yeh and Chuang, 2011; Soto et al., 2017; Lee et al., 2013; Ghadimi et al., 2018; Keskin et al., 2010; Firouz et al., 2017). Exceptionally, MCDM is useful when only the problems hold single-sourcing with a single period (Yadav and Sharma, 2016; Dulmin and Mininno, 2003; Azimifard et al., 2018; Banaeian et al., 2018; Zimmer et al., 2017; Lee et al., 2009).

According to the analysis, we found that among the dimensions, supplier selection criteria, decision scope, and decision environment play a vital role in the applicability and suitability of the approaches. Additionally, the extent of the decision scope relies on the implementation of a multi-sourcing strategy and the incorporation of supplier selection criteria, which typically depend on the purchasing importance and production policy. Hybrid approaches can be used to tackle supplier selection of items whose supply complexity is high (i.e., strategic and bottleneck items). For items with a low supply complexity (as the decision scope and environments' driver) (i.e., leverage items), standalone approaches, including optimization and MCDM, can be employed to solve the problems. To incorporate both qualitative and quantitative criteria (i.e., for strategic items), MCDM-optimization and Hybrid AI are the appropriate approaches.

5. Trends and opportunities for future work

This paper provides a theoretical framework that can be adopted to deal with the supplier selection process, particularly in determining the critical dimensions so that the problem can be appropriately formulated and solved. Holding the principle of Kraljic's purchasing classification and incorporating the characteristics of production policy, the framework is proposed to fit the different types of items comprising different importance levels of purchasing and different production and supply complexities. Over 150 published papers focusing on supplier selection are discussed in light of the novel framework.

Our review highlights the recent developments on the supplier selection studies (e.g., source of uncertainty in supplier selection, sourcing strategy and critical criteria in the current challenge, extensive selection criteria in supply chain network design) and improves the range of works reported by the previous reviews (e.g., the widespread approaches reported by Aissaoui et al. (2007),Ho et al. (2010), Chai and Ngai (2015),Simic et al. (2017), Ocampo et al. (2018)). Four major research trends emerge from our review.

- **Fostering supply chain resilience through risks mitigation** - In today's global market, which is quite challenging, the decision environment in supplier selection is found to be highly uncertain. The source of uncertainty coming from buyers (i.e., demand) and suppliers (quality, capacity, price, lead time) could contribute to a failure to meet customer demand without a proper sourcing strategy (Haleh and Hamidi, 2011) and supplier selection (Li and Zabinsky, 2011). Our review shows that multi-sourcing is the most common strategy considered in supplier selection. This strategy is considered appropriate to approach the supply of items whose supply risks are high (i.e., strategic and bottleneck items), particularly when suppliers experience capacity issues and suffer from disruptions (Firouz et al., 2017). More extensively, recent studies have taken into account resilient supplier selection criteria focusing on risk mitigation for these types of items. Risk-related quality and delivery were found to be the most common factors studied in supplier selection. Solution approaches have been developed, particularly for assessing risk factors. MCDM approaches were often used to evaluate suppliers' risk profiles. Other sources of uncertainty, including decision maker's judgment and managerial goals (target), enhance supplier selection complexity. According to our review, the uncertainty of the decision maker's judgment has been intensively addressed in the pure supplier selection problem. To incorporate these uncertainties (managerial goals and DMs' judgment), fuzzy set theory has been widely applied.
- **Embracing sustainability goals** - More recently, supplier selection criteria have evolved rapidly, from green to sustainable concepts, considering economic, social, and environmental criteria (Bai et al., 2019; Chen et al., 2020; Gören, 2018). In the closed-loop supply chain or reverse logistics, mainly in the high-tech industry (i.e., automotive, electronic, and energy industries), sustainability is essential to improve the design of the supply chain network (Govindan et al., 2020). This integrated selection is generally concerned with strategic and tactical decisions in a wide scope, involving multiple objectives. Since the right supplier selection approaches depend on the criteria and the decision scope (which relies on the sourcing strategy and criteria), MCDM-optimization is widely used to solve this problem, thus dealing with the aforementioned dimensions.
- **Integrating supply chain processes** - Our review shows that the more complex the supply and the more important the purchasing process are, the wider the decision scope and the more diverse the source of uncertainty are. Integrating supplier selection with supply chain activities, including order allocation, inventory management, and production planning, is essential in this context (Duan and Ventura, 2019; Hamdan and Cheaitou, 2017). In addition, there is an increased added value to achieve and additional criteria to consider. The suitability of the approach in supplier selection appears to depend on both the complexity of supply and production and the importance of purchasing. In other words, a particular situation related to sourcing strategy, supplier selection criteria, decision environment, and decision scope should be addressed through a specific approach, such as hybrid approaches (MCDM-Optimization, Simulation–Optimization, Hybrid AI) for the complex problems.
- **Considering distributed ledger technology adoption** - Establishing mutually beneficial long-term supplier relationships, particularly for strategic items, is a vital step in enhancing a firm's performance across the supply chain. The adoption of distributed ledger technology (i.e., blockchain) can improve the supplier selection process (Chen et al., 2020; Kaur and Prakash Singh, 2020), thus enabling a firm and suppliers to build mutual trust and honesty through traceability and transparency of the shared information using smart contracts (Babich and Hilary, 2020). Furthermore, the suppliers' historical performance and data that are not easily accessible or certifiable, especially in sustainability and resilience criteria underlying the research trends, can be accommodated effectively using

blockchain technology. Therefore, in the presence of this technology, suppliers' participation in a blockchain system plays a key role, with its associated selection criteria supporting this initiative (i.e., management commitment, sharing information, ease of communication (Hashemi et al., 2015; Lin et al., 2011; Yadav and Sharma, 2016; Singh, 2014), and technology capability (Kaur and Prakash Singh, 2020; Chen et al., 2020; Hasan et al., 2020)). Besides these aforementioned criteria, the inclusion of smart technology as supplier selection criteria is essential (Chen et al., 2020; Kaur and Prakash Singh, 2020).

Although uncertainty in terms of decision maker's judgment, managerial goals, and buyer's parameter (e.g., demand) have been widely considered in the literature, the vast majority of research does not incorporate uncertain parameters, particularly from suppliers, such as their capacity, quality, and delivery (Guo and Li, 2014; Arikan, 2013; Wu and Olson, 2008; Moghadam et al., 2008; Yin et al., 2015). In addition, the incorporation of supplier selection criteria in the context of smart sustainability needs serious attention since the number of studies addressing this concern is still limited (Chen et al., 2020; Kaur and Prakash Singh, 2020). On the other hand, most studies address the problem by considering just a few relevant dimensions, leading to significant gaps. Table 3 summarizes supplier selection problems from past studies according to critical dimensions, including sourcing strategy, decision environment, and decision scope. For instance, the integration of some related problems, including transportation, inventory, production planning, and reverse logistics, still has important gaps (indicated in Table 3). Therefore, future work should focus on the following problems:

(i) Integration of supplier selection and transportation with multi-sourcing, a single period, multi-items for bottleneck and strategic items considering uncertainty in MTO/ ATO/ MTS production policy.
(ii) Integration of supplier selection and inventory management with multi-sourcing for strategic or bottleneck items with multi-item under joint replenishment in ATO and MTS production policies.
(iii) Integration of supplier selection with a single sourcing strategy, multi-period for leverage items in ATO/ MTS production policy under uncertainty.
(iv) Integration of supplier selection and material flow in reverse logistics considering sustainability and distributed ledger technology adoption under uncertainty.

Table 3
Research trend in supplier selection problems.

SCOPE	DECISION ENVIRONMENT	Single Sourcing				Multi Sourcing			
		Single Item		Multi Item		Single Item		Multi Item	
		Single Period	Multi Period	Single Period	Multi Period	Single Period	Multi Period	Single Period	Multi Period
Pure	Certain	Chen & Wu (2013); Jain et al. (2016); Azimifard et al. (2018); Govindan et al. (2018); Kaya & Yet (2019); Matic et al. (2019); Gao et al. (2020)	Not Applicable						
	Uncertain	Abdollahi et al. (2015); Chai & Ngai (2015); Awasthi & Kannan (2016); Wu et al. (2016); Zimmer et al. (2017); KhanMohammadi et al. (2018); Chen at al. (2019); Lu et al. (2019); Singh (2020); Chen et al. (2020)							
Order Allocation	Certain	Not Applicable				Weber et al. (2000); Sanayei, Farid Mousavi, Abdi, and Mohaghar (2008); Kokangul and Susuz (2009); Demirtas and Üstün (2008); Kull and Talluri (2008); Liao & Kao (2010); Lin et al. (2011); Talluri and Narasimhan (2003); Ruiz-Torres et al. (2013); Kasirian & Yusuff (2013); Sawik (2014); Aghai et al. (2014); Balcik & Ak (2014); Jadidi et al. (2015); Chen et al. (2016); Meena & Sarmah (2016); Sodenkamp et al. (2016); Keshavarz Ghorabaee et al. (2017); Bakeshlou et al. (2017); Kernell & Utz (2019);	Emirhüseyinoğlu & A. Ekici (2019); Hamdan & Cheaitou (2017)	Wadhwa and Ravindran (2007); Wang et al. (2004); Wang et al. (2005); Perçin (2006); Xia and Wu (2007); Esmaeili Aliabadi et al. (2013); Sadigh et al. (2013); Sawik (2013); Babić & Perić (2014); Kuo et al. (2015); Arabzad et al. (2015); Yu & Wong (2015); Yousefi et a. (2017); Narasimhan et al. (2006); Ghadimi et al. (2018); Bodaghi et al. (2018); Esmaeili-Najafabadi et al. (2019); Deng et al. (2014); Bohner & Minner (2017); Niknamfar & Niaki (2016); Toffano et al. (2021)	Ware et al. (2014); Lamba et al. (2018); Moheb-Alizadeh & Handfield (2019); Tirkolaee et al. (2020); Feng & Gong (2020);
	Uncertain					Memon, Lee, and Mari (2015); Scott et al. (2015); Wu and Olson (2008b); Xu and Ding (2011); Sawik (2011); Jia et al. (2020); Choi (2013); Zhang & Chen (2013); Arikan (2016); Arikan (2013); Kazemi et. al (2015); Jadidi, Zolfaghari, and Cavalieri (2014); Banaeian et al. (2015); Kannan, Khodaverdi, Olfat, Jafarian, and Diabat (2013); Singh (2014); Fang et al. (2016); Ulutas et al. (2016); Mohammed et al. (2018), Dupont et al. (2018); Mohammed et al. (2019); Ho (2019); Olanrewaju et al. (2020); Wong (2020); Abel et al. (2020)	Hamdan & Cheaitou (2017)	Li and Zabinsky (2011); Amin et al. (2011); Nazari-Shirkouhi et al. (2013); Sheikhalishahi & Torabi (2014); Gupta et al. (2016); Ayhan and Kilic (2015); Aggarwal & Singh (2015); Ozkok and Tiryaki (2011); Xu and Yan (2011), Kilic (2013); Lo et al. (2018); Manerba & Perboli (2019); Çebi & Otay (2020)	Razmi and Maghool (2010); Haleh and Hamidi (2011); Goren (2018); Arabsheybaniet al. (2018); Kilic & Yalcin (2020); Kaur & Singh (2020); Bektur (2020); Babbar & Amin (2018); Cheraghalipour et al. (2018)
Transportation	Certain			Nasiri et al. (2018)		Liao and Rittscher (2007)	Jafari Songhori et al. (2011); Choudhary and Shankar (2013);		Kirschstein & Meisel (2019); Golpira (2020)
	Uncertain			(i)		Ghorbani & Ramezanian (2020)	Choudhary and Shankar (2014)	(i)	
Inventory Mangement	Certain		Mazdeh, Emadikhiav, and Parsa (2015); Soto et al. (2017)			Mendoza and Ventura (2008); Pazhani et al. (2016); Ghodsypour and O'Brien (2001); Alejo-Reyes et al. (2021)	Mafakheri, Breton, and Ghoniem (2011); Ustun and Demı˙rtas (2008); Lee, Kang, Lai, and Hong (2013); Ventura et al. (2013); Demirtas and Üstün (2009); Hamdan & Jarndal (2017); Razmi and Rafiei (2010); Talluri et al. (2018); Hu & Dong (2019)	Mohammaditabar and Ghodsypour (2016); Niknamfar & Niaki (2018)	Basnet and Leung (2005); Rezaei and Davoodi (2012); Moghadam et al. (2008); Rezaei and Davoodi (2008); Alfares et al. (2019)
	Uncertain	Keskin, Melouk, and Meyer (2010)	(ii)	Hlioui et al. (2017); Yang et al. (2011)	(ii)	Guo and Li (2014), Keskin, Melouk, and Firouz (2017); Jain, Kundu, Chan, and Patel (2015); Shadkam & Bijari (2017)	Hammami et al. (2014); Zarindast et al. (2017); Cheaitou & Hamdan (2017)	(ii)	Turk et al. (2017); Azadnia et al. (2015); Jolai et al. (2012); Assadipour & Razmi (2013);
Production Planning	Certain			Che (2017)		Ling et al. (2006); Chen et al. (2018)	Duan & Ventura (2018); Sahling (2016)	Sarvestani et al. (2019)	Paydar & Mehrabad (2017); Che (2010a); Chui (2016); Megahed & Goetschalckx (2019)
	Uncertain		Nguyen & Chen (2018)		(iii)			Du et al. (2015)	Yin, Nishi, and Grossmann (2015);
Reverse Logistics (Closed-Loop Supply Chain)	Certain	Talluri and Baker (2002); Huang et al. (2016)				Yeh and Chuang (2011);	Zouadi et al. (2018)	Rezaee et al. (2017)	
	Uncertain		(iv)	Govindan et al. (2020)	(iv)	Che (2010b)		Moghaddam (2015a); Moghaddam (2015b); Amin and Zhang (2012); Tsai et al. (2009); Shakourloo et al. (2016)	Amorim et al. (2016); Ahmadi & Amin (2019)

Explored Implicitly Explored Unexplored

Furthermore, we observed that the studies engaged in supply disruptions and risks in supplier selection are still limited in a partial mitigation strategy. For instance, the adoption of risk factors into selection criteria (Awasthi et al., 2018; Igoulalene et al., 2015; Rajesh and Ravi, 2015) and multi-sourcing (Haleh and Hamidi, 2011), as well as integrating with inventory management (Firouz et al., 2017; Keskin et al., 2010) become the major focus for risk mitigation in the related areas of supplier selection. Yet, some aspects still need further improvement, particularly to deal with the parameters influenced by the disruptions. Redesigning supplier selection processes for mitigating risks of strategic items needs to be integrated with other dimensions (sourcing strategy, criteria, and scope) since none of the studies have been concerned with this implementation. Thus, future work should also address the parameter that might change dynamically according to the disruptions. Accordingly, developing a comprehensive methodology or solution approach to model disruptions and assess risk factors along with the mitigation strategy implementation is imperative as a proactive strategy that enables firms to strengthen supply chain management.

6. Conclusion

This study provides a theoretical framework for dealing with the supplier selection process, particularly in determining the dimensions so that the problem can be appropriately formulated and solved. 326 published papers focusing on supplier selection are discussed in light of the novel framework. According to KPM and production policy, the framework is proposed to fit the different types of items in terms of the importance of purchasing and supply complexities in different production environments.

Four main dimensions in supplier selection are disclosed, including sourcing strategy, selection criteria, decision scope, and decision environment. We found that sourcing strategy and selection criteria play a role in extending the decision scope. Supplier selection problems should be formulated with respect to these dimensions that are distinctive for different types of items depending on the complexity of supply, importance of purchasing, and production policy. For instance, the higher the complexity of supply and production, as well as the importance of purchasing, are, the larger the inclusion of the criteria and the higher the diversity of the input of uncertainty are.

A number of different approaches have been proposed to tackle supplier problems. Some stand-alone and hybrid approaches have some limitations to address a particular dimension. Depending on these dimensions, an appropriate approach can tackle supplier selection for a particular type of item. Supplier selection problems can be solved using either a standalone or hybrid approach that accommodates sourcing strategy, criteria, decision scope, and decision environment that correspond to each type of item. A hybrid approach is suitable for dealing with the problems that concern a high supply complexity and high purchasing importance. A stand-alone approach can tackle the problem that constitutes a low supply complexity.

In addition, the literature review explores the research avenues. It indicates some research trends that become the driving forces on supplier selection. These driving forces include fostering supply chain resilience through risk mitigation, embracing sustainability goals, integrating supply chain processes, and adopting distributed ledger technology. These driving forces promote an advanced and futuristic perspective on supplier selection in the current challenging environment.

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