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Social, political, and technological dimensions of the sustainability evaluation of a recycling network. A literature review

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ABSTRACT

The development and implementation of recycling networks seems to be a promising way to cope with and mitigate the environmental problems of waste. As a mandatory condition, recycling networks must guarantee the achievement of sustainability requirements. Since the first proposal of the TBL (Triple Bottom Line) in the early 1990s, some authors have suggested that this model should be extended to include more dimensions. Recent studies have proposed that for a system to be sustainable, it should not only include the economic, environmental, and social dimensions but must also consider technological and political aspects and their subsequent sustainability indicators for their evaluation. In regard to recycling networks, however, social, technological, and political dimensions are still to be formalized to facilitate their use when designing recycling networks or evaluating their impact. In order to understand how these social, political, and technological dimensions should be integrated into the sustainability evaluation process of a potential recycling network, a systematic literature review has been conducted. A total of 160 journal articles were selected and analyzed. Information was identified on the problem addressed, the recycling domain, the methodologies used, and the social, technological, and political aspects under consideration. A set of social, political, and technological indicators to be considered for the main recycling network problems (design and planning, decision-making and performance evaluation, provider selection, price, and coordination) is then proposed. The main contribution of this work lies in the understanding for future research of how to consider social, political, and technological aspects taking into account the most common problems addressed in a recycling network. At the same time, findings and research gaps have been derived from these results. This study provides a basis for future work oriented toward the holistic evaluation of sustainable recycling networks.

1. Introduction

Over the last 25 years, supply chain management has undergone many changes. At its earliest stages, supply chain networks were structured in a linear manner, products were manufactured and distributed to the consumer through the supply chain and then discarded once consumed. This type of supply chain is defined by different authors as a “forward supply chain” (FSC) (see Battini et al. (2017) and Govindan et al. (2015) through a literature review; Haddadsisakht and Ryan (2018) for supply chains under uncertainty; Kannan et al. (2010) for the case of battery recycling; Östlin et al. (2008) in product remanufacturing; Sahebjamnia et al. (2018) for large scale supply chain network design). However, the need for and social challenge of coping with the environmental impacts generated by the linear manufacture-consumption-disposal model led to questions of how to recover the value of discarded products in order to mitigate their environmental impacts. In this way, reverse supply chains (RSC) and reverse logistics networks (RL) emerged, later giving rise to closed loop supply chains (CLSC) as a response to this societal challenge. Different authors have defined a RSC-RL as the network for the recovery of discarded products for recycling or reuse in other products, while a CLSC network emerges as an integrative network where forward and reverse supply chains act at the same time (see Bai and Sarkis (2019); Govindan et al. (2015); Haddadsisakht and Ryan (2018); Kannan et al. (2010); Östlin et al. (2008); Yu and Solvang (2016a); Kilic et al. (2015); Kannan Govindan (2017)). Therefore, a recycling network structure can be present in these two types of supply chain structures.

Today, to address the environmental problems of waste, there is significant interest in the development and implementation of these types of supply chain networks that consider recycling as a recovery

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activity (Pavlo et al., 2018; Santander et al., 2020). However, the evaluation of different networks should be oriented toward sustainable development. A network is sustainable if it integrates the economic, environmental, and social dimensions, traditionally referred to as the three pillars of sustainability (triple bottom lines - TBL) (Elkington's, 1997; Hacking and Guthrie, 2008). However, some studies suggest that new dimensions need to be integrated in order to address the sustainability approach. For example, Fritz and Silva (2018) suggest the integration of institutional and cultural dimensions. On the other hand, Bautista et al. (2016) argue that while political and technological aspects are of great importance in the system to evaluate, they should also be considered in the sustainability evaluation (TBL+). In the context of general recycling, Islam and Huda (2018) proposed the incorporation of these two dimensions (political and technological) into the analysis of RL and CLSC of electronic waste, with the purpose to obtain a more holistic vision of the system from the sustainability perspective. This holistic vision involves sustainability in waste management at the micro, meso, and macro levels (Mahmoudi et al., 2021). From a political aspect, there is great interest among authorities in increasing the recycling rates of products and achieving a Circular Economy through recycling (European Commission, 2019). This interest can be clearly seen, for example, in the case of plastic recycling, where China was the largest recycler of plastics globally before that country passed its waste embargo. As a consequence, the whole supply chain has been reshaped, and plastic exporting countries must rethink the way they manage their plastic waste in a sustainable way (Simon, 2019; Wen et al., 2021). One option would be promoting a new global and sustainable recycling network. Other options would be to promote sustainable recycling networks at national, regional, or local scale. These new approaches to recycling pose new challenges for industry and academia from the point of view of conception, design, and implementation of these recycling network. From a technological perspective, the technologies associated with the specific recycling process are key elements in the global sustainability of the process. For example, in the case of plastic recycling, the economic efficiency of the recycling process greatly depends on the technology that is used (Simon, 2019). Indeed, some research proposes distributed and local plastic recycling using open-source technologies in order to reduce costs and mitigate environmental impacts (Cruz Sanchez et al., 2020). On WEEE, Islam and Huda (2018) highlighted the use of the Internet of Things in inventory management and product-recovery information management for "resource savings at low cost." Therefore, similarly to the political aspects, new approaches of recycling derived from technological changes and developments imply new challenges for industry and academia from the point of view of conception, design, and implementation of these recycling networks. In conclusion, political and technological aspects can highly affect or change the way in which recycling networks should be conceived and designed, which has economic, environmental, and social implications from the sustainability perspective.

Different literature reviews have been conducted on sustainability in CLSC and RSC-RL networks considering different contexts and problems, such as, company context (Fernandes et al., 2017), sustainable inventory routing problems (Malladi and Sowlati, 2018), network design problems (Moreno-Camacho et al., 2019), Game theory problems (Shekarian, 2020), textile and apparel industry (Jia et al., 2020), and WEEE/E-waste (Islam and Huda, 2018). However, the question of how the impacts of a recycling network should be evaluated bearing in mind the five dimensions of sustainability remains open. This question could be answered by including sustainability assessments in the context of forward supply chains. However, previous literature reviews highlight: (1) the scant consideration of social, technological and political aspects in sustainability assessments (Espinoza Pérez et al., 2017; Fonseca et al., 2019), and (2) the major focus on economic and environmental aspects (Espinoza Pérez et al., 2017; Fonseca et al., 2019; Moreno-Camacho et al., 2019). On the one hand, economic and environmental aspects are generally represented by costs and air pollution, which can be applied to the recycling network context (Moreno-Camacho et al., 2019). On the other hand, although recent efforts to highlight the social, political and technological dimensions in supply chains have been conducted in the literature (see Badri Ahmadi et al. (2017), Espinoza Pérez et al. (2017), Fonseca et al. (2019); Moreno-Camacho et al. (2019); Yawar and Seuring (2017)) the manner how social, technological and political aspects should be taken into account in a recycling network is not clear for the scientific community and public actors. A clear vision of how to account for these dimensions in the context of recycling would potentially assist policy-makers, stakeholders, and researchers in the sustainability evaluation process of future emerging recycling networks, such as distributed recycling networks (Cruz Sanchez et al., 2020; Kerdlap et al., 2021). In order to tackle this issue, the purpose of this article is to map the way in which social, political, and technological aspects have been considered in the evaluation of recycling networks. Firstly, this analysis will provide a basis for how these dimensions should be considered in future research. Secondly, research gaps will be identified upon consideration of these aspects in the evaluation of recycling networks, keeping in mind that the evaluation should be as holistic as possible from a sustainability perspective. Formally, this paper seeks to provide answers to the following research questions: How should social, technological, and political aspects be taken into account in the evaluation of a sustainable recycling network? What are the criteria or aspects to be considered for these dimensions during sustainability evaluations? Are these criteria useable in all recycling domains?

This article aims to address this research gap by means of a bibliographic analysis of a set of articles about recycling networks with a sustainability orientation. The bibliographic analysis is carried out through a systematic literature review. The originality of this research lies in the way it seeks to understand how social, technological, and political dimensions or aspects have been included in the sustainability evaluation of recycling networks, identifying the main problems addressed, along with the factors and methodologies in the literature. The understanding and establishment of a pertinent set of criteria for each of these dimensions allows researchers, practitioners, and policy-makers to conduct a more holistic evaluation of the sustainability of the recycling network studied.

This article is structured as follows. Section 2 presents this literature review's positioning in the literature. Section 3 presents the methodology used for article selection. Section 4 presents the results obtained for each sustainability dimension, along with a quantitative and qualitative analysis. Section 5 discusses the results. Finally, Section 6 presents conclusions and perspectives.

2. Positioning in the literature

As mentioned in the introduction, various literature reviews have been carried out on sustainability in CLSC and RL-RSC networks. Table 1 presents a summary of the literature reviews found that explore sustainability analysis in CLSC and RL-RSC networks.

As shown in Table 1, six previous literature reviews have looked at sustainability evaluation in RSC-RL or CLSC networks in their analysis. Fernandes et al. (2017) carried out an analysis of the literature on performance indicators for RL in the context of a company. The analysis identified indicators related to economic, consumer, internal operations, learning and growth, social, environmental, and supplier aspects. Malladi and Sowlati (2018) carried out a literature review on sustainable inventory routing models in the context of CLSC and RL networks. They identified the way in which economic, environmental, and social objectives are considered in this type of problem. Moreno-Camacho et al. (2019) conducted a literature analysis on the way in which economic, social, and environmental aspects are included in supply chain network design problems. In the analysis, they considered FSC, RSC, and CLSC networks. Jia et al. (2020) conducted a literature review in order to identify the drivers, barriers, practices, and indicators of sustainable performance applied to the circular economy in the textile and apparel

Table 1
Positioning in the literature.

Author	Scope	Sustainability dimensions				
		Economic	Environmental	Social	Political	Technological
Fernandes et al. (2017)	Performance indicators of RL in the context of a company.	x	x	x		
Malladi and Sowlati (2018)	Sustainable inventory routing models in the context of CLSC and RL networks.	x	x	x		
Moreno-Camacho et al. (2019)	Supply chain network design problems.	x	x	x		
Jia et al. (2020)	Sustainable performance for applying Circular Economy in the textile and apparel industry.	x	x	x		
Shekarian (2020)	Game theory applied to CLSC networks.	x	x	x	x	x
Islam and Huda (2018)	RL and CLSC networks in WEEE/E-waste.	x	x	x		
This literature review	RL and CLSC networks for recycling.			x	x	x

industry. From the point of view of indicators, they found that the literature in this industry has been focused on the measurement of economic and environmental aspects, without measuring social factors. Shekarian (2020) analyzed the aspects related to game theory applied to CLSC networks. In his analysis he explored economic, environmental, political (subsidy, reward-penalty), technological (inventory systems, information systems and quality considerations, e-tails, and online operations), and social (trade-in or subsidy to the customer per returned product) aspects. Islam and Huda (2018) conducted a literature review on RL and CLSC in WEEE/e-waste, analyzing the main research problems in the field of RL and CLSC (design and planning of reverse distribution, decision-making and performance evaluation, conceptual framework, and qualitative studies). As regards sustainability dimensions, their results show a strong focus on economic and environmental aspects and a lack of consideration of social aspects in these types of problems.

These literature reviews address the problem of sustainability assessment in CLSC or RSC-RL networks. Considering the sustainability dimensions, Table 1 shows that regarding the economic, environmental and social dimensions, all the documents analyzed address these three dimensions taking into account different network types (CLSC and RL-RSC) and products (WEEE/E-waste, textile and apparel industry). However, only one review addresses all dimensions, although this review is limited only to the application of game theory problems in CLSC networks (Shekarian, 2020). Another important conclusion is the lack of consideration of social aspects as mentioned in the literature reviews of Fernandes et al. (2017), Islam and Huda (2018), Jia et al. (2020), Malladi and Sowlati (2018) and Moreno-Camacho et al. (2019). For example, the results of Fernandes et al. (2017) showed a lack of consideration of the social performance of reverse logistics in the context of a company. The work of Islam and Huda (2018) demonstrated a lack of consideration of social aspects in RL and CLSC networks of WEEE/E-waste, suggesting the inclusion of the three dimensions (economic, environmental and social) in further research. The literature review of Jia et al. (2020) about Circular Economy in the textile and apparel industry, showed the need to explore how social factors influence the application and performance of companies' CE implementation. The results of Malladi and Sowlati (2018) evidenced that the social impacts of Inventory Routing problems have been considered in a limited number of studies. Finally, the results of the literature review conducted by Moreno-Camacho et al. (2019) on supply chain network design problems showed that economic and environmental aspects have received more attention than social aspects. They also mentioned that social aspects are becoming a relevant topic of study in the context of supply chain design. Moreover, although these reviews include recycling in their analysis, these reviews are not totally focused on recycling networks and are limited by the product under consideration (Islam and Huda, 2018; Jia et al., 2020).

In conclusion, we can say that to the best of our knowledge, no specific literature review has been found on the topic of recycling in RSC-RL and CLSC networks considering the understanding of the social, political, and technological dimensions. Our research addresses this research gap by providing a literature review on the inclusion of social, political, and technological aspects in the sustainability evaluation of RL-RSC and CLSC networks for recycling.

3. Methodology and data selection

In this research, a systematic literature review is carried out based on the guidelines of Siddaway et al. (2019). Table 2 details the steps followed for article selection. Next, a systematic selection of the literature is performed. The article selection procedure is shown in Fig. 1.

As shown in Table 2, the search was conducted on the keywords "Closed-loop supply chains," "Reverse Logistics," "Reverse supply chains," "Recycling," "Sustainable," "Political dimension," "Technological dimension," and "Social dimension." "Closed-loop supply chains," "Reverse Logistics," and "Reverse supply chains" were included because, from a structural point of view, recycling activity can be present in these two types of supply chains. The keyword "recycling" was included to obtain documents that necessarily consider recycling as an activity in the supply chain. Finally, the keywords "Sustainable," "Political dimension," "Technological dimension," and "Social dimension" were included to obtain studies that address sustainability in recycling supply chains with at least one of the three sustainability dimensions specified. As for the databases, Springer, Web of Science, and Scopus were used. The search equation indicated in Table 2 was applied to the Title, Abstract, and Keywords. From the search in these databases, a total of 809 studies written in English were identified. Among the studies identified, 109 correspond to duplicate studies, leaving a total of 700 articles to be selected. Next, a selection by abstract was carried out, leaving only those articles related to the analysis or evaluation of recycling networks. Only 372 articles passed this filter. Finally, a selection by reading was carried out, selecting only those articles that consider at least one of the three dimensions of sustainability studied in this research (social, political, and technological). The social dimension is understood as the (positive or negative) impacts on society of the implementation of the recycling system (Bautista et al., 2016; Espinoza Pérez et al., 2017). The political dimension is understood as the influence of governmental/legal policies (for example, taxes and subsidies or other types of incentives/penalties) on the recycling system (Bautista et al., 2016; Espinoza Pérez et al., 2017). Finally, the technological dimension is understood as the influence on the system exerted by the technological constraints as well as by the development of the technologies used in the system (Bautista et al., 2016; Espinoza Pérez et al., 2017). As a result of the literature selection methodology used, 160 articles were selected for this research.

In order to answer the research questions relating to social, technological, and political dimensions in the sustainability evaluation of recycling networks, the data extracted from the selected documents correspond to: (1) sustainability dimensions considered and how they have been considered, (2) the problem addressed, (3) the domain/application of the recycling network and (4) the methodology used for the integration of sustainability dimensions. The results obtained are

Table 2
Systematic literature review protocol.

Stage	Principle	Description
Search strategy	Type of studies	Journals, papers
	Keywords	Closed-loop supply chains, Reverse logistics, Reverse supply chains, Recycling, Sustainable, Political dimension, Technological dimension, Social dimension
	Search equation	("Closed-loop supply chain*" OR "Closed loop supply chain*" OR "Reverse Logistic*" OR "Reverse supply chain*") AND (recycl*) AND (sustainab*) AND (social* OR (politic* OR polic*) OR technolog*)
	Period of time	Until December 2020
	Databases	Scopus, Springer, and Web of Science
Study selection	Criteria	1) Articles related to the analysis or evaluation of recycling networks (for selection by abstract). 2) Articles that consider the social, technological, or political dimensions of sustainability (for selection by reading).
	Procedure	1) Title, abstract, and keywords are screened 2) Full article is reviewed 3) Selection is made based on selection criteria
Data extraction	Social, political and technological dimensions	Problem addressed, methodology, domain/application, criteria and indicators considered for each dimension

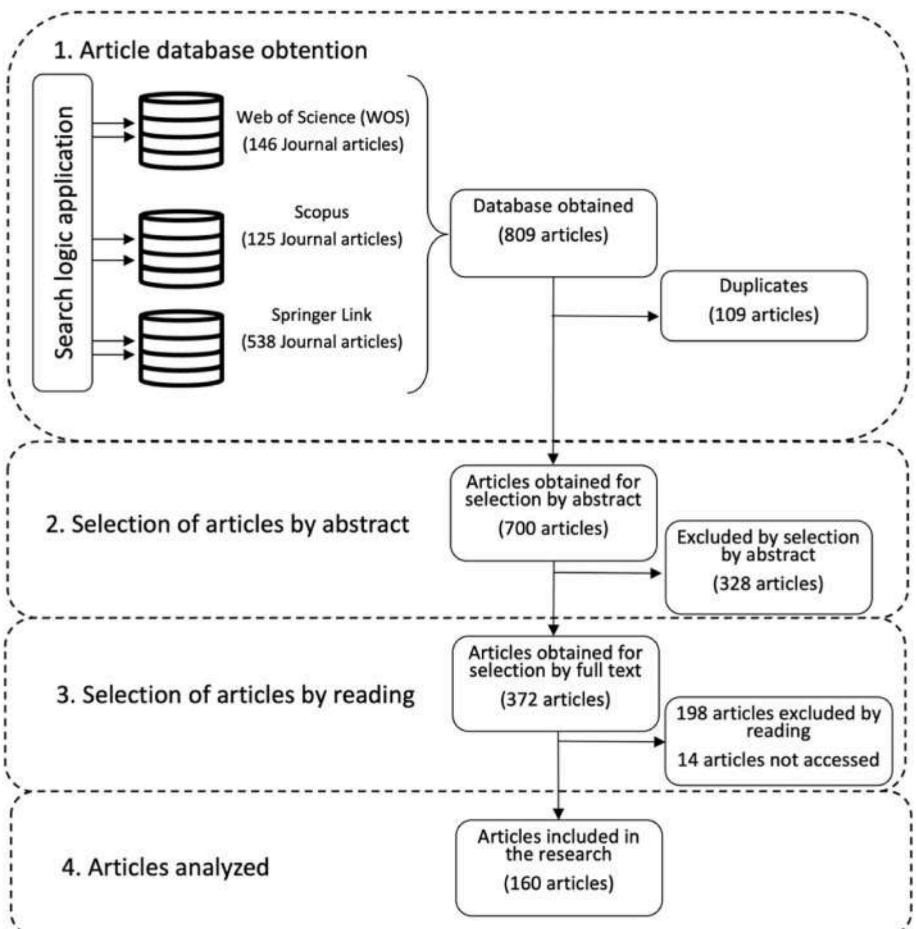

Fig. 1. Systematic article selection.

presented in the next section.

4. Results

Table 3 presents a detailed description of the set of 160 studies considered in this review. Fig. 2 schematizes the conducted analysis.

As can be observed in Fig. 2, the selected documents were analyzed based on the sustainability dimensions (economic, environmental, social, political and technological) in order to identify which ones were included, and how. The type of problem addressed was also analyzed by classifying it according to the characteristics described by (Govindan et al., 2015):

- Design and planning: This type of problem addresses strategic and tactical decisions, e.g., location of recycling facilities (design) and the flow of material between them (planning).
- Price and coordination: This type of problem deals with coordination decisions between actors in the recycling chain; for example, decisions regarding prices for the purchase and sale of materials.
- Decision-making and performance evaluation: These studies address the evaluation of different types of recycling options in order to support the decision-making process.
- 3PRLP selection: These problems address the criteria and methodologies for the selection of a Third Party Reverse Logistic Provider (3PRLP) who will carry out the recovery process.

Table 3
Analysis of the 160 publications selected in this study.

Article	Problem						Sustainability dimensions					Methods					Domain/ Application
	3PRL provider selection	Design and planning	Decision-making and performance evaluation	Price and coordination	Vehicle routing problems	Other studies	Social	Technological	Political	Economic	Environmental	Optimization	Game theory	Multi-criteria decision-making	System dynamics	Others	
Govindan et al. (2019)	x						x	x	x	x	x	x		x			E-waste
Govindan et al. (2013)	x						x	x		x				x			Automotive industry
Kafa et al. (2018)	x						x	x		x	x			x			Household waste and Municipal solid waste
Mavi et al. (2017)	x						x		x	x	x	x		x			Plastic
Rani et al. (2020)	x						x			x	x			x			General
Kara (2011)	x							x		x				x			E-waste
Darbari et al. (2019)		x					x	x	x	x	x	x		x			E-waste
Yang and Chen (2020)		x					x	x	x	x	x	x		x			General
Kumar et al. (2020)		x					x	x	x	x	x	x					Automotive industry
Bal and Satoglu (2018)		x					x	x	x	x	x	x					E-waste
Safdar et al. (2020)		x					x	x	x	x	x	x					E-waste
Garai and Roy (2020)		x					x	x	x	x		x					General
Ferri et al. (2015)		x					x	x	x	x		x					Household waste and Municipal solid waste
Feitó-Cespón et al. (2017)		x					x	x		x	x	x				x	Plastic
Liu et al. (2019a)		x					x	x		x	x	x		x			Bicycles
Liu et al. (2020a)		x					x	x		x	x	x		x			General
Sahebjamnia et al. (2018)		x					x	x		x	x	x					Automotive industry
Jafari and Kazemi Abharian (2020)		x					x	x		x	x	x					Automotive industry
Fazli-Khalaf et al. (2020)		x					x	x		x	x	x					Automotive industry
Rahimi and Ghezavati (2018)		x					x	x		x	x	x					Construction and demolition wastes
Shokohyar and Mansour (2013)		x					x	x		x	x	x					E-waste
Ramos et al. (2014)		x					x	x		x	x	x					E-waste
Aalirezaei and Shokouhyar (2017)		x					x	x		x	x	x					E-waste
Temur and Bolat (2017)		x					x	x		x	x	x					E-waste
Budak (2020)		x					x	x		x	x	x					E-waste
Fattahi and Govindan (2017)		x					x	x		x		x					General
Rezaei and Kheirkhah (2018)		x					x	x		x	x	x					General
Masoudipour et al. (2020)		x					x	x		x	x	x					General

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Table 3 (*continued*)

Article	Problem						Sustainability dimensions					Methods					Domain/ Application
	3PRL provider selection	Design and planning	Decision-making and performance evaluation	Price and coordination	Vehicle routing problems	Other studies	Social	Technological	Political	Economic	Environmental	Optimization	Game theory	Multi-criteria decision-making	System dynamics	Others	
Pourjavad and Mayorga (2019)		x					x	x		x	x	x					General
Sajedi et al. (2020)		x					x	x		x	x	x					General
Dutta et al. (2020)		x					x	x		x	x	x					General
Zarbakhshnia et al. (2020)		x					x	x		x	x	x					General
Hajiaghaei-Keshteli and Fathollahi Fard (2019)		x					x	x		x	x	x					Glass
Saeidi et al. (2020)		x					x	x		x	x	x					Hazardous waste
Niranjan et al. (2019)		x					x	x		x	x	x					Household waste and Municipal solid waste
Taleizadeh et al. (2019)		x					x	x		x	x	x					Household waste and Municipal solid waste
Edalatpour et al. (2018)		x					x	x		x	x	x					Household waste and Municipal solid waste
Govindan et al. (2016)		x					x	x		x	x	x					Medical waste
Homayouni and Pishvaee (2020)		x					x	x		x	x	x					Medical waste
Jin et al. (2018)		x					x	x		x	x	x					Metals
Mohammadi et al. (2020)		x					x	x		x	x	x					Plastic
Ng and Wang (2017)		x					x			x		x					Biorefinery/ Biomass
Saxena et al. (2018)		x						x	x	x	x	x					Automotive industry
Capraz et al. (2015)		x						x	x	x		x					E-waste
Gao and Ryan (2014)		x						x	x	x	x	x					General
Yu and Solvang (2017a)		x						x	x	x	x	x					General
Porkar et al. (2018)		x						x	x	x	x	x					General
Aljuneidi and Bulgak (2020)		x						x	x	x	x	x					General
Ansbro and Wang (2013)		x						x	x	x		x					Metals
Çalık (2020)		x						x		x	x	x		x			General
Ghasemzadeh et al. (2020)		x						x		x	x	x				x	Automotive industry
Wang et al. (2019)		x						x		x	x	x				x	Medical waste
Kannegiesser and Günther (2014)		x						x		x	x	x					Automotive industry
Hoyer et al. (2015)		x						x		x		x					Automotive industry

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Table 3 (*continued*)

Article	Problem						Sustainability dimensions					Methods					Domain/ Application
	3PRL provider selection	Design and planning	Decision-making and performance evaluation	Price and coordination	Vehicle routing problems	Other studies	Social	Technological	Political	Economic	Environmental	Optimization	Game theory	Multi-criteria decision-making	System dynamics	Others	
Phuc et al. (2017)		x						x		x		x					Automotive industry
Tadaros et al. (2020)		x						x			x	x					Automotive industry
Liang and Lee (2018)		x						x			x	x					Construction and demolition wastes
Dong et al. (2017)		x						x		x	x	x					Construction and demolition wastes
Dubey et al. (2015)		x						x		x		x					E-waste
Gholizadeh et al. (2020)		x						x		x		x					E-waste
John et al. (2018)		x						x				x					E-waste
Ali et al. (2020)		x						x		x	x	x					E-waste
Moslehi et al. (2020)		x						x		x	x	x					E-waste
Khorshidian et al. (2019)		x						x		x		x					Food industry
Accorsi et al. (2020)		x						x		x		x					Food industry
Wang and Hsu (2012)		x						x		x		x					General
Altmann and Bogaschewsky (2014)		x						x		x	x	x					General
Faccio et al. (2014)		x						x		x		x					General
Yu and Solvang (2016b)		x						x		x	x	x					General
Zandieh and Chensebli (2016)		x						x		x		x					General
Sarkar et al. (2017)		x						x		x	x	x					General
Rezaei and Kheirkhah (2017)		x						x		x		x					General
Benaissa et al. (2018)		x						x		x		x					General
Shahparvari et al. (2018)		x						x		x		x					General
Ren et al. (2020)		x						x		x	x	x					General
Guo et al. (2017)		x						x		x		x					Household waste and Municipal solid waste
Yu and Solvang (2017b)		x						x		x	x	x					Household waste and Municipal solid waste
Couto et al. (2017)		x						x		x		x					Household waste and Municipal solid waste
Bing et al. (2014)		x						x		x	x	x					Plastic
Han et al. (2020a)		x						x				x					Plastic
Papen and Amin (2019)		x						x		x	x	x					Plastic

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Table 3 (*continued*)

Article	Problem						Sustainability dimensions					Methods					Domain/ Application
	3PRL provider selection	Design and planning	Decision-making and performance evaluation	Price and coordination	Vehicle routing problems	Other studies	Social	Technological	Political	Economic	Environmental	Optimization	Game theory	Multi-criteria decision-making	System dynamics	Others	
Hassanzadeh Amin et al. (2018)		x						x		x		x					Plastic
Valizadeh et al. (2020)		x						x		x	x	x					Plastic
Choi and Fthenakis (2014)		x						x		x		x					Solar energy industry
Chen et al. (2017)		x						x		x	x	x					Solar energy industry
Son et al. (2018)		x							x	x		x					Metals
Bing et al. (2015)		x							x	x	x	x					Plastic
Nidhi and Pillai (2019)			x				x	x	x	x	x	x					Medical waste
Agrawal et al. (2016a)			x				x	x	x	x	x			x			E-waste
Pongeluppe Wadhy Rebehy et al. (2017)			x				x	x	x	x	x					x	Household waste and Municipal solid waste
Chavez and Sharma (2018)			x				x	x	x	x	x					x	Plastic
Georgiadis and Besiou (2008)			x				x	x	x		x				x		E-waste
Georgiadis and Besiou (2010)			x				x	x	x	x	x				x		E-waste
Besiou et al. (2012)			x				x	x	x	x	x				x		E-waste
Ghisolfi et al. (2017)			x				x	x	x		x				x		E-waste
Beiler et al. (2020)			x				x	x	x	x	x				x		Glass
Ahmed et al. (2016b)			x				x	x		x	x			x			Automotive industry
Ahmed et al. (2016a)			x				x	x		x	x			x			Automotive industry
Jindal and Sangwan (2016)			x				x	x		x	x			x			E-waste
Awan and Ali (2019)			x				x	x		x	x			x			Household waste and Municipal solid waste
de Oliveira et al. (2020)			x				x	x		x	x					x	Household waste and Municipal solid waste
Chaudhary and Vrat (2020)			x				x	x		x	x				x		Metals
Agarwal et al. (2016)			x				x		x	x		x		x			E-waste
Agrawal et al. (2016b)			x				x			x	x			x			E-waste
Santos and Magrini (2018)			x				x			x	x					x	Biorefinery/ Biomass
de Souza et al. (2016)			x				x			x	x					x	E-waste
Slomski et al. (2018)			x				x			x	x					x	E-waste
Ottoni et al. (2020)			x				x			x	x					x	E-waste
Mutingi et al. (2014)			x				x			x	x					x	General

(*continued on next page*)

Table 3 (*continued*)

Article	Problem						Sustainability dimensions					Methods					Domain/ Application
	3PRL provider selection	Design and planning	Decision-making and performance evaluation	Price and coordination	Vehicle routing problems	Other studies	Social	Technological	Political	Economic	Environmental	Optimization	Game theory	Multi-criteria decision-making	System dynamics	Others	
Motevali Haghighi et al. (2016)			x				x			x	x					x	Plastic
Tong et al. (2018)			x					x	x	x						x	E-waste
Mohan and Amit (2020)			x					x		x					x		Automotive industry
Jia et al. (2018)			x						x	x					x	x	Construction and demolition wastes
Azevedo et al. (2017)			x						x	x	x					x	E-waste
Ghalehkhondabi and Ardjmand (2020)				X			x	x	x	x	x		x				E-waste
Saha et al. (2019)				X			x	x	x	x			x				General
Wu et al. (2019a)				X			x	x	x	x			x				General
Mondal and Giri (2020)				X			x	x	x	x	x		x				General
Allevi et al. (2018)				X			x	x	x	x	x					x	General
Ma and Huang (2019)				X			x	x		x			x				General
Mondal et al. (2020)				X			x	x					x				General
Xiang and Xu (2020)				X			x	x		x			x				General
Yu et al. (2020)				X			x		x	x			x				Automotive industry
Han et al. (2020b)				X			x		x	x	x		x				General
Duan et al. (2019)				X			x		x	x			x				General
Rezaei and Maihami (2020)				X			x		x	x	x		x				General
Kim et al. (2020)				X			x		x	x	x		x				General
Song et al. (2020)				X			x		x	x			x				General
Liu et al. (2020b)				X			x		x	x			x				Medical waste
Johari and Hosseini-Motlagh (2019)				X			x			x	x		x				Automotive industry
Li et al. (2017)				X			x			x			x				E-waste
Modak et al. (2019a)				X			x			x			x				General
Ma et al. (2019)				X			x			x			x				General
Modak et al. (2019b)				X			x			x			x				Plastic, glass and metal
Liu et al. (2019b)				X				x	x	x			x				Food industry
Tan and Guo (2019)				X				x	x	x			x				General
Liu et al. (2016)				X				x	x	x						x	E-waste
Chen et al. (2018)				X				x		x			x				E-waste
Huang et al. (2020)				X					x	x			x				General
Wu et al. (2019b)				X					x	x			x				Solar energy industry
Rahimi et al. (2016)					x		x	x	x	x	x	x					Food industry
Farrokhi-Asl et al. (2020)					x		x	x		x	x	x					Hazardous waste
le Blanc et al. (2006)					x			x		x		x					Automotive industry
Aksen et al. (2012)					x			x		x		x					Food industry

(*continued on next page*)

Table 3 (*continued*)

Article	Problem						Sustainability dimensions					Methods					Domain/ Application
	3PRL provider selection	Design and planning	Decision-making and performance evaluation	Price and coordination	Vehicle routing problems	Other studies	Social	Technological	Political	Economic	Environmental	Optimization	Game theory	Multi-criteria decision-making	System dynamics	Others	
Bányai et al. (2019)					x			x			x	x					Household waste and Municipal solid waste
Kızıltaş et al. (2020)					x			x			x	x					Household waste and Municipal solid waste
Mangla et al. (2012)						x	x	x		x	x					x	Paper
Lapko et al. (2019)						x	x	x		x	x					x	Solar energy industry
Uriarte-Miranda et al. (2018)						x	x			x						x	Automotive industry
Agrawal and Singh (2019)						x	x			x	x	x				x	E-waste
Sarkis et al. (2010)						x	x									x	General
Lai et al. (2013)						x	x				x	x				x	General
Abdullah and Yaakub (2014)						x	x				x					x	General
Murakami et al. (2015)						x		x		x	x					x	General
Yang et al. (2016)						x		x			x	x	x				E-waste
Prasad et al. (2018)						x		x			x	x				x	Metals
Bai et al. (2020)						x				x	x	x	x				General
Zoeteman et al. (2010)						x				x						x	E-waste
Nambu and Murakami-Suzuki (2016)						x				x	x					x	E-waste
Shi et al. (2010)						x		x			x		x				General

- Vehicle routing problem: These studies address the problem of collection of wastes to be treated.
- Other studies: This group contains those problems not classified in the previous groups.

For each sustainability dimension and problem addressed, the aspects considered (criteria and indicators) and the methodology used to integrate the sustainability dimensions (and their identified criteria) were also analyzed. Finally, the specific domain/application of the recycling network studied (where "general" means that the domain/application is not specified/limited in the study) was also analyzed in order to define whether the identified criteria are applicable transversally given the product/material treated in the recycling network.

This analysis will identify (1) the most commonly used criteria in the context of recycling networks for each sustainability dimension studied, (2) the type of problem in which they have been used, (3) whether these criteria are useable independently of the material/product to be treated and (4) how the criteria are integrated, from a methodological point of view.

Table 3 summarizes the results obtained from the analysis of the 160 selected articles. The articles have been ordered according to the problem addressed, number of dimensions considered (between social, technological, and political dimensions), methodology, and finally by type of domain/application. The following subsections present the results obtained from the analysis. First, a quantitative analysis is presented in section 4.1, statistically showing the information obtained from the documents (problems, sustainability dimensions, methodologies and domains/application). Then, a qualitative analysis is presented in section 4.2 showing the social, political and technological aspects present in the selected documents.

4.1. Quantitative analysis

Fig. 3 shows the ranking of journals with at least three documents included in this review. *Journal of Cleaner Production* is the most representative in the databases. As regards the profile of journals, two types of journals are observed. The first one is oriented toward environmental aspects and sustainable development. For example, *Journal of Cleaner Production*, *Waste Management*, *Sustainability*, and *Resources, Conservation & Recycling*. On the other hand, many journals have an operational or manufacturing profile. For example, *International Journal of Advanced Manufacturing Technology*, *Annals of Operations Research*, *Journal of Remanufacturing, Operational Research*.

Fig. 4 shows the temporal distribution of the articles addressing the dimensions studied in this research. As in other literature reviews, Fig. 4 shows that economic and environmental dimensions are frequently addressed. In addition, Fig. 4 confirms an interest in the social, political, and technological dimensions, interest which has been growing since 2016. In comparing the three dimensions, we can see that the technological dimension has been the most widely studied. On the other hand, the political dimension has been addressed the least. Fig. 5 shows the temporal distribution of the dimensions in terms of integration. This figure shows the growing interest in recent years in the technological dimension as well as the integration of the social and technological dimensions. It also confirms an increased integration of all three dimensions (social, political, and technological) since 2016. Regarding the political dimension, Fig. 5 shows an interest in its integration since 2016.

Additionally, Fig. 6 presents the methodology used to address the different problems identified. As can be observed, 3PRL provider selection problems have been addressed mainly by means of multi-criteria methods. Decision-making and performance evaluation problems have been addressed mainly by means of system dynamics and multi-criteria methods. Design and planning problems have been addressed by means of optimization modeling. Finally, the problems of price and coordination of a recycling network have been addressed mainly by means of game theory.

Fig. 7 shows the distribution of the identified criteria in terms of their dimension, type of indicator (if the criterion was measured qualitatively or quantitatively, or if it has no indicator or has been included indirectly), and the methodology used. An indicator is defined in an indirect way if the criterion has been considered by means of social, political, or technological scenarios to be evaluated. As can be observed in Fig. 7, the criteria associated with the social dimension have been measured using both qualitative and quantitative indicators in almost equal numbers. On the other hand, most of the criteria associated with the technological and political dimensions have been measured using mostly quantitative indicators. From the methodological point of view, the criteria associated with quantitative indicators have been integrated using optimization, game theory, or systems dynamics. Conversely, most of the criteria associated with qualitative indicators have been integrated by means of multi-criteria methods.

Finally, Fig. 8 shows the distribution of the selected literature according to the domain/application considered. This figure shows that the articles selected in the research concentrate on recycling networks applied to products "in general" and recycling networks applied to e-waste, the automotive industry, and household and municipal waste. It should be mentioned that "general" corresponds to those recycling networks which are not limited to one type of product, or when the domain has not been specified in the document.

4.2. Qualitative analysis

The following subsections present a detailed qualitative analysis of how sustainability-oriented recycling networks include social, political, and technological dimensions. First, an analysis of the social dimension is presented in Section 4.2.1. Next, an analysis of the political dimension is presented in Section 4.2.2. The technological dimension is presented in Section 4.2.3. Finally, a transversal analysis is presented in Section 4.2.4.

4.2.1. Social dimension

As regards the social dimension, a total of 90 aspects were identified in 93 of the 160 documents selected from the literature. To enable a better understanding, the identified aspects of the social dimension were divided into five types of perspectives regarding the stakeholders toward which each criterion was oriented: 1) the worker, 2) the customers, 3) the community, 4) the company, and 5) other social aspects. In the worker's perspective, we identified those criteria that relate to the impact on workers who are active in the recycling field. In the customers' perspective, we identified those criteria that relate to the impact of the recycled product on customers or their preferences. In the community perspective, we identified those criteria that relate to the impact of the recycling activity on the community. In the company perspective, we identified those criteria that relate to the impact of the recycling activity on the social performance/image of the company. Finally, the fifth category grouped certain social factors that are not classified in some of the perspectives already mentioned. Fig. 9 presents the distribution of the criteria in each defined group.

4.2.1.1. Worker-oriented. From the literature selected and analyzed, a total of 42 documents (26%) considered this type of orientation, where 22 documents address design and planning problems, four documents address 3PRL provider selection problems and 13 documents address decision-making and performance evaluation problems. As can be observed in Fig. 9, a total of 17 worker-oriented social criteria were identified from these documents. Table A1 details the problem, criteria, the indicators and the methodologies in which the criterion was used.

One main result found is that **job creation**, **worker health**, and **safety** are the three most considered worker-oriented social aspects in the context literature of recycling networks. These three aspects were

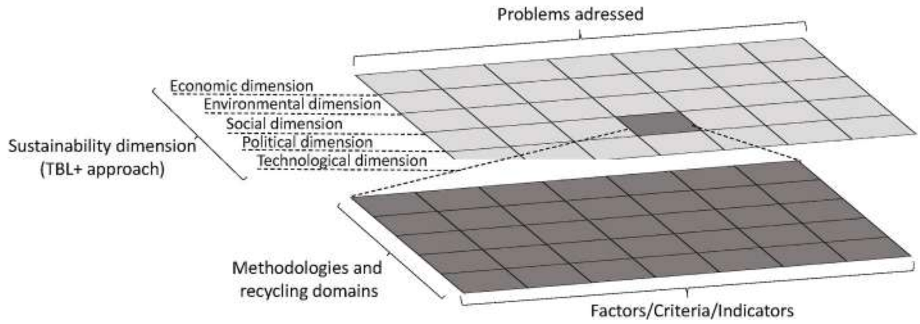

Fig. 2. Conceptual diagram of the analyzed information (Example of analysis of documents addressing political aspects).

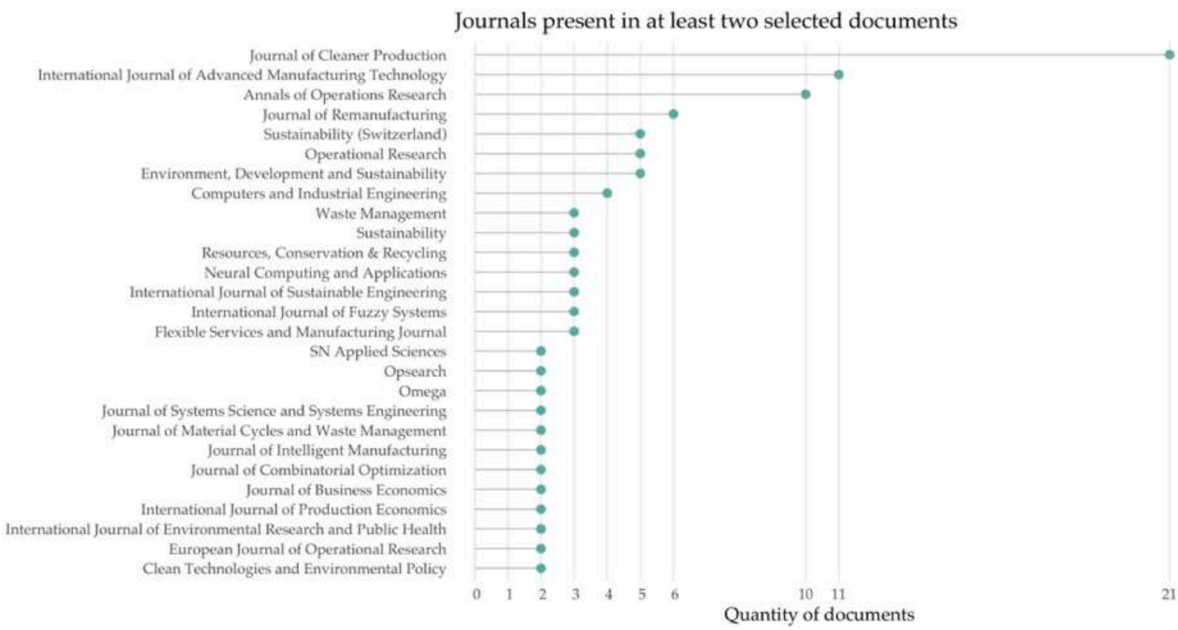

Fig. 3. Descriptive analysis of selected article (total number of documents: 160).

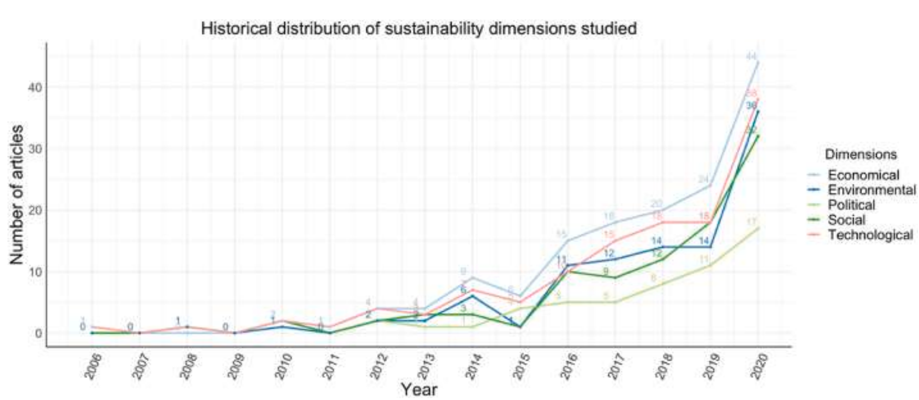

Fig. 4. Historical integration of dimensions (total number of documents: 160).

considered to address design and planning problems, 3PRL provider selection problems, and decision-making and performance evaluation problems, as can be observed in Fig. 9. **Job creation or employment** is related to the number of jobs created or the number of employees involved in the implementation of a recycling network or new facilities. From a design and planning problems perspective, this criterion has been used mainly by means of optimization models. For example, Taleizadeh et al. (2019), in their study of a sustainable CLSC problem with pricing decisions and discount on returned product, considered the number of created jobs installing facilities. Sahebjamnia et al. (2018) presented a multi-objective MILP model for the design of a sustainable tire CLSC network. In their model, they considered the fixed and variable job opportunities created in the network.

Similarly, the aspects regarding **Safety of workers** and **Health of workers** were identified as frequently considered in the design and planning perspective. Both criteria are focused on the operations in the

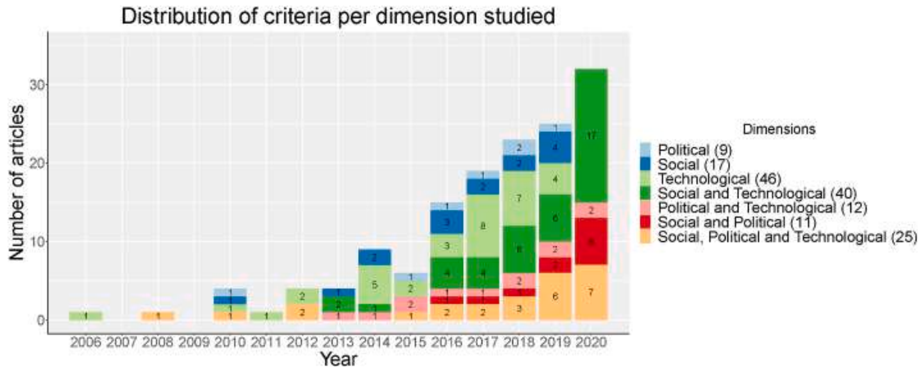

Fig. 5. Historical distribution of integrated dimensions (total number of documents: 160).

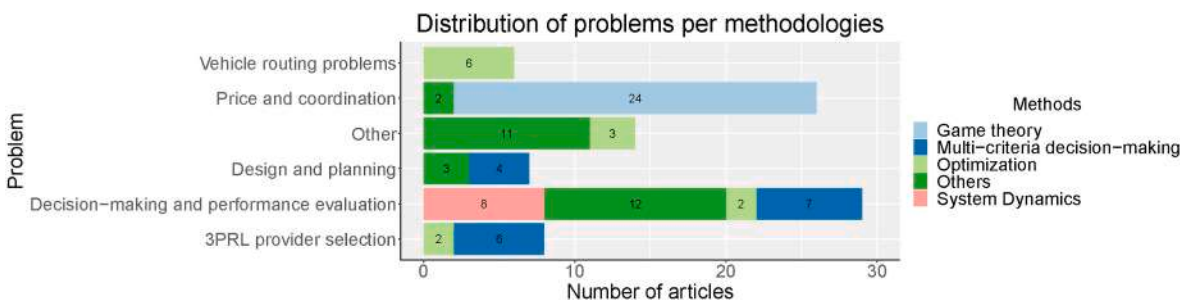

Fig. 6. Distribution of problems by methodology (total number of articles: 160).

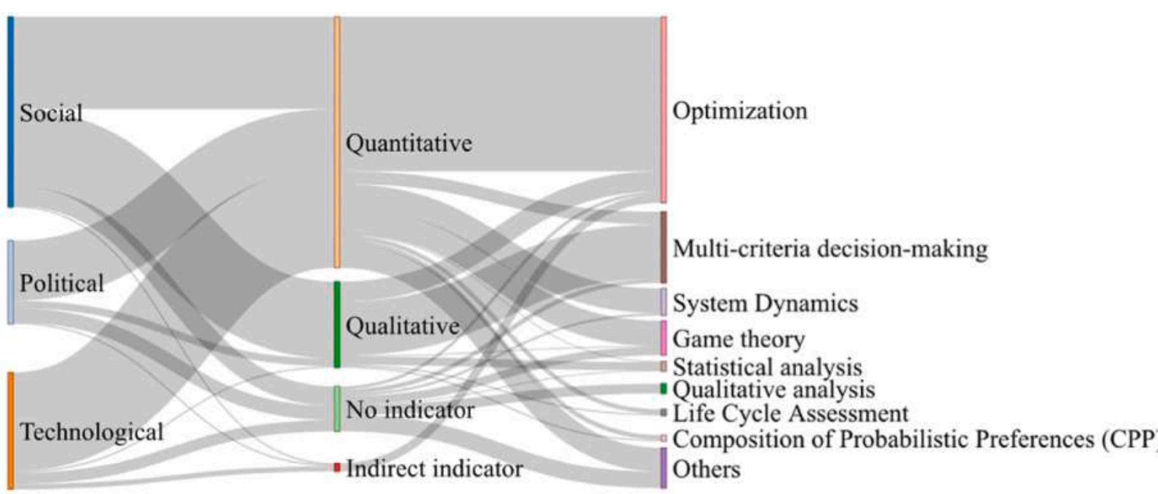

Fig. 7. Distribution of criteria, indicators, and methodologies (total number of indicators = 521 indicators considering methodologies and references). "Others" include: Variational inequality, Survey analysis, PESTLE analysis, Interpretive Structural Modeling (ISM), Discounted cash flow, Quality-based price competition model, Hybrid BSC-DEA (balanced scorecard - data envelopment analysis), Case study analysis, Grey model theory, Discrete event simulation, Action research, Theoretical model, Scenario analysis and quantification, Financial analysis, Cost analysis, and Grey prediction model.

recycling network, in which the use of indicators such as lost days enabled a quantitative description. For example, in the sustainable CLSC problem with pricing decisions and discount on returned product studied by Taleizadeh et al. (2019), they considered the lost working days due to employees sickness and accidents to measure the labor health and safety.

Concerning decision-making and performance evaluation problems, **job creation** was evaluated mainly by means of system dynamics (SD) (Beiler et al., 2020; Besiou et al., 2012; Chaudhary and Vrat, 2020). For example, Beiler et al. (2020) considered job creation ratio as social indicator in their analysis of a RL system of a Brazilian beverage company. Besiou et al. (2012) studied the impact of informal recycling of WEEE. In their study, they considered the number of unemployed scavengers as social indicator. Chaudhary and Vrat (2020) studied a circular economy model of gold recovery, where they considered the job creation per ton of waste recycled. On the other hand, the **health and safety of workers** was evaluated principally using multi-criteria method, where Ahmed et al. (2016a) and Ahmed et al. (2016b) considered these criteria to analyze sustainable management options of end-of-life vehicles. This is important to know because SD enables analysis of recycling system performance (Beiler et al., 2020; Besiou et al., 2012; Chaudhary and Vrat, 2020) while multi-criteria methods are better suited to decision-making with respect to the management option (Ahmed et al., 2016a; 2016b).

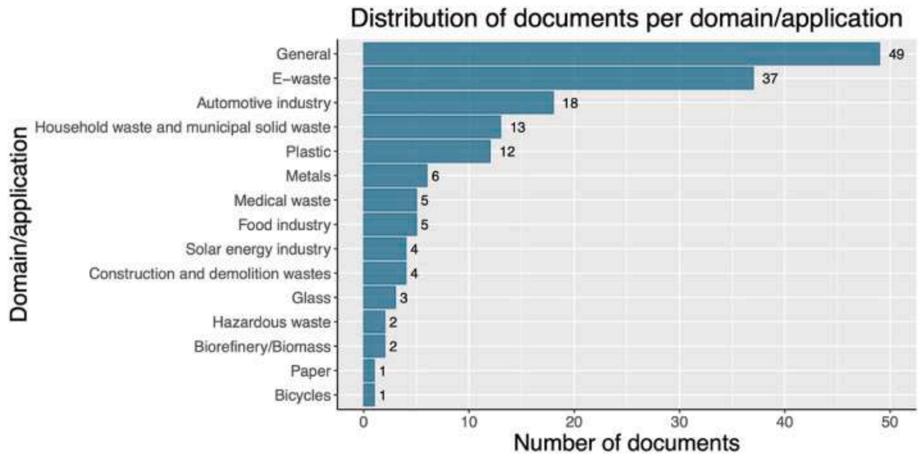

Fig. 8. Distribution of the selected literature according to the domain considered (total number of documents: 160).

Regarding 3PRL provider selection problems, the **health and safety** of workers were the most used criteria, in which multi-criteria methods have been mainly considered in order to qualitatively measure these aspects in the 3PRL provider selection process. Examples of this are the works developed by Govindan et al. (2019), Kafa et al. (2018) and Mavi et al. (2017).

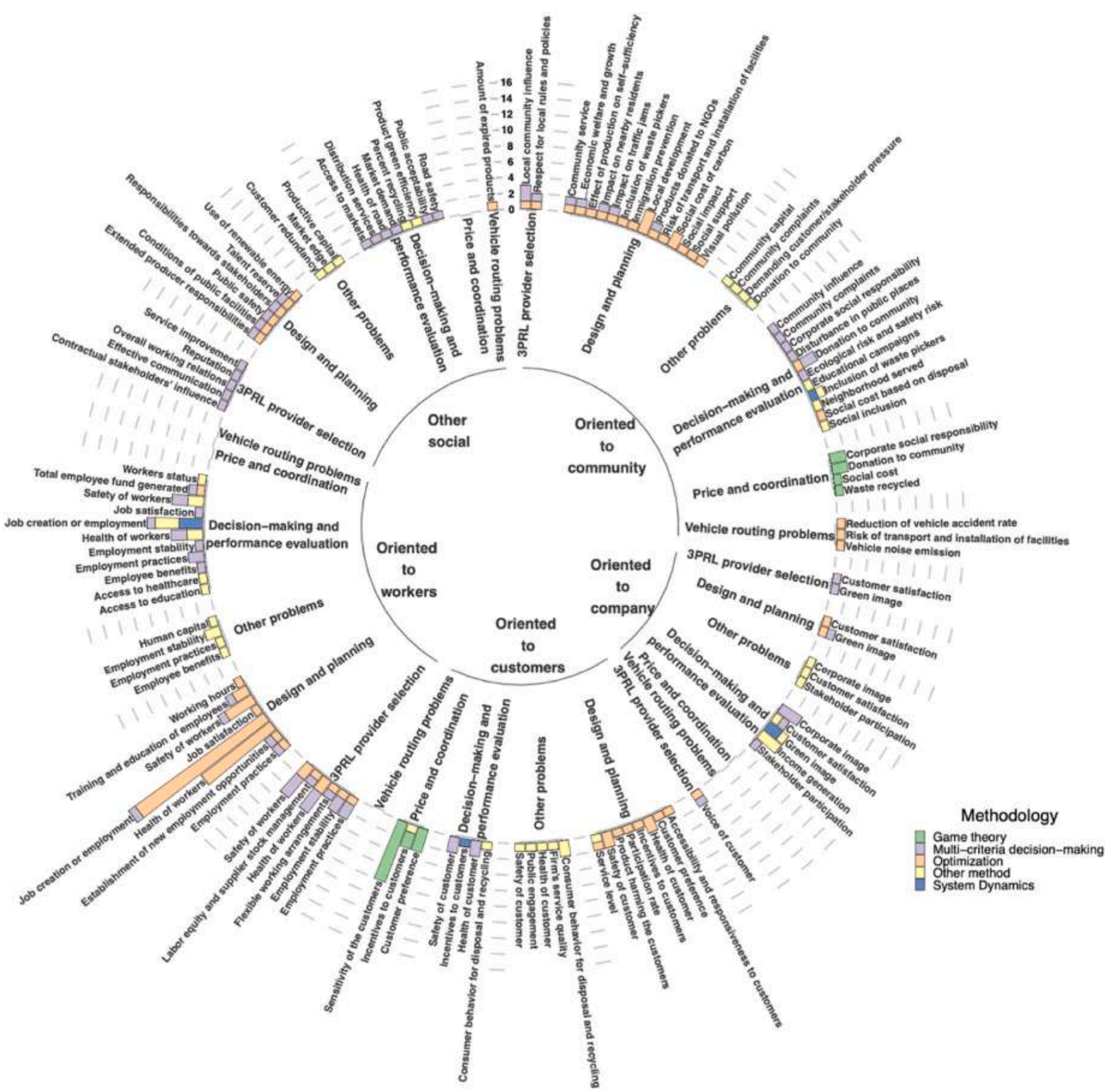

Fig. 9. Occurrences of identified social aspects of the sustainability evaluation of recycling networks.

Finally, some documents were found to consider worker-oriented aspects in other subjects, such as employment stability to analyze disposition decisions (Agrawal and Singh, 2019) and reverse logistic practices (Sarkis et al., 2010), employee benefits to analyze disposition decisions (Agrawal and Singh, 2019), and employment practices and human capital to analyze reverse logistic practices (Sarkis et al., 2010).

4.2.1.2. Customer-oriented. Looking at the customer-oriented social criteria, a total of 32 documents (20%) considered this type of orientation, where 14 documents address price and coordination problems, eight documents address design and planning problems, one document address 3PRL provider selection problems and four documents address decision-making and performance evaluation problems. A total of 13 customer-oriented aspects were identified, as displayed in Fig. 9. Table A2 details the problem, criteria, the indicators, and the methodologies in which the criterion was used.

One can highlight that the **sensitivity of the customers**, the **incentive to customers**, **customer preference**, and the **health and safety of customers** correspond to the most considered customer-oriented aspects in the analyzed literature. Regarding the problems in which they have been considered, **customer sensitivity**, **customer incentive**, and **customer preference** have been considered mainly in price and coordination problems using game theory models. On the other hand, **health and safety of customers** have been considered mainly in design and planning problems, and decision-making and performance evaluation problems.

Regarding price and coordination problems, the **sensitivity of customers** represents customer preference for a product according to its characteristics (whether the product is manufactured from recycled or non-recycled materials, or its level of quality and sustainability). For example, Ghalehkhondabi and Ardjmand (2020) studied, using game theory models, an e-waste supply chain considering customer sensitivity for price and sustainability of products, and government intervention. Rezaei and Maihami (2020) presented a two-period game-theoretic-based model to study the sustainable decision in a CLSC. In their model, they considered the sustainability sensitivity of then consumers per product as parameter. Manufacturers' characteristics can also affect this sensitivity (e.g., level of green innovation) (Ma and Huang, 2019; Mondal et al., 2020). **Customer preference** and the **incentive to customers** are other customer-oriented aspects frequently considered in this type of problems. On the one hand, **customer preference** is defined as the preference for recycled or green products (Duan et al., 2019; Han et al.,2020b; Wu et al., 2019a). For example, Duan et al. (2019) and Han et al. (2020b) considered the consumers preference in the on the optimization models, for supply chain design, developed in their studies. Another form of customer preference was included in the work of Niranjan et al. (2019), which considers customer preference for online or offline sales channels in a CLSC. On the other hand, **incentives to customers** refer to monetary incentives to customers in order to foster the return of discarded products for proper treatment (e.g., Fattahi and Govindan (2017); Allevi et al. (2018)).

Concerning decision-making and performance evaluation problems, the **health of customers** and **safety of customers** correspond to the most used customer-oriented social criteria. The **health of customers** and **safety of customers** refer to safety and health related to the use of products obtained from the recycling of waste. As can be observed in Fig. 9, these criteria have been used qualitatively in multi-criteria methods to evaluate RL networks (e.g., Agrawal et al. (2016b); Agrawal et al. (2016a)).

Considering design and planning problems, similarly to the decision-making and performance evaluation problems, the **health of customers** and **safety of customers** correspond to the most used customer-oriented social criteria. However, in those problems, these aspects have been considered quantitatively (e.g., fraction of potentially perilous/harmful products) using optimization models (e.g., Taleizadeh et al. (2019)).

Finally, regarding 3PRL provider selection problems, the **voice of customers** regarding the potential third-party reverse logistic provider, corresponds to the only customer-oriented criterion identified (Mavi et al., 2017).

4.2.1.3. Community-oriented. Regarding community-oriented social criteria, a total of 40 documents (25%) considered this type of orientation, where 15 documents address design and planning problems, three documents address 3PRL provider selection problems, 11 documents address decision-making and performance evaluation problems, six documents address price and coordination problems and two documents address vehicle routing problems. As can be observed in Fig. 9, a total of 32 community-oriented aspects were identified. Table A3 details the problem, criteria, the indicators and the methodologies in which the criterion was used.

There have been different community-oriented criteria depending on the problem addressed. Particularly, considering the problems that most consider these aspects, **local development** and the **social cost of carbon** correspond to the most considered criteria in design and planning problems. On the other hand, the **donation to the community** and the **inclusion of waste pickers** have been aspects considered in decision-making and performance evaluation problems. Specifically, **donation to the community** has also been considered in price and coordination problems.

The **local development** and the **social cost of carbon** community-oriented social criteria are those most considered in the design and planning problems. **Local development** refers to the development of the community by the installation of network facilities (Aalirezaei and Shokouhyar, 2017; Mohammadi et al., 2020; Shokohyar and Mansour, 2013). For example, in their optimization model for the design and planning of an e-waste recovery network, Aalirezaei and Shokouhyar (2017) consider that the installation of facilities in less developed areas stimulates local development. Local development has also been in the stochastic model of Mohammadi et al. (2020) for supply chain network design. Similarly, the **social cost of carbon** represents monetarily the social benefits/impacts of the implementation of the network (Edalatpour et al., 2018; Saxena et al., 2018). Both aspects have been considered quantitatively in studies of supply chain planning using optimization models.

With respect to decision-making and performance evaluation problems, **donation to community** and **inclusion of waste pickers** are predominant community-oriented social criteria in the evaluation. **Donation to community** refers to monetary assistance for social work. This criterion has been qualitatively measured using multi-criteria methods (e.g., Agrawal et al. (2016b)). On the other hand, the **inclusion of waste pickers** refers to the inclusion of non-formal collectors in a recycling network. This aspect has been explored in decision-making and performance evaluation problems. For example, Ghisolfi et al. (2017) considered this aspect quantitatively as a ratio of formalization of waste pickers in a CLSC of desktops and laptops. For their part, Pongeluppe Wadhy Rebehy et al. (2017) studied a network based on the integration of waste pickers for municipal solid waste.

Regarding price and coordination problems, **corporate social responsibility** and **donation to community** appear to be the most studied. On the one hand, **corporate social responsibility** refers to the company's commitment to social impacts (Jindal and Sangwan, 2016; Johari and Hosseini-Motlagh, 2019; Modak et al., 2019b). For example, Modak et al. (2019b) studied the effects of manufacturers' corporate social responsibility on the amount of product that is collected and recycled by the network. Jindal and Sangwan (2016) considered the corporate social responsibility as evaluation criteria for product recovery process selection. Finally, Johari and Hosseini-Motlagh (2019) studied a competitive sustainable CLSC considering corporate social responsibility. On the other hand, **donation to community** has been considered by Song et al. (2020) and Modak et al. (2019b) as a monetary amount donated per unit sell. Both aspects have been considered quantitatively using game theory models.

Concerning 3PRL provider selection problems, **local community influence** and **respect for local rules and policies** correspond to the identified criteria. **Local community influence** refers to cultural support and activities in the community (Govindan et al., 2019; Kafa et al., 2018). On the other hand, **respect for local rules and policies** has been used by Mavi et al. (2017) for 3PRLP selection. These aspects have been considered mainly by means of multi-criteria methods.

Finally, the **reduction of vehicle accident rate**, **vehicle noise emission,** and **risk of transport and installation of facilities** were aspects identified in vehicle routing problems. **Reduction of vehicle accident rate** and **vehicle noise emission have been** used by Rahimi et al. (2016) to evaluate sustainable inventory routing problems in the context of perishable products. On the other hand, **risk of transport and installation of facilities** has been used by Farrokhi-Asl et al. (2020) for the collection of hazardous wastes.

4.2.1.4. Company-oriented. Looking at company-oriented social criteria, a total of 19 documents (12%) considered this type of orientation, where two documents address design and planning problems, two documents address 3PRL provider selection problems, and 12 document address decision-making and performance evaluation problems. A total of five company-oriented aspects were identified, as evidenced in Fig. 9. Table A4 details the problem, criteria, the indicators and the methodologies in which the criterion was used.

For company-oriented perspective, the social aspects that have been considered mainly in decision-making and performance evaluation problems were **corporate image/green image** and **customer satisfaction**.

Regarding decision-making and performance evaluation problems, **corporate image**, **green image**, **income generation**, and **customer satisfaction** correspond to the most considered company-oriented social criteria. **Corporate image** considers the reputation of the company in the eyes of the public after the implementation of the network. This criterion has been measured qualitatively in the literature using MCDM methods (Agrawal et al., 2016a; Ahmed et al., 2016a, 2016b). For example, Ahmed et al. (2016a) and Ahmed et al. (2016b) considered this aspect to analyze sustainable management options of end-of-life vehicles. Agrawal et al. (2016a) considered corporate image in their study about outsourcing decisions in reverse logistics. Similarly, **green image** is related to the image of the company in the eyes of consumers or society when the company carries out recycling activities. This factor has been considered quantitatively in system dynamics for CLSC network evaluation (Georgiadis and Besiou, 2008, 2010). **Income generation** represents the generation of monetary income by new actors integrated in the recycling network (collector or contracted company) (de Oliveira et al., 2020; de Souza et al., 2016; Slomski et al., 2018). For example, de Oliveira et al. (2020) considered the income generation of collectors as social indicator in their evaluation of municipal solid waste (MSW) management schemes. de Souza et al. (2016) studied and evaluated the sustainability of different alternatives of e-waste management in Brazil, where the average income of e-waste workers was considered as social criterion. Finally, **customer satisfaction** refers to conformity to customer expectations of the product or service provided by the company (Ahmed et al., 2016a; Garai and Roy, 2020; Mangla et al., 2012; Rani et al., 2020). For example, Ahmed et al. (2016a) considered this aspect in their study about end-of-life vehicle management selection. Garai and Roy (2020) proposed a cost-effective and customer-centric CLSC management model, where customer satisfaction is one of the indicators considered in the optimization model. Rani et al. (2020) proposed customer satisfaction as social criterion in their study about sustainable recycling partner selection.

Concerning 3PRL provider selection problem and design and planning problems, it is possible to observe that **corporate image** and **green image** have been considered in design and planning problems and in 3PRL provider selection problems. In the case of 3PRL provider selection, these have been considered qualitatively using multi-criteria methods. For design and planning problems, **customer satisfaction** has been considered as the percentage of demand satisfied (Garai and Roy, 2020), and **green image** has been qualitatively considered using optimization models and multi-criteria methods (Liu et al., 2019a).

4.2.1.5. Other social aspects. A total of 21 identified social criteria have been grouped as others social aspects. Table A5 presents the problem, criteria, the indicators and the methodologies in which the criterion was used. As can be evidenced in Fig. 9, these criteria seem infrequently studied in the selected literature as most were included in one document.

Aspects such as **safety/health of road**, **distribution services**, and **market access/demands** for recovery selection were identified (Awan and Ali, 2019; Jindal and Sangwan, 2016), as well as **Amount of expired products** for sustainable inventory routing problems of perishable products (Rahimi et al., 2016); **Productive capital**, which refers to the service infrastructure available to collect and recycle (Sarkis et al., 2010); **Contractual stakeholder influence** and **Reputation** for 3PRLP provider selection (Kafa et al., 2018); **Percent recycling** and **Product green efficiency** for performance evaluation of RL (Mutingi et al., 2014); **Effective communication**, **Service improvement**, and **Overall working relations** for 3PRLP selection (Govindan et al., 2013); **Public acceptability** for sustainable alternative selection management (Ahmed et al., 2016b); **Market edge** and **Customer redundancy** for a product recovery system (Mangla et al., 2012); and **Extended producer responsibilities** (Liu et al., 2020a), **Responsibilities towards stakeholders** (Liu et al., 2020a), **Public facilities conditions** (Yang and Chen, 2020), **Public safety** (Yang and Chen, 2020), **Talents reserve** (Yang and Chen, 2020), and **Use of renewable energy** (Fazli-Khalaf et al., 2020) for CLSC network design and planning.

4.2.2. Political dimension

Regarding the political dimension, a total of 31 criteria were identified in 57 of the 160 documents selected from the literature. To enable better understanding, the identified political criteria were divided into four groups: 1) incentive/punishment-oriented policies, 2) Active government policies, 3) Emission policies and 4) Legal policies. In terms of Incentive/punishment-oriented policies, we identified those that are directly focused on recycling. Among active government policies we identified those policies in which the government actively participates. Among emission policies, we identified those related to emissions generated by recycling activity. Regarding legal policies, we identified the legal context of the recycling activity. Finally, a fifth category was created to group together certain political factors that are not classified in the groups mentioned. Fig. 10 presents the distribution of the criteria in each defined group.

4.2.2.1. Incentive/punishment-oriented policies. A total of 35 documents (22%) considered this incentive/punishment orientation, where nine documents address design and planning problems, six documents address decision-making and performance evaluation problems, and 16 documents address price and coordination problems. In summary, eight incentive/punishment-oriented political aspects were identified. Table B1 details the problem, criteria, the indicators and the methodologies in which the criterion was used.

The **subsidies**, **penalties**, and **taxes** correspond to the incentive/punishment-oriented policies most considered in the selected literature. These three aspects have been considered in price and coordination problems, design and planning problems, and decision-making and performance evaluation problems.

Regarding price and coordination problems, the **subsidy** and **taxes** correspond to the most considered political aspect. On the one hand,

Table 4
Summary of results.

Dimensions	Orientations	Factor/Criteria	Problems			
			Design and planning	Decision-making and performance evaluation	3PRL provider selection problems	Price and coordination problems
Social	Oriented to workers	Job creation or employment	x	x		(not addressed)
		Health and safety of workers	x	x	x	
		Employment stability		x	x	
		Employment practices		x	x	
		Job satisfaction	x	x		
		Training and education of employees	x			
	Oriented to customers	Health and safety of customers	x	x	(not addressed)	
		Incentives to customers	x	x		x
		Customer preference	x			x
		Sensitivity of customers				x
		Customer behavior		x		
	Oriented to community	Donation to community		x		x
		Corporate social responsibility		x		x
		Social cost of carbon	x			
		Local development	x			
		Local community influence			x	
		Inclusion of waste pickers	x	x		
		Risk of transport and installation of facilities	x			
	Oriented to company	Customer satisfaction	x	x	x	(not addressed)
		Green image	x	x	x	
		Corporate image		x		
		Income generation of actors		x		
Political	Incentive/Punishment oriented	Subsidies	x	x	(not addressed)	x
		Penalties	x	x		x
		Taxes	x	x		x
		Reward and punishment policy				x
	Emission policies	Emissions quota	x	x	(not addressed)	x
		Emissions cap	x	x		
	Legal	Legal limits (collected, recycled, etc.)	x	x	x	x
	Active government policies	Network imposition	x	x	(not addressed)	(not addressed)
Technological	Process oriented	Capacity of facilities	x	x	x	x
		Capacity extension	x			
		Capacity of equipment	x			
		Capacity per product	x			
		Conversion rate	x			
		Recycling rate	x	x		x
		Quality of returned products	x			x
		Quality of recycled product			x	x
		Technical feasibility of recycling		x		
		Recovery selection	x	x		
		Technology selection	x	x		
		Processing time	x	x		
	Transport oriented	Capacity of vehicles	x	(not addressed)	(not addressed)	x
	Product design oriented		(not addressed)	(not addressed)	(not addressed)	(not addressed)
	Technological level oriented	Green technology innovation	(not addressed)	x	(not addressed)	x
		Green innovation level				x

subsidies have been addressed in three main ways: subsidy for investment (e.g., Saha et al. (2019)), subsidy for products (e.g., Duan et al. (2019)), and subsidy to consumers (e.g., Saha et al. (2019)), where the impact of **subsidy** in the price and coordination of the network is analyzed using game theory models. In relation to the **taxes** dimension, these have been considered by product (Ghalehkhondabi and Ardjmand, 2020; Liu et al., 2020b) or by emissions (Allevi et al., 2018).

Concerning decision-making and performance evaluation problems, **subsidy** and **penalties** correspond to the most considered political aspect. Similarly to price and coordination problems, **subsidy** for products has been considered (Agarwal et al., 2016; Jia et al., 2018; Tong et al., 2018). However, **penalties** represent additional costs due to regulations. These **penalties** can be applied to different aspects. For example, Georgiadis and Besiou (2010) looked at a penalty cost per unit due to non-compliance with regulations. (Ghalehkhondabi and Ardjmand, 2020) considered penalty a cost due to emissions. Jia et al. (2018) studied a penalty for illegally dumped waste. Nidhi and Pillai (2019) addressed a penalty for non-recyclable product disposed as landfill.

Finally, likewise to price and coordination problems, **subsidy** and **taxes** correspond to the most considered political aspect for design and planning problems, and they have been quantitatively considered using optimization models (e.g., Darbari et al. (2019)).

4.2.2.2. Emission policies. Regarding emissions policies, a total of 10 documents (6%) considered this type of orientation, where six documents address design and planning problems, one document addresses decision-making and performance evaluation problems, and two documents address price and coordination problems. Fig. 10 shows that three emissions policies have been identified in the literature. Table B2 details the problem, criteria, the indicators and the methodology in which the criterion was used. In this group, **Emission quota** and **Emission cap** are the most widely addressed policies (nine documents). The **Emission quota** represents a way of trading the carbon emissions allowed by a company (e.g., Bing et al. (2015)), and the **Emission cap** corresponds to a limit on permitted emissions (e.g., Yu and Solvang (2017a)). For the case of **emissions cap**, these limits are generally considered as constraints in optimization models used in design and planning problems. For example, these types of constraints have been considered in the work of Bing et al. (2015), Yu and Solvang (2017a) and Gao and Ryan (2014), among others. In the case of **emission quota**, these are considered as costs of emission trading in optimization models for design and planning problems. This type of policy has been considered, for example, in the works of Bing et al. (2015) and Gao and Ryan (2014), among others. Regarding the problem addressed, Fig. 10 shows that these criteria have been considered mainly in design and planning problems, but have also been considered in price and coordination problems and decision-making and performance evaluation problems.

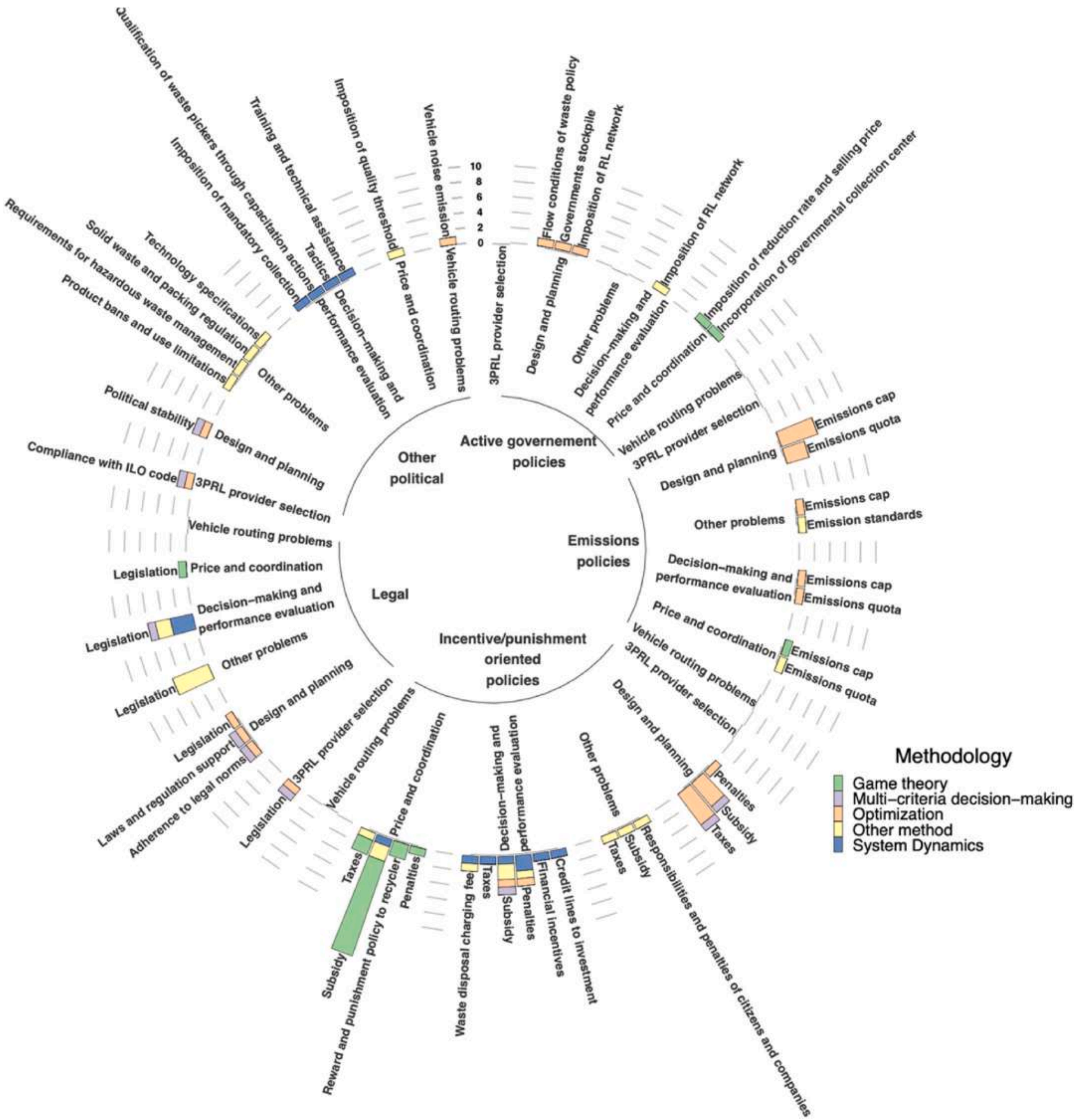

Fig. 10. Occurrences of identified political aspects for the sustainability evaluation of recycling networks.

4.2.2.3. Legal aspects. From the legal perspective, a total of 17 documents (11%) considered this type of orientation, where three documents address design and planning problems, six documents address decision-making and performance evaluation problems, two documents address 3PRL provider selection, and one document addresses price and coordination problems. Fig. 10 shows that only three aspects have been identified. Table B3 details the problem, criteria, the indicators and the methodology in which the criterion was used. **Legislation** has been frequently addressed in the literature (14 documents). This aspect encompasses the legislative environment with respect to the operation and treatment of waste. For example, Chavez and Sharma (2018) evaluated, using PESTLE analysis, the profitability and environmental friendliness of a CLSC for PET (Polyethylene terephthalate) in Mexico, where the legal context has been considered in the evaluation. For their part, Lapko et al. (2019) studied the factors influencing CLSC for CRM (Critical raw materials) development in photovoltaic panels and wind turbine technologies. In its study, the legal context has been a factor considered. The legal aspects can also quantitatively include limits on waste treatment. Examples are the legal limits considered in different system dynamics models developed for recycling systems, such as, minimum recycling percentage and minimum collection percentage (Besiou et al., 2012; Georgiadis and Besiou, 2008, 2010), minimum recyclability of product (Georgiadis and Besiou, 2008, 2010), minimum recycled content (Georgiadis and Besiou, 2010), or minimum amount of waste to be submitted (Liu et al., 2019b). Some works have qualitatively considered this aspect by means of multi-criteria methods (Agrawal et al., 2016a, 2016b; Mavi et al., 2017). For example, Agrawal et al. (2016a) considered the Regulatory Satisfaction as an attribute for outsourcing decisions in RL. For their part, Mavi et al. (2017) in their study about 3PRL provider selection, considered the respect for the local rules and policies as as an evaluation criterion. Finally, in general, Fig. 10 shows that aspects related to legislation have been mainly addressed in decision-making and performance evaluation problems (see Agrawal et al. (2016a); Besiou et al. (2012), Chavez and Sharma (2018); Georgiadis and Besiou (2008, 2010); Pongeluppe Wadhy Rebehy et al. (2017)).

4.2.2.4. Active government policies. From the point of view of government participation, a total of four documents (3%) considered this type of orientation, where two documents address design and planning problems, one document addresses decision-making and performance evaluation problems, and one document addresses price and coordination problems. Fig. 10 shows that five policies related to active government participation have been identified. Table B4 details the problem, criteria, the indicators and the methodology in which the criterion was used. The most widely studied active policies include **imposition of the RL network** (two documents), where the government determines or proposes a network or conditions for the network (Azevedo et al., 2017; Ferri et al., 2015). The imposition of **Flow conditions of waste policy** has also been addressed (Ferri et al., 2015). These two policies were found in the context of e-waste (Azevedo et al., 2017) and municipal solid waste (Ferri et al., 2015) in Brazil.

Another policy studied in the literature is the **Government's stockpile**, where the government maintains a stock of raw materials to regulate the Korean market (Son et al., 2018). **Incorporation of governmental collection centers** and **Imposition of reduction rate and selling price of the product** are two other policies studied in the work of Rezaei and Maihami (2020). In general, active government policies have been addressed in design and planning problems, decision-making and performance evaluation problems, and price and coordination problems.

4.2.2.5. Other political aspects. Finally, a total of 11 identified political aspects were considered under "others." The main reason for this was that little evidence was found to be addressed in the selected literature; mainly in one article, as can be seen from Fig. 10. Table B5 details the problem, criteria, the indicators and the methodology in which the criterion was used.

Several aspects, such as **imposition of mandatory collection**, **qualification of waste pickers through capacitation actions**, and **training and technical assistance** were reported by Ghisolfi et al. (2017) to analyze the inclusion of informal collectors in a CLSC of desktops and laptops. In the same way, the **imposition of quality threshold** was explored by Liu et al. (2016) in their analysis of a dual-channel (informal and formal sectors) RL network. On the other hand, **technology specifications**, p**roduct bans and use limitations**, **requirements for hazardous waste management**, and **solid waste and packing regulation** were studied by Murakami et al. (2015) as policies to encourage recycling.

In decision-making and performance evaluation problems, another policy considered was **tactics**, which refers to the behavior of legislators with respect to environmental policies. This political aspect has been explored by Georgiadis and Besiou (2010) for the sustainability evaluation of electronic waste in CLSC networks.

In relation to 3PRL provider selection problems, the potential provider's **compliance with international labor organization codes** has been considered by Govindan et al. (2019).

For the design and planning problem, the **political stability** of the potential location of facilities has been considered by Yang and Chen (2020) for the location facility decision in CLSC design.

Finally, a maximum allowed **vehicle noise emission** has been used by Rahimi et al. (2016) to evaluate sustainable inventory routing problems.

4.2.3. Technological dimension

Regarding the technological dimension, a total of 45 criteria were identified in 123 of the 160 documents selected from the literature. The criteria identified for the technological dimension were separated into five perspectives: 1) process-oriented technological factors, 2) transport, 3) product design, 4) technology and experience level, and 5) other technological aspects. The process-oriented perspective encompasses those aspects related to material transformation. The transport perspective refers to technological aspects related to means of transport. Product design considers technological aspects in relation to the design of products and their recovery process. The technology and experience level addresses aspects regarding the technological infrastructure and experience. Finally, the other technological dimension aspects group together the criteria that are not classified in the perspectives defined. Fig. 11 presents the distribution of the criteria in each defined group.

4.2.3.1. Process-oriented. Looking at the process-oriented technological aspect, a total of 103 documents (64%) considered this type of orientation, where 77 documents address design and planning problems, two documents address 3PRL provider selection problems, 11 documents address decision-making and performance evaluation problems, and six documents address price and coordination problems. A total of 17 criteria were identified as process-oriented. Table C1 details the problem, criteria, the indicators and the methodology in which the criterion was used.

As can be observed in Fig. 11, the **capacity of facilities** corresponds to the most considered process-oriented technological aspect in the selected literature. This aspect has been considered in design and planning problems, decision-making and performance evaluation problems, 3PRL provider selection problems, price and coordination problems, and vehicle routing problems. **Recycling rate** is another process-oriented technological aspect frequently considered. However, this factor has been considered only in design and planning problems, and in decision-making and performance evaluation problems.

Regarding design and planning problems, **capacity of facilities** has been identified as the most widely used factor. **Capacity of facilities** refers to a maximum amount of material/product that can be processed by the facilities of the recycling network. This factor has generally been considered as a constraint in the design and planning of networks used in optimization models (e.g., Pourjavad and Mayorga (2019); Hajiaghaei-Keshteli and Fathollahi Fard (2019)). **Technology selection** and **recycling rate** are other process-oriented technological aspects widely considered in design and planning of recycling networks. **Technology selection** refers to decisions regarding the technology to be used in the process. For example, Chen et al. (2017) considered, in their optimization model, the decision of capacity expansion selecting a technology type. For their part, Rezaei and Kheirkhah (2018) developed an optimization model for the design of a sustainable CLSC network. In their model, they considered the quantity of product manufactured per technology type as decision variable. Finally, Valizadeh et al. (2020) considered, in their optimization model for CLSC design, the recycling rate of using a technology type in recycling centers of the network. On the other hand, **Recycling rate** represents the fraction of a product that is recycled. These aspects have been considered mainly by means of optimization models. Examples are the work of Moslehi et al. (2020) and Valizadeh et al. (2020), who developed optimization models for supply chain design.

Concerning decision-making and performance evaluation problems, similarly to design and planning problems, the **capacity of facilities** and **recycling rate** are the most considered factors. However, these are mainly considered by means of system dynamics models for the sustainability evaluation of recycling systems (e.g., Chaudhary and Vrat (2020); Besiou et al. (2012)). **Recovery option** is another technological

Fig. 11. Occurrences of identified technological aspects of the sustainability evaluation of recycling networks.

decision frequently considered in this type of problems. **Recovery option or selection** represents decisions about the alternatives to recovery (incineration, recycling, remanufacturing, etc.) (e.g., Awan and Ali (2019)). This technological aspect has been mainly considered using multicriteria methods (e.g., Awan and Ali (2019); Jindal and Sangwan (2016)).

With respect to price and coordination problems, **capacity of facilities** and **quality of returned product** correspond to the most considered process-oriented technological factors identified. Similarly to the previous problems, **capacity of facilities** refers to a maximum amount of material/product that can be processed by the recycling facilities (Allevi et al., 2018; Liu et al., 2019b). On the other hand, **quality of recycling** refers to the quality of the product obtained after the recycling process (Liu et al., 2016; Tan and Guo, 2019).

Finally, regarding 3PRL provider selection problems and vehicle routing problems, **capacity of facilities** correspond to the most considered process-oriented technological aspect (Bányai et al., 2019; Farrokhi-Asl et al., 2020; Govindan et al., 2019; Shi et al., 2010).

4.2.3.2. Transport. Regarding transport-oriented technological aspect, a total of 31 documents (19%) considered this type of orientation, where 20 document address design and planning problems, one document addresses 3PRL provider selection problems, two documents address decision-making and performance evaluation problems, two documents address price and coordination problems, and six documents address vehicle routing problems. As can be observed in Fig. 11, a total of four criteria were identified as transport-oriented technological criteria. Table C2 details the problems, criteria, the indicators and the methodology in which the criterion was used.

In general, Fig. 11 shows that the **capacity of vehicles** corresponds to the most studied factor in this group (28 documents). **Capacity of vehicles** refers to the limits on transport capacity depending on the type of vehicle used. This aspect has mainly been used in optimization models for design and planning problems (e.g., Rezaei and Kheirkhah (2018); Masoudipour et al. (2020); Zarbakhshnia et al. (2020)) or in vehicle routing problems (e.g., Kızıltaş et al. (2020); Rahimi et al., 2016)).

4.2.3.3. Technology and experience level. Regarding the technological factor classified as related to the technology and experience level, a total of 17 documents (11%) considered this type of perspective, where one document addresses design and planning problems, four documents address 3PRL provider selection problems, four documents address decision-making and performance evaluation problems, and eight documents address price and coordination problems. As can be observed in Fig. 11, a total of 19 criteria were identified in this group. Table C3 details the problem, criteria, the indicators and the methodology in which the criterion was used.

Concerning the problem addressed, it is observed that the factors in this group have mainly been used in price and coordination problems and in decision-making and performance evaluation problems. For example, in decision-making and performance evaluation problems, **green technology innovation** and **technology transfer** correspond to the most considered technological aspect. **Green technology** has been defined as the investment made in order to improve the environmental performance of the technology used (e.g., Mondal et al. (2020); Ahmed et al. (2016a)). On the other hand, **Technology transfer** has been used by Ahmed et al. (2016a) and Ahmed et al. (2016b) to refer to the technological flexibility, capability, and availability of waste management. Regarding price and coordination problems, **green technology innovation** has also been used. Another technological aspect considered in these problems is **green innovation**, which refers to the innovations made in the supply chain in order to reduce the consumption of resources in the production process and achieve greener products (Ma and Huang, 2019; Mondal and Giri, 2020).

Finally, regarding 3PRL provider selection problems, technological aspects such as **Technological expertise** (Govindan et al., 2019), **Specialized infrastructure** (Kafa et al., 2018), **Warehouse management**, **Inventory management**, **JIT philosophy**, **Information technology (IT)** and **Demand forecasting** (Govindan et al., 2013), and **Capability of disassembly infrastructure** (Kara, 2011) have been considered.

In conclusion, a wide variety of aspects have been identified in this group for each problem. In general, aspects related to technological and supply chain innovations, such as **green innovation** and **green technology innovation**, have been considered in different studies in order to achieve more environmentally friendly systems.

4.2.3.4. Product design. Looking at the product design-oriented technological factor, a total of three documents (2%) considered this type of perspective, where the three documents address decision-making and performance evaluation problems. As can be observed in Fig. 11, only two aspects have been classified in this group. Table C4 details the problem, criteria, the indicators and the methodology in which the criterion was used. On the one hand, **design for environment products** has been studied by Georgiadis and Besiou (2008, 2010) in the sustainability evaluation of electronic waste in CLSC networks. This aspect refers to whether the manufactured product has been designed with its recovery process (recycling) in mind once it is discarded. On the other hand, **research and development for new products** has been used by Ahmed et al. (2016a) for end-of-life vehicle management selection, which represents the capacity and availability of R&D given the management options.

4.2.3.5. Other technological aspects. A total of three identified technological criteria have not been classified in this group. Table C5 details the criteria, the indicators, and the methodology in which the criterion was used. The **use of new technologies** in recycling networks corresponds to the third most studied aspect in this group. This aspect has been used by Chen et al. (2018) to analyze game theory, the impact of the internet as a new channel of location, collection and negotiation of products/waste. Tong et al. (2018) used this aspect to study the performance of business models based on information technologies as new ways of collecting waste or products. The use of technology 4.0 (Bányai et al., 2019) and data marketing (Xiang and Xu, 2020) have also been explored. **Capacity utilization** has been addressed by Mangla et al. (2012) in the performance evaluation of product recovery systems and by Kara (2011) for 3PRLP selection. Finally, **sell options of discarded product** have been considered by Chavez and Sharma (2018) for the evaluation of CLSC networks.

4.2.4. Transversal analysis

Fig. 12 shows the domains in which the main factors (those present in at least two documents) of each dimension-orientation have been applied. This analysis is performed in order to define those factors applicable to different recycling domains. One of the main remarks among the factors associated with the social dimension, is that **employee benefits** (worker-oriented social factor), **stakeholder participation** (company-oriented social factor), and **social community complaints** (community-oriented social factors) are the only social factors to have been studied in one domain. Regarding the technological dimension, we observe that **design for environment** (factor associated with product design) and **technology transfer** (factor associated with the technological level) are the only technological factors to have been applied in only one domain (e-waste and automotive industry, respectively). Finally, with regard to the political dimension, all the main criteria identified have been used in more than two different recycling domains, especially in the e-waste and general domains.

5. Discussion

Recycling networks such as CLSC and RL-RSC have recently attracted a lot of attention in the literature. In particular, the evaluation of these networks including sustainability aspects has been approached in different reviews from different points of view. However, a common conclusion in the literature on sustainability in supply chain networks is the lack of consideration of social, political, and technological aspects (Espinoza Pérez et al., 2017; Fonseca et al., 2019; Moreno-Camacho et al., 2019). As mentioned in the introduction section, the evaluation of the sustainability of recycling networks strongly depends on the technological development and the political context in which the system is immersed. This is the reason why, in this study, a systematic analysis of the literature was made in order to include the social, political, and technological (SPT) aspects in the evaluation of recycling networks. Moreover, to articulate the SPT dimensions, we mapped four types of general problems in the supply chain field (Govindan et al., 2015), identifying the methodologies associated for each criterion/indicator.

From the analysis of the results, it is possible to observe in the literature a growing interest in integrating SPT dimensions since 2016. In particular, SPT dimensions has been integrated from different perspectives in the sustainability evaluation of recycling networks. The main findings for each dimension are detailed below.

- Considering the social dimension, all the identified criteria have been classified into five perspectives: (1) worker-oriented, (2) community-oriented, (3) customer-oriented, (4) company-oriented, and (5) other social aspects. The results presented in Fig. 12 have shown that, regarding the social arena, the literature on sustainability evaluation of recycling networks is mostly focused on worker-oriented social aspects. Specifically, the criteria **job creation** and the **health and safety of workers** are by far the most relevant indicators that the literature has considered in a design phase or planning phase. These results are consistent with those found by Moreno-Camacho et al. (2019) in the supply chain design context, and the social issues identified in the works of Badri Ahmadi et al. (2017) and Yawar and Seuring (2017) for companies' supply chains. However, additional and less addressed socially oriented aspects, such as community-oriented and company-oriented ones, have been found in this research for the context of recycling networks. Those aspects should be further addressed by the scientific community in the years to come.
- Regarding the technological dimension, the concerned set of criteria has been classified into (1) process-oriented technological factors, (2) transport, (3) product design, and (4) technology and experience level. The results presented in Fig. 12 have shown that, for the technological dimension, the literature on sustainability evaluation of recycling networks is concentrated on process-oriented technological aspects. Among them, the literature has mainly addressed the consideration of the **capacity of facilities, technologies and equipment**, the decision regarding the **technology to be used in the facilities**, and the consideration of **recycling rates** of materials/products. With respect to the other orientations, aspects such as **vehicle capacity** have been considered for transport-oriented technological aspects. Other important and considerably less addressed technological aspects include the **Design for environment** (for product-design oriented technological aspects), and aspects such as **green technology innovation** and **green innovation** (for technological level-oriented aspects). Future research could consider these aspects. From the product perspective, product design is very

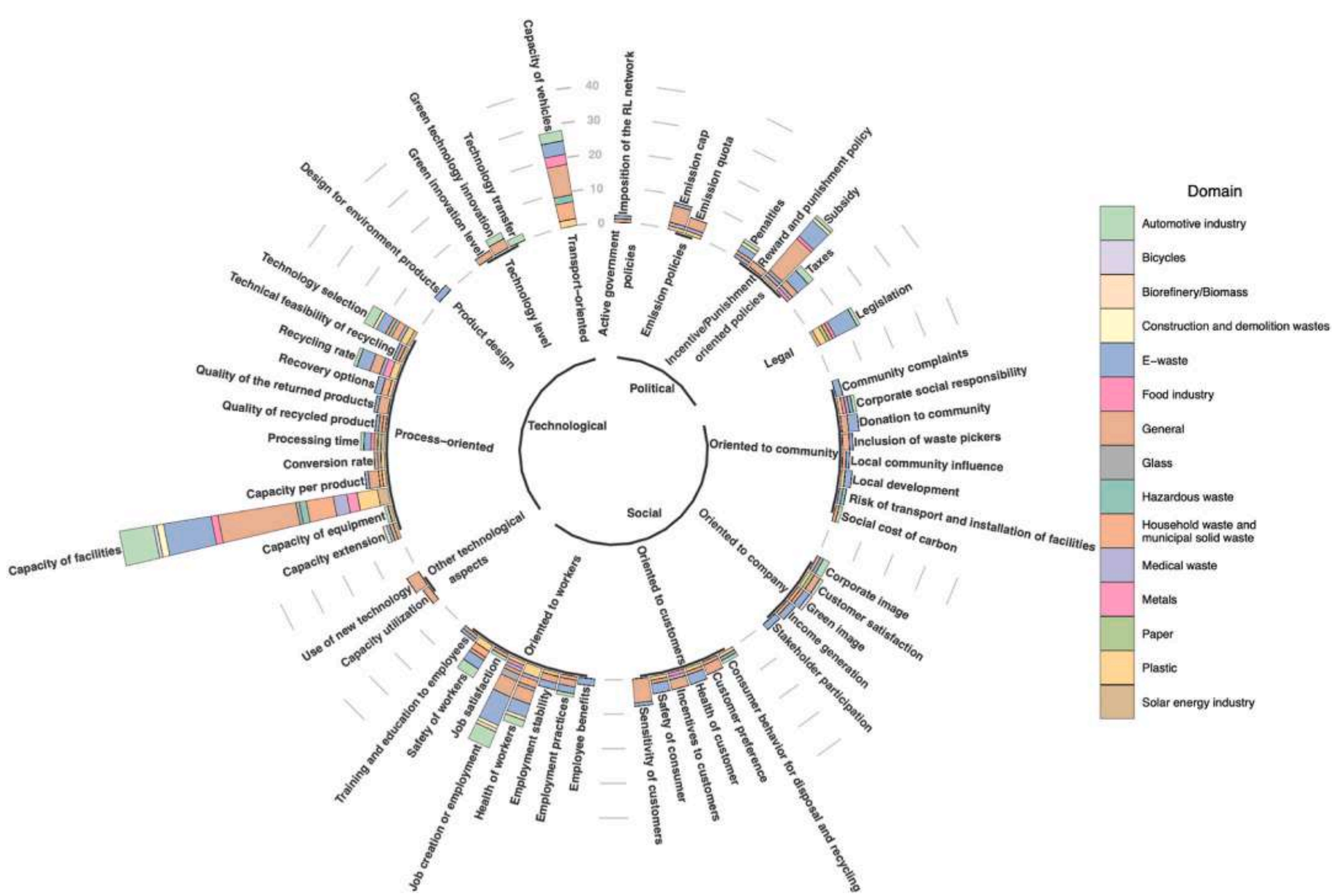

Fig. 12. Global analysis of main criteria and application domains per dimension-orientation.

important in the sustainability of the supply chain (design for sustainability) (Arnette et al., 2014). From the technological level perspective, innovations in recycling technologies for sustainability purposes play an important role, as shown by the recent efforts made by the UNESCO chair in the context of wastewater recycling (Sepehri et al., 2020; Sepehri and Sarrafzadeh, 2018).

- With respect to the political dimension, it has been possible to identify four types of policies: (1) incentive/punishment-oriented, (2) legal policies, (3) emissions policies, and (4) active government policies. Globally, aspects related to subsidies, penalties, taxes, minimum legal limits, and emission quota/limits have been the most considered in the literature. This confirms the statement of the seminal work of Meadowcroft (2009) "the irreducibly political character of governance for sustainable development". These aspects play a fundamental role on the feasibility of the future recycling activity. Considering the political efforts of the European Union (Hartley et al., 2020) and China (Zhu et al., 2019) for a transition to a circular economy, these results could be used in future research on recycling networks for a circular economy.

Based on an analysis of these aspects according to the problem addressed and the application domain of the recycling network, a set of factors to be considered for each dimension-orientation and problem has been obtained. Table 4 summarizes the factors obtained for each dimension-orientation and problem. These factors have been studied in more than one domain of recycling. As evidenced in Table 4, there are some problems that have not been yet addressed in their important social, political, and technological aspects. Specifically, in design and planning problems, technological aspects related to product design and the technological level of installations could be addressed. For decision-making and performance evaluation problems, aspects related to transportation and product design could be integrated. For 3PRL provider selection problems, social aspects associated with customers, political aspects related to incentive/punishment and emissions, and technological aspects related to transportation, product design and the technology level could be integrated. And, finally, for price and coordination problems, social aspects related to workers, companies, political aspects such as government policies, and technological aspects associated with product design could be integrated.

Considering the aforementioned findings, and in order to carry out a more holistic (integral) evaluation of the recycling networks, future research could address social, political, and technological aspects that have not been addressed in the various problems analyzed in this research. For example, although design-for-environment products have been considered in sustainability assessments of e-waste recycling systems (Georgiadis and Besiou, 2008, 2010), this aspect could also be addressed in other types of problems and products. Specifically, the design of the closed loop or reverse supply chain depends on the product design. At the same time, the 3PRL providers and the decisions made in the chain (price and coordination problems) depend on the product design. In addition, technology maturity/coherence of the entire recycling system could be another aspect to explore. Further research could be carried out in order to define how the missing aspects of each problem could be addressed having sustainable development in mind, since, as this research has shown, in the literature on recycling networks there is no single way of addressing social aspects and the implications of political and technological aspects in the sustainability assessment of recycling networks. Moreover, linking technological and social innovation is required in designing such recycling systems, because both sorts of change are necessary if society is to move on to a more sustainable pathway.

Although these findings are obtained from a literature review, they could be useful as a contrast with the aspects that are considered in practice by recycling companies or territorial stakeholders. More research is needed with different stakeholders in real cases in order to validate and complete the proposition made in this article.

The evaluation of recycling networks from a sustainability point of view is a requirement today. Economic and environmental aspects in supply networks have been widely studied. However, it is not very clear in the literature how social, technological, and political aspects of sustainability should be included, especially in the recycling literature. From the management point of view, this research provides a basis for the social, political, and technological factors and indicators used in the literature on sustainable recycling networks considering the problem addressed. These aspects can be used in future research and conception/evaluations of recycling networks in order to produce 1) a more holistic sustainable evaluation and 2) the appropriate factors for each decision-maker involved in the evaluation process. Finally, it should be mentioned that the literature analysis carried out in this research corresponds only to the evaluation of CLSC-RL networks that involve recycling activity. Therefore, the sustainability aspects suggested are limited to this context.

6. Conclusions and perspectives

In this article a systematic literature review was performed on social, political, and technological dimensions in order to understand how these dimensions should be included in the sustainable recycling network evaluation process. A total of 160 journal articles were selected and analyzed.

This is the first literature review on the sustainability evaluation of recycling networks to include these three dimensions (social, technological, and political) proposed in the literature. A set of criteria was identified and analyzed for each of these three dimensions in the literature on the problem addressed and the recycling domain. Based on the results, the conclusion is that, from the quantitative point of view, political and technological aspects have been little explored. From the qualitative point of view, the conclusion is that these dimensions are studied from different orientations/perspectives. With regard to the social dimension, the criteria found were classified into five perspectives: worker-oriented, community-oriented, customer-oriented, company-oriented, and others. The technological dimension was classified into process-oriented technological factors, transport, product design, technology, and experience level. Finally, among the articles analyzed addressing the political dimension, four types of policies were identified: incentive/punishment oriented, legal policies, emissions policies, and active government policies. Based on this classification, a set of social, political, and technological aspects addressed in the literature on sustainability evaluation in recycling networks was associated with the main problems addressed in this topic (design and planning, decision-making and performance evaluation, price and coordination, and 3PRL provider selection).

The main contribution of this work lies in the understanding of how to consider social, political, and technological aspects taking into account the most common problems addressed in a recycling network. At the same time, this analysis of the results has identified research gaps (presented in the discussion section) in the aspects considered for each problem, which could be addressed by future research.

Social, political, and technological dimensions need to be studied in future research in order to develop a holistic evaluation. Based on the results of this article, a set of criteria to be considered for each dimension-orientation and problem have been suggested for this purpose. The results obtained in this research can serve as a basis for future studies and evaluations of sustainable recycling networks. In addition, the classification of the dimensions according to different perspectives can serve to pinpoint the appropriate criteria not only from the point of view of sustainability, but also from the point of view of each of the decision-makers and actors who participate in the evaluation process.

Finally, as perspectives of this research, the sustainability criteria and indicators found in this literature review could be contrasted with territorial actors in the recycling industry.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clet.2022.100397.

Appendix A. Social dimension

Table A1
Workers-oriented social criteria

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Job creation or employment	27	Number of jobs created or number of employees by the implementation of a recycling network	Design and planning	Quantitative	Employment score of facilities	Optimization	E-waste	Aalirezaei and Shokouhyar (2017); Shokohyar and Mansour (2013)
					Increase/decrease of qualified/non-qualified labor force of opening/close facilities	Optimization	E-waste	Temur and Bolat (2017)
					Number of created jobs (opportunities) opening facilities	Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)
						Optimization	Automotive industry	Fazli-Khalaf et al. (2020); Sahebjamnia et al. (2018)
							Construction and demolition wastes	Rahimi and Ghezavati (2018)
							General	Dutta et al. (2020); Pourjavad and Mayorga (2019); Rezaei and Kheirkhah (2018); Sajedi et al. (2020); Zarbakhshnia et al. (2020)
							Glass	Hajiaghaei-Keshteli and Fathollahi Fard (2019)
							Household waste and municipal solid waste	Taleizadeh et al. (2019)
							Medical waste	Govindan et al. (2016)
							Plastic	Mohammadi et al. (2020)
					Number of jobs created at transport level	Optimization	E-waste	Safdar et al. (2020)
					Number of people targeted to be employed at facility	Optimization	E-waste	Bal and Satoglu (2018)
					Variable job creation per product	Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)
						Optimization	Automotive industry	Jafari and Kazemi Abharian (2020); Kumar et al. (2020)
							General	Pourjavad and Mayorga (2019); Rezaei and Kheirkhah (2018)
							Glass	Hajiaghaei-Keshteli and Fathollahi Fard (2019)
			Decision-making and	Qualitative	Relative weight of social		Automotive industry	Ahmed et al. (2016b)

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Table A1 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
			performance evaluation		performance criteria	Multi-criteria decision-making		
				Quantitative	Jobs creation ratio	System Dynamics	Glass	Beiler et al. (2020)
					Number of created jobs (opportunities) opening facilities	Other method	Biorefinery/ Biomass	Santos and Magrini (2018)
					Number of formal e-waste workers	Other method	E-waste	de Souza et al. (2016)
					Number of workers involved in each route	Other method	E-waste	Ottoni et al. (2020)
					Unemployed people	System Dynamics	E-waste	Besiou et al. (2012)
					Variable job creation per product	System Dynamics	Metals	Chaudhary and Vrat (2020)
Health of workers	18	Health of workers during operations in the recycling network	3PRL provider selection	Qualitative	Relative weight of Health and safety criteria	Multi-criteria decision-making and Optimization	E-waste Plastic	Govindan et al. (2019) Mavi et al. (2017)
						Multi-criteria decision-making	Household waste and municipal solid waste	Kafa et al. (2018)
			Design and planning	Quantitative	Average of annual vehicle accidents	Optimization	Plastic	Mohammadi et al. (2020)
					Damage to workers score of facilities	Optimization	E-waste	Aalirezaei and Shokouhyar (2017); Shokohyar and Mansour (2013)
					Lost days	Optimization	Construction and demolition wastes	Rahimi and Ghezavati (2018)
							General	Dutta et al. (2020); Rezaei and Kheirkhah (2018); Sajedi et al. (2020); Zarbakhshnia et al. (2020)
							Glass	Hajiaghaei-Keshteli and Fathollahi Fard (2019)
							Household waste and Municipal solid waste	Taleizadeh et al. (2019)
							Medical waste	Govindan et al. (2016)
							Plastic	Mohammadi et al. (2020)
			Decision-making and performance evaluation	Qualitative	Relative weight of Health and safety criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016a, 2016b)
					Relative weight of Health risks and working conditions criteria	Other method	E-waste	de Souza et al. (2016)
				Quantitative	Number of employees who work under safe conditions	Other method	Plastic	Motevali Haghighi et al. (2016)
Safety of worker	11	Safety of workers during operations in the recycling network	3PRL provider selection	Qualitative	Relative weight of Health and safety criteria	Multi-criteria decision-making and Optimization	E-waste Plastic	Govindan et al. (2019) Mavi et al. (2017)
						Multi-criteria decision-making	Household waste and Municipal solid waste	Kafa et al. (2018)
			Design and planning	No indicator	Without indicator	Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)

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Table A1 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
				Quantitative	Average accident at work per worker	Optimization	General	Zarbakhshnia et al. (2020)
					Lost days	Optimization	Automotive industry Household waste and Municipal solid waste	Sahebjamnia et al. (2018) Taleizadeh et al. (2019)
			Decision-making and performance evaluation	Qualitative	Relative weight of Health and safety criteria	Multi-criteria decision-making	Automotive industry	(Ahmed et al., 2016a; 2016b)
					Relative weight of Health risks and working conditions criteria	Other method	E-waste	de Souza et al. (2016)
				Quantitative	Number of employees who work under safe conditions	Other method	Plastic	Motevali Haghighi et al. (2016)
Employment practices	6	Effects on workers in terms of disciplinary and security practices, employee contracts, equity labor sources, job creation, job satisfaction, wages, employee training, etc.	3PRL provider selection	Qualitative	Relative weight Equity labor sources criteria	Multi-criteria decision-making and Optimization	E-waste	Govindan et al. (2019)
					Relative weight of Employment practices criteria	Multi-criteria decision-making	Household waste and Municipal solid waste	Kafa et al. (2018)
					Relative weight Staff training criteria	Multi-criteria decision-making and Optimization	E-waste	Govindan et al. (2019)
			Design and planning	Qualitative	Index and relative weight of employment practices criteria	Multi-criteria decision-making and Optimization	General	Liu et al. (2020a)
			Other problem	No indicator	Without indicator	Other method	General	Sarkis et al. (2010)
			Decision-making and performance evaluation	Qualitative	Relative weight of Employee training criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016a)
					Relative weight of Employment opportunities & job satisfaction criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016a)
					Relative weight of Employment practices criteria	Multi-criteria decision-making	E-waste	Agrawal et al. (2016a)
Employment stability	5	Variations in the number of employees of the recycling network, mainly due to the uncertainty in which these networks are involved with respect to the collection of waste or discarded products.	3PRL provider selection	Qualitative	Relative weight Employee turnover rate criteria	Multi-criteria decision-making	General	Rani et al. (2020)
					Relative weight of Employment stability criteria	Multi-criteria decision-making and Optimization	Plastic	Mavi et al. (2017)
			Other problem	No indicator	Without indicator	Other method	General	Sarkis et al. (2010)
				Qualitative	Likert scale of Employment stability criteria	Other method	E-waste	Agrawal and Singh (2019)
			Decision-making and performance evaluation	Qualitative	Relative weight of Employment stability criteria	Multi-criteria decision-making	E-waste	Agrawal et al. (2016b)
Employee benefits	2	Wages level received by employees	Other problem	Qualitative	Likert scale of Employee Benefit criteria	Other method	E-waste	Agrawal and Singh (2019)
			Decision-making and performance evaluation	Qualitative	Relative weight of Employee Benefit criteria	Multi-criteria decision-making	E-waste	Agrawal et al. (2016b)
Job satisfaction	2	Labor wages, benefits, and security	Design and planning	Quantitative	Amount of job satisfaction	Optimization	Household waste and	Taleizadeh et al. (2019)

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Table A1 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
					created by employee support		Municipal solid waste	
			Decision-making and performance evaluation	Qualitative	Relative weight of Employment opportunities & job satisfaction criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016a)
Training and education of employees	2	Courses and training classes to use a specific technology	Design and planning	Quantitative	Average courses and training classes held in facilities	Optimization	General	Zarbakhshnia et al. (2020)
					Training hours for skilled staff	Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)
Access to education	1	Number of e-waste workers and relatives with high level of education	Decision-making and performance evaluation	Quantitative	Number of e-waste workers and relatives with high level of education	Other method	E-waste	de Souza et al. (2016)
Access to healthcare	1	Number of e-waste workers and their relatives provided with health insurance	Decision-making and performance evaluation	Quantitative	Number of e-waste workers and their relatives provided with health insurance	Other method	E-waste	de Souza et al. (2016)
Establishment of new employment opportunities	1	Employment opportunities for workers and drivers	Design and planning	Quantitative	Number of drivers hired for transportation	Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)
Flexible working arrangements	1	Flexible working arrangements of the third-party reverse logistic provider	3PRL provider selection	Qualitative	Relative weight of flexible working arrangements criteria	Multi-criteria decision-making and Optimization	Plastic	Mavi et al. (2017)
Human capital	1	Generation of low-skilled jobs	Other problem	No indicator	Without indicator	Other method	General	Sarkis et al. (2010)
Labor equity and supplier stock management	1	Labor equity and supplier stock management of the third-party reverse logistic provider	3PRL provider selection	Qualitative	Relative weight of labor equity and supplier stock management criteria	Multi-criteria decision-making and Optimization	Plastic	Mavi et al. (2017)
Total employee fund generated	1	Total employee fund generated in the facilities	Decision-making and performance evaluation	Quantitative	Fund allocation per employee	Multi-criteria decision-making and Optimization	E-waste	Agarwal et al. (2016)
Worker's status	1	Change of status of waste pickers to formal workers	Decision-making and performance evaluation	No indicator	Without indicator	Other method	Household waste and Municipal solid waste	Pongeluppe Wadhy Rebehy et al. (2017)
Working hours	1	Working hours during operations	Design and planning	Quantitative	Total hour of work per worker	Optimization	E-waste	Ramos et al. (2014)

Table A2
Customer-oriented social criteria

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Sensitivity of customers	8	Customers preference for a product considering its characteristics	Price and coordination	No indicator	Without indicator	Game theory	General	Kim et al. (2020); Ma and Huang (2019); Mondal et al. (2020); Mondal and Giri (2020); Rezaei and Maihami (2020); Song et al. (2020); Xiang and Xu (2020)
							E-waste	Ghalehkhondabi and Ardjmand (2020)
Health of customer	5	Heath of customers regarding to the use of products obtained from the recycling of waste	Design and planning	Quantitative	Fraction of potentially harmful products which	Optimization	Plastic	Mohammadi et al. (2020)

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Table A2 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
					harm the consumer			
					Fraction of potentially perilous products	Optimization	Household waste and Municipal solid waste	Taleizadeh et al. (2019)
			Other problem	Qualitative	Likert scale of Health and safety criteria	Other method	E-waste	Agrawal and Singh (2019)
			Decision-making and performance evaluation	Qualitative	Relative weight of Health and safety criteria	Multi-criteria decision-making	E-waste	Agrawal et al. (2016a), (2016b)
Incentives to customers	5	Monetary incentives to consumers to motivate the return of discarded products for proper treatment	Design and planning	Quantitative	Offered acquisition prices to customer	Optimization	General	Fattahi and Govindan (2017)
			Decision-making and performance evaluation	Quantitative	Percentage of product	System Dynamics	Metals	Chaudhary and Vrat (2020)
			Price and coordination	Quantitative	Offered acquisition prices to customer	Game theory	General	Ma et al. (2019)
							Medical waste	Liu et al. (2020b)
						Other method	General	Allevi et al. (2018)
Safety of customer	5	Safety due to the use of products obtained from the recycling of waste	Design and planning	Quantitative	Fraction of potentially harmful products which harm the consumer	Optimization	Plastic	Mohammadi et al. (2020)
					Fraction of potentially perilous products	Optimization	Household waste and Municipal solid waste	Taleizadeh et al. (2019)
			Other problem	Qualitative	Likert scale of Health and safety criteria	Other method	E-waste	Agrawal and Singh (2019)
			Decision-making and performance evaluation	Qualitative	Relative weight of Health and safety criteria	Multi-criteria decision-making	E-waste	(Agrawal et al., 2016a, 2016b)
Customer preference	4	Customer preference for recycled products or service	Design and planning	Indirect indicator	Without indicator	Optimization	Household waste and Municipal solid waste	Niranjan et al. (2019)
			Price and coordination	Quantitative	Degree of preference (Number between 0 and 1)	Game theory	General	Duan et al. (2019); Han et al. (2020b); Wu et al. (2019a)
Consumer behavior for disposal and recycling	3	Behavior of consumers in terms of how they dispose their product	Other problem	No indicator	Without indicator	Other method	Automotive industry	Uriarte-Miranda et al. (2018)
				Qualitative	Likert scale of Consumer behavior criteria	Other method	E-waste	Agrawal and Singh (2019)
			Decision-making and performance evaluation	No indicator	Without indicator	Other method	Plastic	Chavez and Sharma (2018)
Accessibility and responsiveness to customers	1	Distances from the facilities/ distributers to the customers for better accessibility and responsiveness.	Design and planning	Quantitative	Distances from the facilities/ distributers to the customers	Optimization	General	Masoudipour et al. (2020)
Firms' service quality	1	Improvement of firms' service quality adopting RL	Other problem	Qualitative	Likert scale of Improve our firm's service quality criteria	Other method	General	Lai et al. (2013)
Participation rate	1	Participation of sectors in a recycling network	Design and planning	Quantitative	Function of incentive rate	Optimization	Biorefinery/ Biomass	Ng and Wang (2017)

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Table A2 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Product harming the customers	1	Damages caused to consumers due to certain products, which are made from recycled material	Design and planning	Quantitative	Percentage of the products harming the customers	Optimization	General	Rezaei and Kheirkhah (2018)
Public engagement	1	Awareness and participation of consumers in relation to recycling	Other problem	No indicator	Without indicator	Other method	Solar energy industry	Lapko et al. (2019)
Service level	1	Quantity of recycled material sent to the consumer	Design and planning	Quantitative	Amount of product transported to customer	Optimization and LCA	Plastic	Feitó-Cespón et al. (2017)
Voice of customer	1	Voice of customer about the third-party reverse logistic provider	3PRL provider selection	Qualitative	Relative weight of Voice of customer criteria	Multi-criteria decision-making and Optimization	Plastic	Mavi et al. (2017)

Table A3
Community-oriented social criteria

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Donation to community	5	Monetary donation for social work	Other problem	Qualitative	Likert scale of Donation to community criteria	Other method	E-waste	Agrawal and Singh (2019)
			Decision-making and performance evaluation	Qualitative	Relative weight of Donation to community criteria	Multi-criteria decision-making	E-waste	Agrawal et al. (2016b)
				Quantitative	NGO fund allocation	Multi-criteria decision-making and Optimization	E-waste	Agarwal et al. (2016)
			Price and coordination	Quantitative	Amount of direct donation	Game theory	General	Song et al. (2020)
					Monetary amount per unit sells	Game theory	General	Modak et al. (2019a)
Corporate social responsibility	3	Company's commitment to social impacts	Decision-making and performance evaluation	Qualitative	Relative weight of Corporate social responsibility criteria	Multi-criteria decision-making	E-waste	Jindal and Sangwan (2016)
			Price and coordination	Qualitative	Degree of CSR (Corporate social responsibility)	Game theory	Automotive industry	Johari and Hosseini-Motlagh (2019)
				Quantitative	Fraction of CSR	Game theory	Plastic, glass, and metal	Modak et al. (2019b)
Inclusion of waste pickers	3	Inclusion of non-formal collectors in a recycling network	Design and planning	Indirect indicator	Without indicator	Optimization	Household waste and Municipal solid waste	Ferri et al. (2015)
			Decision-making and performance evaluation	No indicator	Without indicator	Other method	Household waste and Municipal solid waste	Pongeluppe Wadhy Rebehy et al. (2017)
				Quantitative	Formalization rate	System Dynamics	E-waste	Ghisolfi et al. (2017)
Local development	3	Development of the community by the installation of network facilities	Design and planning	Qualitative	Local development score of facilities	Optimization	E-waste	Aalirezaei and Shokouhyar (2017); Shokohyar and Mansour (2013)
				Quantitative	importance rate of location in the region	Optimization	Plastic	Mohammadi et al. (2020)
Community complaints	2	Number of complaints received, and the number of complaints resolved to the	Other problem	Qualitative	Likert scale of Community complaints criteria	Other method	E-waste	Agrawal and Singh (2019)
			Decision-making and	Qualitative			E-waste	Agrawal et al. (2016b)

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Table A3 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
		satisfaction of the complainants	performance evaluation		Relative weight of Community complaints criteria	Multi-criteria decision-making		
Local community influence	2	Promotion of activities for the betterment of the society	3PRL provider selection	Qualitative	Relative weight Local community influence criteria	Multi-criteria decision-making and Optimization	E-waste	Govindan et al. (2019)
						Multi-criteria decision-making	Household waste and Municipal solid waste	Kafa et al. (2018)
Risk of transport and installation of facilities	2	Risk due to the treatment and transport of waste	Design and planning	Quantitative	Transport risk between facilities and operational risk at facilities	Optimization	Medical waste	Homayouni and Pishvaee (2020)
			Vehicle routing problems	Quantitative	Number of people around the route and facility	Optimization	Hazardous waste	Farrokhi-Asl et al. (2020)
Social cost of carbon	2	Social benefits/impacts for the implementation of the network (in terms of carbon emissions)	Design and planning	Quantitative	Cost of emitting one extra ton of carbon	Optimization	Automotive industry	Saxena et al. (2018)
					Estimate of the damages associated with a small increase in carbon dioxide emissions (ton/year)	Optimization	Household waste and Municipal solid waste	Edalatpour et al. (2018)
Community Influence	1	Impacts on the community (Health, education, service infrastructure, etc.)	Decision-making and performance evaluation	Qualitative	Relative weight of Communities Influence criteria	Multi-criteria decision-making	E-waste	Agrawal et al. (2016a)
Community capital	1	Impacts on the community in terms of food and health security, economic security, etc.	Other problem	No indicator	Without indicator	Other method	General	Sarkis et al. (2010)
Community service	1	Hours dedicated for community service per facility	Design and planning	Quantitative	Hours dedicated for community service	Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)
Demanding customer/ Stakeholder pressure	1	Demanding customer/ stakeholder pressure to implement RL	Other problem	No indicator	Without indicator	Other method	General	Abdullah and Yaakub (2014)
Disturbance in public places	1	Disturbance in public areas due to recovery option adoption	Decision-making and performance evaluation	Qualitative	Fuzzy weights of Disturbance in public places criteria	Multi-criteria decision-making	Household waste and Municipal solid waste	Awan and Ali (2019)
Ecological risk and safety risk	1	Ecological risk and safety risk of a waste management option	Decision-making and performance evaluation	Qualitative	Relative weight of Ecological risk and safety risk criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016a)
Economic welfare and growth	1	Economic impact of the system including the impact on local education concepts, employment concepts, and the impact on the lives of surrounding residents	Design and planning	Qualitative	Index and relative weight of Economic welfare and growth criteria	Multi-criteria decision-making and Optimization	General	Liu et al. (2020a)
Educational campaigns	1	Number of annual campaigns to increase participation of local residents with the disposal of their e-waste	Decision-making and performance evaluation	Quantitative	Number of annual campaigns to increase participation of local residents with the disposal of their e-waste	Other method	E-waste	Ottoni et al. (2020)
Effect of production on self-sufficiency	1	Impact of the amount of production on the self-sufficiency of the country's economy due to the implementation of a CLSC network	Design and planning	Quantitative	Coefficient of production effect on self-sufficiency	Optimization	Household waste and Municipal solid waste	Taleizadeh et al. (2019)
Impact on nearby residents	1	Impact of facilities on the community	Design and planning	Qualitative	Penalty coefficient	Multi-criteria decision-	General	Yang and Chen (2020)

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Table A3 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
						making and Optimization		
Impact on traffic jams	1	Impact of facilities on traffic	Design and planning	Qualitative	Penalty coefficient	Multi-criteria decision-making and Optimization	General	Yang and Chen (2020)
Immigration prevention	1	Immigration prevention via opening facilities in divergent locations	Design and planning	Quantitative	Immigration rate	Optimization	Automotive industry	Fazli-Khalaf et al. (2020)
Neighborhood server by each collection	1	Number of neighborhoods served by each collection route	Decision-making and performance evaluation	Quantitative	Number of neighborhoods served by each collection	Other method	E-waste	Ottoni et al. (2020)
Products donated to NGOs	1	Number of products donated to NGOs	Design and planning	Quantitative	Number of products donated to NGOs	Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)
Reduction of vehicle accident rate	1	Rate of accident during distribution products and gathering the expired products	Vehicle routing problems	Quantitative	Vehicle accident rate proposed as a function	Optimization	Food industry	Rahimi et al. (2016)
Respect for the local rules and policies	1	Respect for the local rules and policies of the third-party reverse logistic provider	3PRL provider selection	Qualitative	Relative weight of Respect for the local rules and policies criteria	Multi-criteria decision-making and Optimization	Plastic	Mavi et al. (2017)
Social cost	1	Social cost of illegal recycling, such as pollution and traffic accident	Price and coordination	Quantitative	Average negative social cost	Game theory	Automotive industry	Yu et al. (2020)
Social cost based on disposal	1	Economical representation of the social impact due to the use of landfill	Decision-making and performance evaluation	Quantitative	Cost per unit quantity disposed to environment	Optimization	Medical waste	Nidhi and Pillai (2019)
Social impact	1	Social impact by opening facilities to socially underdeveloped areas in terms of GDP (Gross domestic product) level	Design and planning	Quantitative	Social utility factor	Optimization	E-waste	Budak (2020)
Social inclusion	1	Social integration of workers that come from groups such as: women, informality, prison, slums, alcoholism, drug addiction, crime, physical and mental disabilities	Decision-making and performance evaluation	Quantitative	Number of new e-waste workers that come from specific groups	Other method	E-waste	de Souza et al. (2016)
Social support	1	New business opportunity (workforce, education, and business friendliness) due to the implementation of the network	Design and planning	Quantitative	Level of social support of facility	Optimization	Metals	Jin et al. (2018)
Vehicle noise emissions	1	Total vehicle noise emissions per route	Vehicle routing problems	Quantitative	Amount of vehicle noise emission function	Optimization	Food industry	Rahimi et al. (2016)
Visual pollution	1	Visual pollution factor of transport and facility location	Design and planning	Quantitative	Visual pollution factor of transport and facility location	Optimization	Hazardous waste	Saeidi et al. (2020)
Waste recycled	1	Social benefit in a reverse supply chain derived from the maximization of the amount of waste recycled	Price and coordination	Quantitative	Quantity of WEEE recycled	Game theory	E-waste	Li et al. (2017)

Table A4
Company-oriented social criteria

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Customer satisfaction	5	Conformity to customer expectations of the product or service provided by the company	3PRL provider selection	Qualitative	Relative weight of Brand image & customer satisfaction criteria	Multi-criteria decision-making	General	Rani et al. (2020)
			Design and planning	Quantitative	Percentage of demand satisfied	Optimization	General	Garai and Roy (2020)
			Other problem	No indicator	Without indicator	Other method	Paper	Mangla et al. (2012)
			Decision-making and performance evaluation	Qualitative	Relative weight of Brand image & customer satisfaction criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016a)
				Quantitative	Percentage of customers who are satisfied with the final products	Other method	Plastic	Motevali Haghighi et al. (2016)
Green image	5	Image of the company in the eyes of consumers or society, when the company carries out recycling activities	3PRL provider selection	Qualitative	Relative weight of Green Image criteria	Multi-criteria decision-making	Household waste and Municipal solid waste	Kafa et al. (2018)
			Design and planning	No indicator	Without indicator	Multi-criteria decision-making and Optimization	Bicycles	Liu et al. (2019)
			Decision-making and performance evaluation	Quantitative	Increase in customer goodwill due to greening activities	Other method	General	Mutingi et al. (2014)
					Percentage with respect to reuse index and market behavior	System Dynamics	E-waste	Georgiadis and Besiou (2010)
					Relation between “Market behavior” and “reuse index”	System Dynamics	E-waste	Georgiadis and Besiou (2008)
Corporate image	4	Reputation of the company in the eyes of the public after the implementation of the network	Other problem	Qualitative	Likert Scale of Corporate Image criteria	Other method	General	Lai et al. (2013)
			Decision-making and performance evaluation	Qualitative	Relative weight of Brand image & customer satisfaction criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016a)
					Relative weight of Corporate image criteria	Multi-criteria decision-making	E-waste	Agrawal et al. (2016a)
					Relative weight of Social performance criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016b)
Income generation	3	Generation of monetary incomes by new actors integrated in the recycling network (collector or contracted company)	Decision-making and performance evaluation	Quantitative	Monetary incomes	Other method	E-waste	de Souza et al. (2016); Slomski et al. (2018)
					Monetary incomes	Other method	Household waste and Municipal solid waste	de Oliveira et al. (2020)
Stakeholder participation	2	Stakeholders' engagement with the network	Other problem	Qualitative	Likert scale of Stakeholders participation criteria	Other method	E-waste	Agrawal and Singh (2019)
			Decision-making and performance evaluation	Qualitative	Relative weight of Stakeholders participation criteria	Multi-criteria decision-making	E-waste	Agrawal et al. (2016b)

Table A5
Other social criteria

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Road safety	1	Impact on road safety due to recovery option adoption	Decision-making and performance evaluation	Qualitative	Fuzzy weights of Road safety criteria	Multi-criteria decision-making	Household waste and Municipal solid waste	Awan and Ali (2019)
Health of road	1	Impact on health of road due to recovery option adoption	Decision-making and performance evaluation	Qualitative	Fuzzy weights of Health of road criteria	Multi-criteria decision-making	Household waste and Municipal solid waste	Awan and Ali (2019)
Distribution Services	1	Impact on distribution services due to recovery option adoption	Decision-making and performance evaluation	Qualitative	Fuzzy weights of Distribution Services criteria	Multi-criteria decision-making	Household waste and Municipal solid waste	Awan and Ali (2019)
Access to markets	1	Impact on access to markets due to recovery option adoption	Decision-making and performance evaluation	Qualitative	Fuzzy weights of Access to markets criteria	Multi-criteria decision-making	Household waste and Municipal solid waste	Awan and Ali (2019)
Amount of expired products	1	Minimization of the amount of expired products which should be recycled	Vehicle routing problems	Quantitative	Age and price policy in the model	Optimization	Food industry	Rahimi et al. (2016)
Market demand	1	Demand of the recycled product or the other recovery options	Decision-making and performance evaluation	Qualitative	Relative weight of Market demand criteria	Multi-criteria decision-making	E-waste	Jindal and Sangwan (2016)
Productive capital	1	Service infrastructure available to collect and recycle consumer-generated waste	Other problem	No indicator	Without indicator	Other method	General	Sarkis et al. (2010)
Contractual stakeholders' influence	1	Flexibility of partnership standards, enterprise alliances, and stakeholders' engagement	3PRL provider selection	Qualitative	Relative weight of Contractual stakeholder's influence criteria	Multi-criteria decision-making	Household waste and Municipal solid waste	Kafa et al. (2018)
Reputation	1	Reputation of the potential partner	3PRL provider selection	Qualitative	Relative weight of Reputation criteria	Multi-criteria decision-making	Household waste and Municipal solid waste	Kafa et al. (2018)
Percent recycling	1	Increase in recycled material compared to material disposal	Decision-making and performance evaluation	Quantitative	Increase in recycled material compared to material disposal	Other method	General	Mutingi et al. (2014)
Product green efficiency	1	Increase of green design features in a product, number of parts, etc.	Decision-making and performance evaluation	Quantitative	Increase of green design features in a product, number of parts, etc.	Other method	General	Mutingi et al. (2014)
Effective communication (EC)	1	Effective communication of the third-party reverse logistic provider	3PRL provider selection	Qualitative	Relative weight of Effective communication criteria	Multi-criteria decision-making	Automotive industry	Govindan et al. (2013)
Service improvement	1	Service improvement of the third-party reverse logistic provider	3PRL provider selection	Qualitative	Relative weight of Service improvement criteria	Multi-criteria decision-making	Automotive industry	Govindan et al. (2013)
Overall working relations	1	Overall working relations of the third-party reverse logistic provider	3PRL provider selection	Qualitative	Relative weight of Overall working relations criteria	Multi-criteria decision-making	Automotive industry	Govindan et al. (2013)
Public acceptability	1	Public acceptability adopting waste management option	Decision-making and performance evaluation	Qualitative	Relative weight social performance criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016b)
Market edge	1	Market edge adopting product recovery system	Other problem	No indicator	Without indicator	Other method	Paper	Mangla et al. (2012)
Customer redundancy	1	Customer redundancy adopting product recovery system	Other problem	No indicator	Without indicator	Other method	Paper	Mangla et al. (2012)
Extended producer responsibilities	1	Series of measures taken by producers to promote product collection	Design and planning	Qualitative	Index and relative weight of extended producer responsibilities criteria	Multi-criteria decision-making and Optimization	General	Liu et al. (2020a)
	1	Tasks performed by internal members of the	Design and planning	Qualitative	Index and relative weight of	Multi-criteria decision-making	General	Liu et al. (2020a)

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Table A5 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Responsibilities towards stakeholders		system to maintain system operation and stability			Responsibilities towards stakeholders' criteria	and Optimization		
Conditions of public facilities	1	Impact of the public facilities conditions on the facility location	Design and planning	Qualitative	Penalty coefficient	Multi-criteria decision-making and Optimization	General	Yang and Chen (2020)
Public safety	1	Impact of safety on the facility location	Design and planning	Qualitative	Penalty coefficient	Multi-criteria decision-making and Optimization	General	Yang and Chen (2020)
Talent reserve	1	Impact of talent reserve on the facility location	Design and planning	Qualitative	Penalty coefficient	Multi-criteria decision-making and Optimization	General	Yang and Chen (2020)
Use of renewable energy	1	Use of renewable energy via opening facilities in divergent locations	Design and planning	Quantitative	Rate of available renewable energies	Optimization	Automotive industry	Fazli-Khalaf et al. (2020)

Appendix B. Political dimension

Table B1
Incentive/punishment-oriented policies

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Subsidy	24	Monetary incomes to promote recovery/ recycling	Design and planning	Quantitative	Percentage of subsidy earned from the government for training employees	Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)
					Subsidy per unit collected/ recovered/ produced	Optimization	E-waste	Capraz et al. (2015)
							General	Garai and Roy (2020); Yu and Solvang (2017a)
			Other problem	Quantitative	Subsidy per unit collected/ recovered/ produced	Other method	E-waste	Nambu and Murakami-Suzuki (2016)
			Decision-making and performance evaluation	No indicator	Subsidy and incentive to reusable material procurement	System Dynamics	Glass	Beiler et al. (2020)
				Quantitative	Subsidy per unit collected/ recovered/ produced	Multi-criteria decision-making and Optimization	E-waste	Agarwal et al. (2016)
						Other method	E-waste	Tong et al. (2018)
						System Dynamics and Grey Model Theory	Construction and demolition wastes	Jia et al. (2018)
			Price and coordination	Quantitative	Degree of subsidy for remanufacturing technology	Game theory	General	Tan and Guo (2019); Wu et al. (2019a)
					Subsidy to investment	Game theory	General	Kim et al. (2020); Saha et al. (2019)
					Subsidy to the consumer (price)	Game theory	General	Saha et al. (2019)
					Subsidy per unit collected/ recovered/ produced	Game theory	Automotive industry	Yu et al. (2020)
							Food industry	Liu et al. (2019b)
							General	Duan et al. (2019); Han et al. (2020b); Huang et al. (2020); Mondal and Giri (2020); Song et al. (2020)
							Medical waste	Liu et al. (2020b) Wu et al. (2019a)

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Table B1 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
							Solar energy industry	
						Other method	E-waste	Liu et al. (2016)
							General	Allevi et al. (2018)
Taxes	10	Additional costs imposed by the government to control carbon emissions or promote recycling	Design and planning	Quantitative	Carbon tax (tax per carbon emission)	Optimization	Automotive industry	Kumar et al. (2020); Saxena et al. (2018)
							General	Gao and Ryan (2014)
					Landfill tax	Optimization	Metals	Ansbro and Wang (2013)
					Per unit tax credit from donation of returns	Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)
			Other problem	Quantitative	Tax to new product (recycling fee per product)	Other method	E-waste	Nambu and Murakami-Suzuki (2016)
			Decision-making and performance evaluation	Quantitative	Tax for scavengers' uncontrollable disposal	System Dynamics	E-waste	Besiou et al. (2012)
					Tax if the firm does not comply with the legislative recycling percentage	System Dynamics	E-waste	Besiou et al. (2012)
					Tax in case the firm does not comply with the legislative collection percentage	System Dynamics	E-waste	Besiou et al. (2012)
			Price and coordination	Quantitative	Carbon tax (tax per carbon emission)	Other method	General	Allevi et al. (2018)
					Recovery taxes (monetary unit/per pound)	Game theory	E-waste	Ghalehkhondabi and Ardjmand (2020)
					Tax deduction per donated product	Game theory	Medical waste	Liu et al. (2020a)
Penalties	6	Additional costs due to regulations	Design and planning	Quantitative	Penalty cost by use of paper or plastic in packaging	Optimization	General	Porkar et al. (2018)
			Decision-making and performance evaluation	Quantitative	Cost per item due to regulatory non-compliance	System Dynamics	E-waste	Georgiadis and Besiou (2010)
					Penalty for non-recyclable product disposed as landfill	Optimization	Medical waste	Nidhi and Pillai (2019)
					Penalty for illegally dumped waste	System Dynamics and Grey Model Theory	Construction and demolition wastes	Jia et al. (2018)
			Price and coordination	Quantitative	Emission penalties (unit emission social responsibility cost for the government)	Game theory	E-waste	Ghalehkhondabi and Ardjmand (2020)
					Penalty (reward) for not adopting a legal recycling strategy	Game theory	Automotive industry	Yu et al. (2020)
Reward and punishment policy	2	Imposition of minimum recovery/ collection rates for the application of reward and punishment with respect to it	Price and coordination	Quantitative	Rewards and punishment to collection rate limit	Game theory	General	Kim et al. (2020)
					Rewards and punishment to recovery rate limit	Game theory	General	Tan and Guo (2019)
Credit lines to investment	1	Credit lines given by government to promote recycling	Decision-making and performance evaluation	Quantitative	Formalization ratio due to environmental policies	System Dynamics	E-waste	Ghisolfi et al. (2017)
Financial incentives	1	Financial incentives to projects related to the responsibility for the life cycle of products,	Decision-making and performance evaluation	Quantitative	Formalization ratio due to environmental policies	System Dynamics	E-waste	Ghisolfi et al. (2017)
Responsibilities and penalties (sanctions) of	1	Responsibilities and penalties (sanctions)	Other problem	No indicator	Without indicator	Other method	General	Murakami et al. (2015)

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Table B1 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
citizens and companies		imposed for citizens and companies						
Waste disposal charging fee	1	Cost imposed due to the use of landfills for waste management	Decision-making and performance evaluation	Quantitative	Waste disposal charging fee per product	System Dynamics and Grey Model Theory	Construction and demolition wastes	Jia et al. (2018)

Table B2
Emission policies

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Emissions cap	8	Limit on permitted emissions	Design and planning	Quantitative	Maximum amount of a particular pollutant which can be produced	Optimization	E-waste General Plastic	Safdar et al. (2020) Aljuneidi and Bulgak (2020); Gao and Ryan (2014); Yu and Solvang (2017a) Bing et al. (2015)
			Other problem	Quantitative	Maximum amount of a particular pollutant which can be produced	Optimization	General	Bai et al. (2020)
			Decision-making and performance evaluation	Quantitative	Maximum amount of a particular pollutant which can be produced	Optimization	Medical waste	Nidhi and Pillai (2019)
			Price and coordination	Quantitative	Maximum amount of a particular pollutant which can be produced	Game theory	General	Mondal and Giri (2020)
Emissions quota	5	Amount of carbon emissions traded by a company	Design and planning	Quantitative	Quantity of emissions	Optimization	General Plastic	Gao and Ryan (2014); Yu and Solvang (2017a) Bing et al. (2015)
			Decision-making and performance evaluation	Quantitative	Quantity of emissions	Optimization	Medical waste	Nidhi and Pillai (2019)
			Price and coordination	Quantitative	Quantity of emissions	Other method	General	Allevi et al. (2018)
Emission standards	1	Emission standards imposed	Other problem	No indicator	Without indicator	Other method	General	Murakami et al. (2015)

Table B3
Legal criteria

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Legislation	15	Legislative environment with respect to the operation and treatment of waste	3PRL provider selection	Qualitative	Relative weight of respect for the local rules and policies criteria	Multi-criteria decision-making and Optimization	Plastic	Mavi et al. (2017)
			Design and planning	Quantitative	Legal collection goal (percentage at which product should be collected)	Optimization	E-waste	Bal and Satoglu (2018)
			Other problem	No indicator	Without indicator	Other method	Automotive industry E-waste Paper Solar energy industry	Uriarte-Miranda et al. (2018) Zoeteman et al. (2010) Mangla et al. (2012) Lapko et al. (2019)
				Qualitative	Likert scale of Government rules and regulation criteria	Other method	E-waste	Agrawal and Singh (2019)
				No indicator	Without indicator	Other method		

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Table B3 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
			Decision-making and performance evaluation				Household waste and Municipal solid waste	Pongeluppe Wadhy Rebehy et al. (2017)
							Plastic	Chavez and Sharma (2018)
				Qualitative	Relative weight of Regulatory satisfaction criteria	Multi-criteria decision-making	E-waste	Agrawal et al. (2016a)
				Quantitative	Minimum legislative collection percentage (fraction of collected products vs used products)	System Dynamics	E-waste	Besiou et al. (2012); Georgiadis and Besiou (2008, 2010)
					Minimum legislative limit of recyclability (recyclable percentage of the product)	System Dynamics	E-waste	Georgiadis and Besiou (2008, 2010)
					Minimum legislative limit of recycled content (use of recycled material in production)	System Dynamics	E-waste	Georgiadis and Besiou (2010)
					Minimum legislative recycling percentage (product accepted for recycling vs collected)	System Dynamics	E-waste	Besiou et al. (2012); Georgiadis and Besiou (2008, 2010)
			Price and coordination	Quantitative	Legal minimum amount of waste to be submitted	Game theory	Food industry	Liu et al. (2019b)
Adherence to legal norms	1	Adherence to legal norms of the designed recycling network	Design and planning	No indicator	Without indicator	Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)
Compliance with International Labor Organization (ILO) code	1	Compliance with various laws related to the welfare of the laborer's	3PRL provider selection	Qualitative	Relative weight of compliance with International Labor Organization criteria	Multi-criteria decision-making and Optimization	E-waste	Govindan et al. (2019)
Laws and regulation support	1	Laws and regulation support for the location of facilities	Design and planning	Qualitative	Penalty coefficient	Multi-criteria decision-making and Optimization	General	Yang and Chen (2020)

Table B4
Active government policies

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Imposition of the RL network	2	Imposition of the government regarding a network structure or conditions for the network	Design and planning	Indirect indicator	Without indicator	Optimization	Household waste and Municipal solid waste	Ferri et al. (2015)
			Decision-making and performance evaluation	No indicator	Without indicator	Other method	E-waste	Azevedo et al. (2017)
Flow conditions of waste policy	1	Imposition of flow of waste considering formal and informal collectors	Design and planning	Indirect indicator	Without indicator	Optimization	Household waste and Municipal solid waste	Ferri et al. (2015)
Imposition of reduction rate and selling price of product	1	Minimum unit reduction rate of carbon emissions and maximum unit selling price of remanufactured products proposed by governmental collection center	Price and coordination	No indicator	Without indicator	Game theory	General	Rezaei and Maihami (2020)
Government's stockpile	1		Design and planning	Quantitative		Optimization	Metals	Son et al. (2018)

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Table B4 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
		Government maintains a stock of raw materials (including recycled material) to regulate the market			Stockpile amount of product			
Incorporation of Governmental collection center	1	Incorporation of governmental collection center in the recycling network	Price and coordination	No indicator	Without indicator	Game theory	General	Rezaei and Maihami (2020)

Table B5
Other policies

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Imposition of mandatory collection	1	Mandatory collection of waste by means of waste pickers inclusion	Decision-making and performance evaluation	No indicator	Without indicator	System Dynamics	E-waste	Ghisolfi et al. (2017)
Imposition of quality threshold	1	Quality threshold imposed by government to reuse waste	Price and coordination	Quant	Minimum quality threshold of reusing (number between 0 and 1)	Other method	E-waste	Liu et al. (2016)
Political stability	1	Political stability for the location of facilities	Design and planning	Qualitative	Penalty coefficient	Multi-criteria decision-making and Optimization	General	Yang and Chen (2020)
Product bans and use limitations	1	Imposition of product bans	Other problem	No indicator	Without indicator	Other method	General	Murakami et al. (2015)
Qualification of waste pickers through capacitation actions	1	Qualification of waste pickers through capacitation actions to promote the integration of waste pickers	Decision-making and performance evaluation	Quantitative	Formalization ratio due to environmental policies	System Dynamics	E-waste	Ghisolfi et al. (2017)
Requirements for the hazardous waste management	1	Requirements imposed for the hazardous waste management	Other problem	No indicator	Without indicator	Other method	General	Murakami et al. (2015)
Solid waste and packing regulation	1	Imposition of solid waste and packing regulation	Other problem	No indicator	Without indicator	Other method	General	Murakami et al. (2015)
Tactics	1	Behavior of legislators with respect to environmental policies	Decision-making and performance evaluation	Quantitative	Mathematical relationship between desired collection and sustain product	System Dynamics	E-waste	Georgiadis and Besiou (2010)
Technology specifications	1	Technology specification imposed	Other problem	No indicator	Without indicator	Other method	General	Murakami et al. (2015)
Training and technical assistance	1	Training and technical assistance to promote the integration of waste pickers	Decision-making and performance evaluation	Quantitative	Formalization ratio due to environmental policies	System Dynamics	E-waste	Ghisolfi et al. (2017)
Vehicle noise emission	1	Imposition of maximum allowed vehicle noise emission	Vehicle routing problems	Quantitative	Maximum allowed vehicle noise emission	Optimization	Food industry	Rahimi et al. (2016)

Appendix C. Technological dimension

Table C1
Process-oriented technological criteria

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Capacity of facilities	79	Maximum amount of material/product that can be processes by the facilities of the recycling network.	3PRL provider selection	Quantitative	Amount of product	Multi-criteria and Optimization	E-waste	Govindan et al. (2019)
			Design and planning	Quantitative	Amount of product	Grey prediction model and Optimization	Medical waste	Wang et al. (2019)
							Bicycles	Liu et al. (2019a)

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Table C1 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
						Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)
							General	Çalık (2020)
						Optimization	Automotive industry	Fazli-Khalaf et al. (2020); Jafari and Kazemi Abharian (2020); Kannegiesser and Günther (2014); Kumar et al. (2020); Phuc et al. (2017); Sahebjamnia et al. (2018); Saxena et al. (2018); Tadaros et al. (2020)
							Construction and demolition wastes	Dong et al. (2017); Liang and Lee (2018)
							E-waste	Bal and Satoglu (2018); Budak (2020); Capraz et al. (2015); Dubey et al. (2015); Gholizadeh et al. (2020); John et al. (2018); Moslehi et al. (2020); Safdar et al. (2020); Shokohyar and Mansour (2013); Temur and Bolat (2017)
							Food industry	Accorsi et al. (2020)
							General	Altmann and Bogaschewsky (2014); Benaissa et al. (2018); Dutta et al. (2020); Faccio et al. (2014); Fattahi and Govindan (2017); Gao and Ryan (2014); Garai and Roy (2020); Masoudipour et al. (2020); Porkar et al. (2018); Pourjavad and Mayorga (2019); Ren et al. (2020); Rezaei and Kheirkhah (2017, 2018); Sajedi et al. (2020); Shahparvari et al. (2018); Wang and Hsu (2012); Yu and Solvang (2016b, 2017a); Zandieh and Chensebli (2016); Zarbakhshnia et al. (2020)
							Glass	Hajiaghaei-Keshteli and Fathollahi Fard (2019)
							Hazardous waste	Saeidi et al. (2020)
							Household waste and Municipal solid waste	Couto et al. (2017); Edalatpour et al. (2018); Ferri et al. (2015); Guo et al. (2017); Niranjan et al. (2019); Taleizadeh et al. (2019); Yu and Solvang 2017b)
							Medical waste	Govindan et al. (2016); Homayouni and Pishvaee (2020)
							Metals	Ansbro and Wang (2013); Jin et al. (2018)
							Plastic	Han et al. (2020a); Hassanzadeh Amin et al. (2018); Mohammadi et al. (2020); Papen and Amin (2019)
							Solar energy industry	Chen et al. (2017); Choi and Fthenakis (2014)
						Optimization and LCA	Automotive industry	Ghasemzadeh et al. (2020)
							Plastic	Feitó-Cespón et al. (2017)

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Table C1 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
			Other problem	Quantitative	Amount of product	Optimization	General	Shi et al. (2010)
				No indicator	Without indicator	Other method	Solar energy industry	Lapko et al. (2019)
			Decision-making and performance evaluation	No indicator	Without indicator	Other method	Plastic	Chavez and Sharma (2018)
				Quantitative	Amount of product	Optimization	Medical waste	Nidhi and Pillai (2019)
						System Dynamics	Automotive industry	Mohan and Amit (2020)
							E-waste	Besiou et al. (2012); Ghisolfi et al. (2017)
							Metals	Chaudhary and Vrat (2020)
			Price and coordination	Quantitative	Amount of product	Game theory	Food industry	Liu et al. (2019b)
						Other method	General	Allevi et al. (2018)
			Vehicle routing problems	Quantitative	Amount of product	Optimization	Hazardous waste	Farrokhi-Asl et al. (2020)
							Household waste and Municipal solid waste	Bányai et al. (2019)
Technology selection	15	Decisions regarding the technology to be used in the process	Design and planning	indirect indicator	Without indicator	Optimization	Automotive industry	Sahebjamnia et al. (2018); Saxena et al. (2018)
							Medical waste	Govindan et al. (2016)
							Plastic	Mohammadi et al. (2020); Valizadeh et al. (2020)
				Quantitative	Capacity level using technology type	Optimization	Automotive industry	Hoyer et al. (2015)
							Construction and demolition wastes	Rahimi and Ghezavati (2018)
							E-waste	Aalirezaei and Shokouhyar (2017); Ali et al. (2020); Shokohyar and Mansour (2013)
							General	Rezaei and Kheirkhah (2018)
							Solar energy industry	Chen et al. (2017)
					Number of products to be manufactured using technology	Optimization	Household waste and Municipal solid waste	Taleizadeh et al. (2019)
			Decision-making and performance evaluation	No indicator	Without indicator	Other method	Household waste and Municipal solid waste	Pongeluppe Wadhy Rebehy et al. (2017)
			Vehicle routing problems	Quantitative	Capacity level using technology type	Optimization	Hazardous waste	Farrokhi-Asl et al. (2020)
Recycling rate	13	Fraction of a product that can be recycled	Design and planning	Quantitative	Recycling rate of product	Optimization	Automotive industry	Hoyer et al. (2015)
							E-waste	Gholizadeh et al. (2020); Moslehi et al. (2020)
							General	Benaissa et al. (2018); Pourjavad and Mayorga (2019)
							Plastic	Han et al. (2020a); Valizadeh et al. (2020)
			Other problem	Quantitative	Recycling rate of product	Other method	Metals	Prasad et al. (2018)
			Decision-making and performance evaluation	Quantitative	Recycling rate of product	Optimization	Medical waste	Nidhi and Pillai (2019)
						System Dynamics	E-waste	Ghisolfi et al. (2017)
								Besiou et al. (2012)
							Metals	Chaudhary and Vrat (2020)
			Price and coordination	Quantitative	Recycling rate of product	Other method	General	Allevi et al. (2018)
Processing time	7	Time required to process a waste unit or product	Design and planning	Quantitative	Processing time per unit of product	Optimization	Automotive industry	Jafari and Kazemi Abharian (2020)
							E-waste	Capraz et al. (2015)
							Food industry	Khorshidian et al. (2019)

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Table C1 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
							General	Zarbakhshnia et al. (2020)
							Solar energy industry	Choi and Fthenakis (2014)
			Other problem	No indicator	Without indicator	Other method	Paper	Mangla et al. (2012)
			Decision-making and performance evaluation	Quantitative	Processing time per unit of product	System Dynamics	E-waste	Ghisolfi et al. (2017)
Capacity per product	6	Maximum amount of material/product that can be processes considering each product	Design and planning	Quantitative	Amount of product	Multi-criteria decision-making and Optimization	General	Liu et al. (2020a); Yang and Chen (2020)
						Optimization	E-waste	Ali et al. (2020)
							General	Aljuneidi and Bulgak (2020)
							Household waste and Municipal solid waste	Couto et al. (2017)
							Plastic	Valizadeh et al. (2020)
Recovery options	5	Decisions about the alternatives to recovery (incineration, recycling, remanufacturing, etc.)	Design and planning	Indirect indicator	Without indicator	Optimization	Plastic	Bing et al. (2014)
			Other problem	Indirect indicator	Without indicator	Optimization	E-waste	Yang et al. (2016)
			Decision-making and performance evaluation	No indicator	Without indicator	Multi-criteria decision-making	E-waste	Jindal and Sangwan (2016)
							Household waste and Municipal solid waste	Awan and Ali (2019)
						Other method	Household waste and Municipal solid waste	de Oliveira et al. (2020)
Capacity extension	4	Decision regarding the expansion of the capacity defined for the facilities	Design and planning	Quantitative	Quantity of expanding capacity level	Optimization	Construction and demolition wastes	Rahimi and Ghezavati (2018)
							E-waste	Dubey et al. (2015)
							Household waste and Municipal solid waste	Taleizadeh et al. (2019)
							Solar energy industry	Chen et al. (2017)
Quality of the returned products	4	Decision regarding whether the product is recycled or not	Design and planning	No indicator	Without indicator	Multi-criteria decision-making and Optimization	General	Liu et al. (2020a)
				Quantitative	Number between 0 and 1	Optimization	General	Sarkar et al. (2017); Yu and Solvang (2017a)
			Price and coordination	Quantitative	Number between 0 and 1	Other method	E-waste	Liu et al. (2016)
Conversion rate	3	Amount of material needed to produce the product	Design and planning	Quantitative	Conversion coefficient from chips to a bottle	Optimization	Plastic	Han et al. (2020a)
					Conversion rate of repaired or recycled products	Optimization	General	Yu and Solvang (2016b)
			Decision-making and performance evaluation	No indicator	Loss of material in processing	System Dynamics	Glass	Beiler et al. (2020)
Quality of recycled product	3	Quality of the product obtained after the recycling process	3PRL provider selection	Qualitative	Relative weight of Quality of product criteria	Multi-criteria decision-making	Household waste and Municipal solid waste	Kafa et al. (2018)
			Price and coordination	Quantitative	Number between 0 and 1	Other method	E-waste	Liu et al. (2016)
					Quality factor of recycled product	Game theory	General	Tan and Guo (2019)

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Table C1 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Technical feasibility of recycling	3	Complexity of recycling the materials that compose the products and their access to them	Other problem	No indicator	Without indicator	Other method	General Solar energy industry	Murakami et al. (2015) Lapko et al. (2019)
			Decision-making and performance evaluation	Qualitative	Relative weight of Technical/ operational feasibility criteria	Multi-criteria decision-making	E-waste	Jindal and Sangwan (2016)
Capacity of equipment	2	Maximum amount of material/product that can be processes by the equipment	Design and planning	Quantitative	Amount of product	Optimization	Automotive industry Solar energy industry	Hoyer et al. (2015) Choi and Fthenakis (2014)
Capacity using recycling technique	1	Maximum amount of material/product that can be processes using a specific recycling technique	Design and planning	Quantitative	Amount of product	Optimization	Construction and demolition wastes	Dong et al. (2017)
Compatibility between wastes and applied technology in the facility	1	Parameter defined to determine the amount of waste to be sent to the facility that will be associated with that technology	Vehicle routing problems	Quantitative	Binary parameter (yes, no)	Optimization	Hazardous waste	Farrokhi-Asl et al. (2020)
Difficulty coefficient of recycling worn-out products	1	Difficulty of recycling worn-out products for a third-party recycler	Price and coordination	No indicator	Without indicator	Game theory	General	Ma and Huang (2019)
Necessary technology of the recovery centers	1	Availability of the necessary technology to carry out the specific recycling process	Decision-making and performance evaluation	No indicator	Without indicator	Other method	Plastic	Chavez and Sharma (2018)
Technical capacity	1	Technical capacity for reusable materials	Decision-making and performance evaluation	No indicator	No specified	System Dynamics	Glass	Beiler et al. (2020)

Table C2
Transport

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Capacity of vehicles	28	Limits on transport capacity depending on the type of vehicle used.	Design and planning	Quantitative	Amount of product	Multi-criteria decision-making and Optimization	E-waste General	Darbari et al. (2019) Çalık (2020)
						Optimization	Automotive industry E-waste	Kannegiesser and Günther (2014) Gholizadeh et al. (2020); Ramos et al. (2014); Safdar et al. (2020)
							Food industry	Khorshidian et al. (2019)
							General	Faccio et al. (2014); Masoudipour et al. (2020); Ren et al. (2020); Rezaei and Kheirkhah (2017, 2018); Zarbakhshnia et al. (2020)
							Hazardous waste	Saeidi et al. (2020)
							Household waste and Municipal solid waste	Niranjan et al. (2019); Taleizadeh et al. (2019); Yu and Solvang (2017b)
							Plastic	Valizadeh et al. (2020)

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Table C2 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
						Optimization and LCA	Automotive industry	Ghasemzadeh et al. (2020)
							Plastic	Feitó-Cespón et al. (2017)
			Price and coordination	Quantitative	Amount of product	Game theory	General	Wu et al. (2019a)
						Other method	General	Allevi et al. (2018)
			Vehicle routing problems	Quantitative	Amount of product	Optimization	Automotive industry	le Blanc et al. (2006)
							Food industry	Aksen et al. (2012); Rahimi et al. (2016)
							Hazardous waste	Farrokhi-Asl et al. (2020)
							Household waste and Municipal solid waste	Bányai et al. (2019); Kızıltaş et al. (2020)
Means of transport for waste	1	Means of transport available for the transport of waste	Decision-making and performance evaluation	No indicator	Without indicator	Other method	Plastic	Chavez and Sharma (2018)
Transport efficiency	1	Internal transport efficiency for waste collection	Decision-making and performance evaluation	No indicator	No specified	System Dynamics	Glass	Beiler et al. (2020)
Transportation management	1	Transportation management of the third-party reverse logistic provider	3PRL provider selection	Qualitative	Relative weight of Transportation management criteria	Multi-criteria decision-making	Automotive industry	Govindan et al. (2013)

Table C3
Technology level and experience level

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Green technology innovation	5	Investment made to improve the environmental performance of the technology used	Decision-making and performance evaluation	Qualitative	Relative weigh of green technology innovation criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016a, 2016b)
				Quantitative	Level of green innovation	Game theory	General	Mondal et al. (2020); Saha et al. (2019)
					Technological innovation cost coefficient	Game theory	General	Xiang and Xu (2020)
Green innovation level	2	Innovations made in the supply chain to reduce the consumption of resources in the production process and achieve greener products	Price and coordination	No indicator	Without indicator	Game theory	General	Ma and Huang (2019); Mondal and Giri (2020)
Technology transfer	2	Technological flexibility, capability, and availability for waste management	Decision-making and performance evaluation	Qualitative	Relative weigh of Technology transfer criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al., (2016a, 2016b)
Capability of disassembly infrastructure	1	Infrastructure available by the partner for dismantling according to the needs of the company	3PRL provider selection	Qualitative	Relative weight of Capability of disassembly infrastructure criteria	Multi-criteria decision-making	E-waste	Kara (2011)
Clean and upgraded technology	1	Clean and upgraded technology to be used in the designed recycling network	Design and planning	No indicator	Without indicator	Multi-criteria decision-making and Optimization	E-waste	Darbari et al. (2019)
Communication Systems	1	EDI capacity and IT level of outsourcing option	Decision-making and performance evaluation	Qualitative	Relative weight of Communication Systems criteria	Multi-criteria decision-making	E-waste	Agrawal et al. (2016a)

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Table C3 (*continued*)

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Demand forecasting	1	Demand forecasting of the 3PRL provider	3PRL provider selection	Qualitative	Relative weight of Demand forecasting criteria	Multi-criteria decision-making	Automotive industry	Govindan et al. (2013)
Effort to improve the level of technology	1	Efforts of the company to invest in the improvement of its technology	Price and coordination	Quantitative	Effort cost to improve the level of technology	Game theory	General	Tan and Guo (2019)
Expert decision and skill manpower	1	Technological availability to make decisions on waste disposal and waste treatment manpower	Decision-making and performance evaluation	Qualitative	Relative weigh of Expert decision and skill manpower criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016a)
Green rate	1	Rate of energy saved and resources due to recycling implementation	Price and coordination	Quantitative	Rate of energy saved and resources	Game theory	General	Wu et al. (2019a)
Information technology (IT)	1	Information technology of the third-party reverse logistic provider	3PRL provider selection	Qualitative	Relative weight of Information technology (IT) criteria	Multi-criteria decision-making	Automotive industry	Govindan et al. (2013)
Inventory management	1	Inventory management of the third-party reverse logistic provider	3PRL provider selection	Qualitative	Relative weight of Inventory management criteria	Multi-criteria decision-making	Automotive industry	Govindan et al. (2013)
Investment to sustainably improve recovery technology	1	Investment needed to improve the technology recovery of the recycling center and achieve the level of sustainability decided	Price and coordination	No indicator	Without indicator	Game theory	E-waste	Ghalehkhondabi and Ardjmand (2020)
JIT philosophy	1	JIT philosophy of the third-party reverse logistic provider	3PRL provider selection	Qualitative	Relative weight of JIT philosophy criteria	Multi-criteria decision-making	Automotive industry	Govindan et al. (2013)
Resource Capacity	1	Technological and human capacity or resources available	Decision-making and performance evaluation	Qualitative	Relative weight of Relative weight of Resource Capacity criteria	Multi-criteria decision-making	E-waste	Agrawal et al. (2016a)
Specialized infrastructures	1	Technological and engineering capacity of the partner to carry out the process	3PRL provider selection	Qualitative	Relative weight of Specialized infrastructures criteria	Multi-criteria decision-making	Household waste and Municipal solid waste	Kafa et al. (2018)
Technological expertise	1	Level of knowledge and experience of the partner to carry out the recovery process	3PRL provider selection	Qualitative	Relative weight of Technological expertise criteria	Multi-criteria decision-making and Optimization	E-waste	Govindan et al. (2019)
Technological level at each stage of network	1	Level of technology in each facility to perform each of the recycling activities	Other	No indicator	No indicator	Other method	Solar energy industry	Lapko et al. (2019)

Table C4
Product design

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Design for environment products	2	Design of products with its recovery process (recycling) in mind once it is discarded.	Decision-making and performance evaluation	Quantitative	Design for environment products ratio (firms' reaction)	System Dynamics	E-waste	Georgiadis and Besiou (2008)
					Minimum Limit of Recyclability (percentage)	System Dynamics	E-waste	Georgiadis and Besiou (2010)
Research and development for new products	1	Capacity and availability of R&D given the management options.	Decision-making and performance evaluation	Qualitative	Relative weigh of Research and development for new products criteria	Multi-criteria decision-making	Automotive industry	Ahmed et al. (2016a)

Table C5
Other technological aspects

Factor	Number of articles	General description	Problem	Type of indicator	Indicator	Method	Domain/ Application	References
Use of new technology	4	Use of new technologies such as information technologies, internet, big data marketing, etc. In the recycling activity	Decision-making and performance evaluation	No indicator	Without indicator	Other method	E-waste	Tong et al. (2018)
			Price and coordination	No indicator	Without indicator	Game theory	General	Xiang and Xu (2020)
							E-waste	Chen et al. (2018)
			Vehicle routing problems	Indirect indicator	Without indicator	Optimization	Household waste and Municipal solid waste	Bányai et al. (2019)
Capacity utilization	2	Capacity that the company can assign to each process	3PRL provider selection	Qual	Relative weight of Capacity utilization criteria	Multi-criteria decision-making	E-waste	Kara (2011)
			Other	No indicator	Without indicator	Other method	Paper	Mangla et al. (2012)
Sells options of discarded product (collect)	1	Options that consumers have to dispose or sell the waste	Decision-making and performance evaluation	No indicator	Without indicator	Other method	Plastic	Chavez and Sharma (2018)

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