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Review article

Disruptions in the food supply chain: A literature review

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ABSTRACT

Disruptions in the food supply chain are events that affect the flow of products and can be caused by extreme weather, natural disasters, conflicts, pandemics, and political situations, among others. These events can significantly impact food products' availability, quality, and cost, creating risks to the well-being of local populations and livelihoods. The specific literature on food supply chains needs to address other approaches to risk categorisation, which allow for establishing reference frameworks focused on the general classification of types of disruption and parameters related to solution methods. In this paper, we present a literature review to analyse the disruptions in the food supply chain. We classified 74 papers according to the types of disruptions, stakeholders, response level, supply chain echelon, solution methods, goals, and related considerations. The review results showed that the most common disruptions in the food supply chain are climatic, biological and environmental, logistics and infrastructure, and supply. The results of this review allow us to suggest some new research directions.

1. Introduction

Food systems comprise the set of resources and activities involved in producing, processing, marketing, consuming, and disposing of goods from agriculture and forestry, including the necessary inputs and products generated at each stage [26]. Conceptually, food systems have three fundamental elements: food supply chains, environments, and consumer behaviour. These elements are influenced by environmental drivers of change, including innovation, technology, and infrastructure; political and economic factors; sociocultural factors; and demographic factors. These drivers determine diets and outcomes for nutrition and health, as well as economic and social outcomes [39,40].

Within food systems, supply chains represent the activities and agents that bring products from producers to final consumers, including waste disposal [34]. Firstly, food production includes agriculture up to processing and packaging; then, in distribution, activities such as storage and transportation are considered; subsequently, trade covers food economics, directly influenced by supply and demand. On the other hand, consumption adds factors such as food availability, utilization, and preservation. Lastly, disposal involves decomposition, nutritional loss, and recycling [38,39,41]. These activities can be carried out in different ways by various large and small actors in the private and public sectors, implying a complex and specific decision-making process at each link [11,39].

In this context, food supply chain disruptions can refer to any significant failure in the flow of food products from production to consumption [78], representing highly complex risks that can affect the operation and infrastructure of food systems. Supply chain

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disruption and uncertainty risks are growing, and modern Food Supply Chains (FSC) are among the most vulnerable to such threats [11]. The dangers can disrupt local and non-local food systems and are likely to increase in severity and frequency in the coming years, which could lead to negative financial impacts and adverse operating results such as high transportation costs, delays in orders, and inventory shortages [77,103]. For this reason, food system organizations must be able to ensure reliable access to safe food for all people, considering various potential threats [36].

Disruptions affect food production, processing, and distribution throughout the supply network, directly impacting the availability, access, utilization, stability of food security, and nutritional value of the products [21,39]. These losses impact the amount of food available and the deterioration of its nutritional content, particularly in the case of perishable products with special conditions to preserve their safety and quality [28]. Disruptions severely affect the economy of growing countries [70] and can be of natural or man-made origin, e.g., natural disasters; social events such as strikes and recession; terrorist acts; economic or financial crises; and interruptions of essential services such as electricity supply, among others. Disruptions generally cause destruction, damage, human suffering, and loss of life [65], which negatively impacts FSC, causing an imbalance between supply and demand, price instability, variation in operational capabilities, increased uncertainty, reduced availability of quality products and volatility of operational systems.

For example, natural disasters are a type of disruption in the FSC, which often occurs within a limited geographical area, where they can cause partial or complete destruction of the food production and distribution infrastructure, causing severe impacts on markets and local livelihoods in the affected areas [81]. According to Aggarwal et al. [2], a problem of global concern, such as climate change, will trigger more severe weather events, such as fires and floods, exposing FSC to complex challenges to sustain its operation. During 2008 and 2018, the least-developed countries lost approximately US $108 billion due to declining agricultural and livestock production due to natural disasters [27].

These events can seriously impact public health, social order, and the well-being of people [93] because of the impact on food production and distribution operations, affecting product prices, and local suppliers because of crop loss, infrastructure damage, uncertainty in electricity services and fuel shortages, among others [92]. Therefore, food system organizations must improve their ability to ensure reliable access to safe products by considering potential threats [36]. Fig. 1 shows the world's number of disruptions from 1960 to 2020.

The management of the food supply chain involves a complex decision-making process. Different stakeholders must carry out various activities at each chain link to ensure the adequate flow of products, money, and information within the system. These actors are exposed to internal and external risks, such as disruptions, which can impact the overall performance of the operation. This creates the need to mitigate various impacts at different response levels, requiring the strategic selection of methods and strategies with different objectives, considering specific considerations and constraints.

Different literature reviews focused on supply chain networks, agribusiness, and FSC are evidenced in the literature, focusing on specific topics such as network design, risk management models, sustainability and resilience, business model innovations, perishable products, and model-oriented perspectives. However, as far as we know, no comprehensive literature review has addressed the disruptions in FSC. The specific literature on food supply chains needs to address other approaches to risk categorisation, which allow for establishing reference frameworks focused on the general classification of types of disruption and parameters related to solution methods. Furthermore, Shekarian and Parast [85] suggest that it is necessary to address other approaches to risk categorisation in supply chains, which is why our work seeks to provide a perspective of classification considering the specific analysis of disruptions affecting the FSC from a multidisciplinary perspective involving solutions methods, goals, considerations, stakeholders, and response levels. Table 1 shows some of the existing review papers.

Considering that disruptions directly impact the economic and operational performance of the food systems, this review aims to

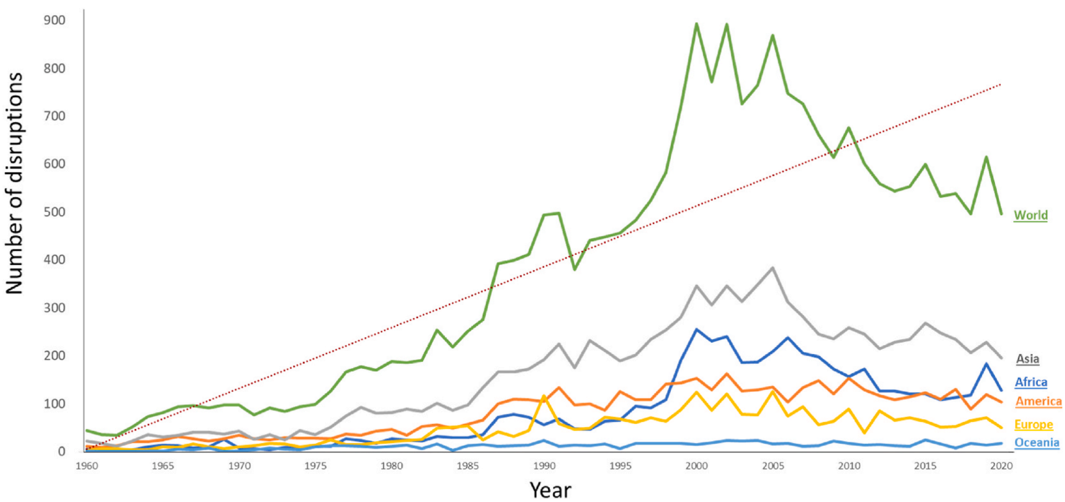

Fig. 1. Disruption behaviour in the world. Source: EM-DAT, CRED [24].

analyse disruptions in the food supply chain to provide a classification and a perspective on future research around the types of disruption, stakeholders, response levels, supply chain links and the methods by which have been addressed, goals, and considerations. This document is organised as follows: This section presents an overview of supply chain disruptions. Section 2 describes the literature review methodology. Section 3 presents the descriptive analysis. In section 4, we discuss the findings of the central theme. Section 5 presents the insights and future research directions. In section 6, we present the conclusion of the review.

2. Review methodology

This section presents a literature review to analyse the impact of disruptions on FSC. This review will employ a content analysis process model proposed by Mayring [59], integrated into a methodological framework for literature reviews proposed by Seuring et al. [83], and practically oriented for conducting literature reviews focussed on supply chain management by Seuring and Gold [82]. Table 2 outlines the methodological framework utilized in this literature review:

The overall research question guiding this work was: ¿How have disruptions in the FSC been addressed in the literature? Additionally, we proposed the following specific research questions:

(1) ¿What types of disruptions in FSC are studied?
(2) ¿What methods have been used to analyse the disruptions in FSC?
(3) ¿What goals have been studied to analyse the disruptions in FSC?
(4) ¿What considerations or restrictions have been defined to analyse the disruptions in FSC?

This review analyses general concepts involving methods and models associated with adaptability, responsiveness, resilience, and sustainability, within a specific context where disruptions in supply chains and network design are examined. Fig. 2 illustrates the relationship of defined keywords that will be adapted through truncation operators in a structured search string for search engines in referential databases.

For the material collection, the scope of this literature review is limited to papers published in English in academic journals indexed in Scopus and Web of Science. We excluded books, conference proceedings, project reports, and professional journals, which could be considered in future works. This review is open to the time horizon because it seeks to explore the distribution of publications over the years until June of 2023. As far as we know, there still needs to be a specific revision in analysing types, solutions, methods, goals, and considerations around disruptions in the FSC. Therefore, a search chain was proposed with keywords related to disruptions in FSC. In this paper, we used the inclusion criteria described in Table 3.

Initially, in the material collection stage, we obtained 875 documents by searching the Scopus and Web of Science databases. Then,

Table 1
Previous literature reviews.

Authors	Title of Review	Journal	Time Horizon	Area	Scope	Number of Papers
Akkerman et al. [3]	Quality, safety and sustainability in food distribution: a review of quantitative operations management approaches and challenges	OR Spectrum	Until 2010	Food distribution management	Distribution network design	–
Behzadi et al. [9]	Agribusiness supply chain risk management: A review of quantitative decision models	Omega	1993–2015	Agribusiness supply chain	Risk management models	42
Zhu et al. [105]	Recent advances and opportunities in sustainable food supply chain: a model-oriented review	International Journal of Production Research	2002–2017	Sustainable FSC	model-oriented perspective	83
Vrat et al. [94]	Literature review analytics (LRA) on sustainable cold-chain for perishable food products: research trends and future directions	OPSEARCH	1985–2017	Sustainable cold chain	Perishable products	94
Nosratabadi et al. [69]	Food supply chain and business model innovation	Foods	2001–2019	FSC	Business model innovations	72
Lopez-Castro and Solano-Charris [53]	Integrating resilience and sustainability criteria in the supply chain network design. A systematic literature review	Sustainability	2010–2021	Supply Chain Networks	Sustainability and resilience	54
Rinaldi et al. [79]	A literature review on quantitative models for supply chain risk management: Can they be applied to pandemic disruptions?	Computers & Industrial Engineering	2005–2020	Supply chain	Risk management and disruptions	99
Yadav et al. [98]	A systematic literature review of the agro-food supply chain: Challenges, network design, and performance measurement perspectives	Sustainable Production and Consumption	2005–2020	Agro-FSC	Challenges, performance, indicator, and modelling	108

Table 2
Steps used in this literature review. Adapted from Seuring et al. [83], Seuring and Gold [82].

Steps	Description	Considerations
1. Material collection	The material to be collected is defined and delimited. This may involve analysing how the material emerged. Additionally, the unit of analysis is specified.	- Defining and delimiting the material. - Topic specification: appropriate keywords for database searches. - Scope of journals: selective or general. - Definition of the unit of analysis. - Consistency throughout the analysis. - Considering bias in similar articles from the same group of authors.
2. Descriptive analysis	The formal aspects of the materials are assessed, such as the number of publications per year. This description serves as a basis for theoretical analysis.	- Temporal distribution. - Distribution using publications (especially journals).
3. Pattern of analytic categories	The structural dimensions and related analytical categories are chosen to be applied in the literature review for field structuring. The structural dimensions represent the main topics of analysis, encompassing various analytical categories, such as the individual year over a period.	- Deductive versus inductive category construction (corresponding to theoretical research approaches versus exploratory research approaches) - Default two-phase approach: 1. Deductive construction of categories, 2. Iterative cycles of inductive category refinement during coding.
4. Material evaluation and research quality	The material is analysed and classified according to the structural dimensions and constructed categories. This should enable the identification of relevant aspects and the interpretation of results.	- Need for iterative coding cycles in case of inductive category refinement or poor inter-rater reliability. - Transparency and objectivity (clear coding rules from the outset). - Reliability (especially inter-coder reliability): at least two coders, cross-coding to check agreement or align mental frameworks. - Validity (theoretical foundation, specific inductive refinements).

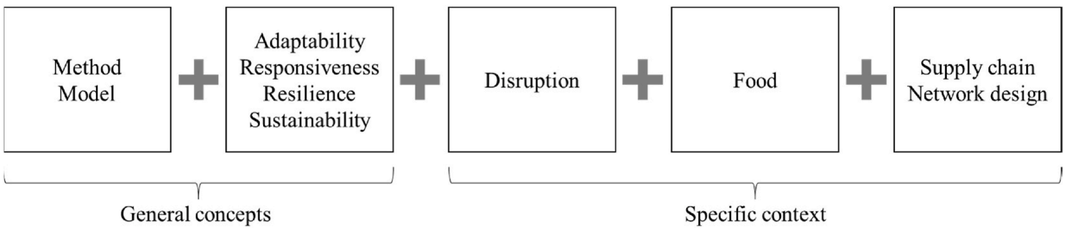

Fig. 2. Relationships between keywords.

we deleted the duplicate documents. Next, the selected documents were thoroughly analysed; finally, we obtained 74 selected papers for their relevance and quality. Fig. 3 shows the details of the paper selection for this research.

The descriptive analysis stage presents the distribution of publications by year and the leading journals. Subsequently, in the category selection stage, a methodological structure is proposed (Fig. 4) to classify the selected documents according to the specific research questions. The proposed categories are (1) types of disruptions, (2) stakeholders, (3) supply chain echelon, (4) response level, (5) analysis methods, (6) model goals, and (7) constraints and considerations.

The selected documents were reviewed and classified according to established criteria to ensure the relevance and reliability of the review. The selection criteria for each category were designed and validated. A count was made depending on the number of applications in each class because an article may contain several solution approaches. Finally, we proceed to synthetise the information and analyse the results.

Table 3
Criteria for inclusion of papers for this literature review.

Detail information	Inclusion criteria
Search string	(Method OR model*) AND (adaptat* OR respons* OR resilien* OR sustain*) AND food AND (network OR supply) AND (disrup*)
Language	English
Type of publications	Only papers published in peer-reviewed scientific journals related to the main topic of supply chain, logistics, management, or related subjects.
Type of databases	Scopus and Web of Science
Year of publication	Until June of 2023

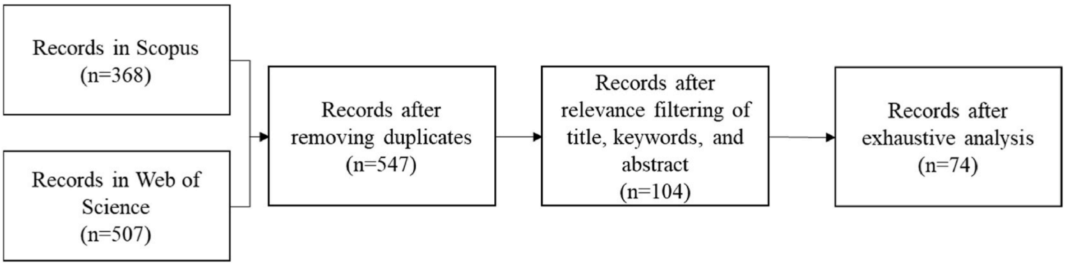

Fig. 3. Document screening.

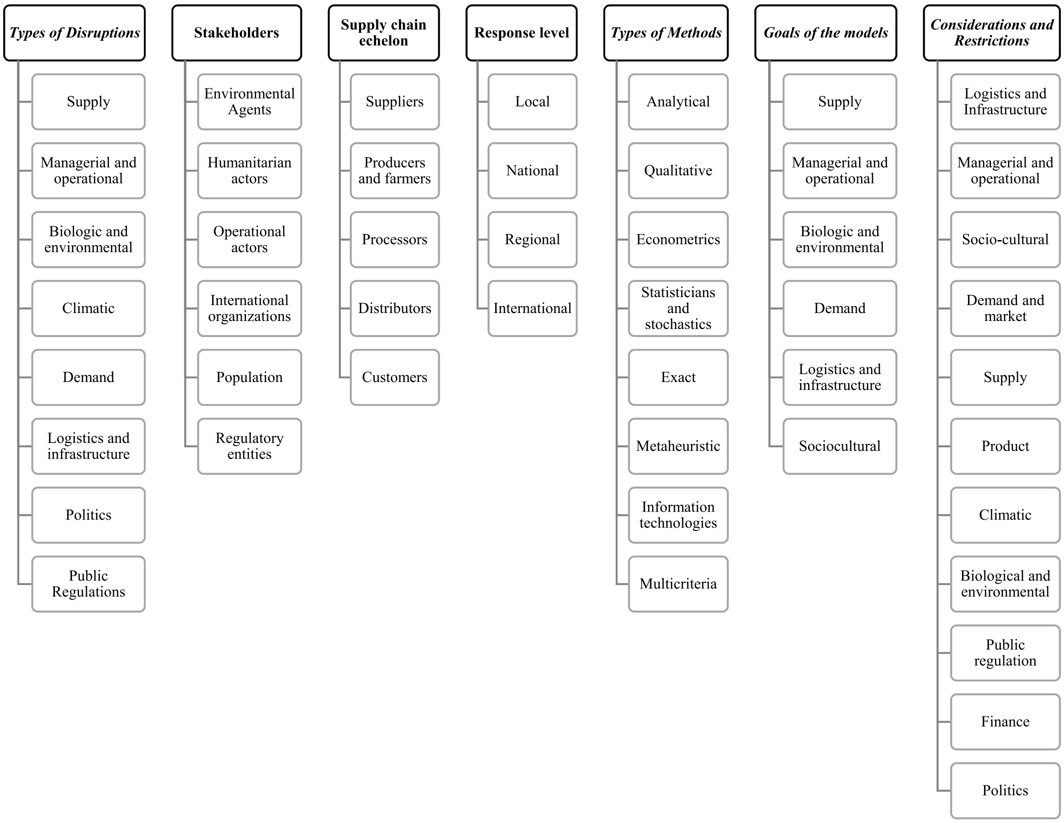

Fig. 4. Methodological structure of papers classification.

3. Descriptive analysis

The results of this review reveal publication records dating back to 1988; however, it is noteworthy that 93 % of the publications have occurred since 2012, indicating a growing trend. From 2018, 55 papers considered in this review have been published, constituting 73 % of the documents analysed. Fig. 5 shows the number of publications per year.

The distribution of specialised journals shows that 54 journals have published at least one article related to supply chain disruptions, indicating a wide range of options for analysing the topic. Within this set, 12 journals stand out, which together have published 43 % of the articles in this review, of which 81 % of the publications were between 2019 and 2023. Among these journals, Sustainability stands out, which has the highest number of publications and other journals such as Agricultural Systems, International Journal of Production Economics, Sustainable Production and Consumption, Socio-Economic Planning Sciences, Management Decision, International Journal of Disaster Risk Reduction, Environmental Research Letters, Transportation Research Part E: Logistics and Transportation Review, Food Security, International Journal of Production Research, International Journal of Logistics Management. Fig. 6 shows the distribution of publications by specialised journals.

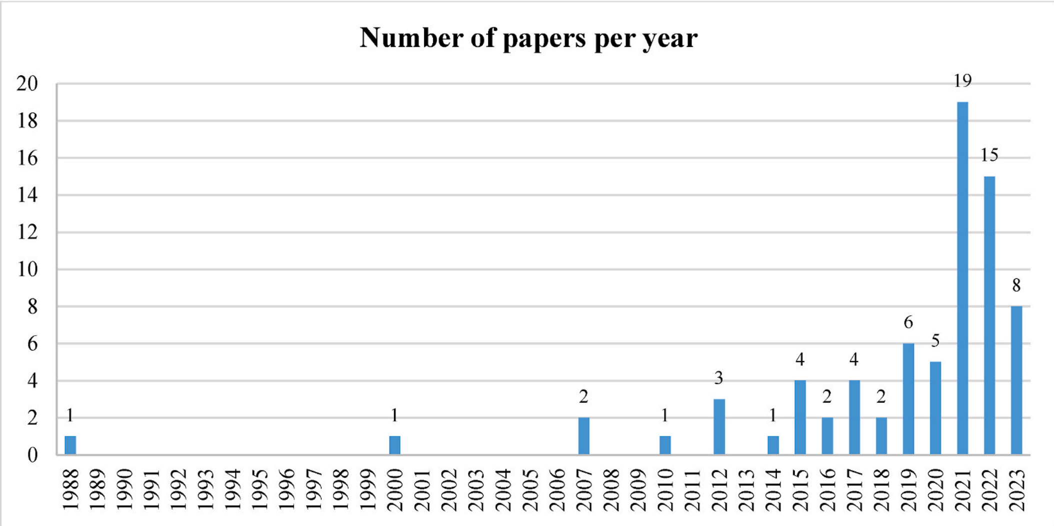

Fig. 5. Number of papers per year.

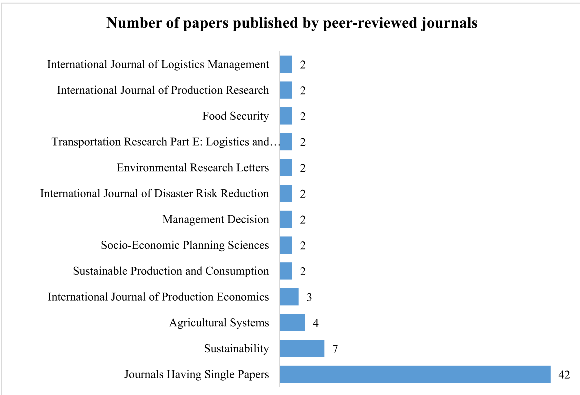

Fig. 6. Number of papers published by peer-reviewed journals.

3.1. Main findings

The main findings of this review indicate that, since 1988, disruptions have been addressed with a focus on seasonal patterns. Subsequently, from the 2000s to 2009, there were highlighted approaches for selecting productive models and humanitarian logistics. During the decade from 2010 to 2019, there was a deepening in the analysis of disruptions in the food supply chain, encompassing

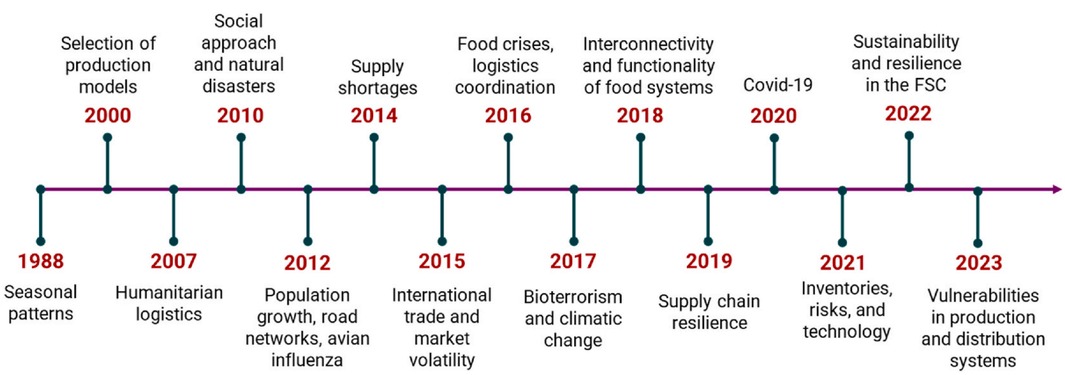

Fig. 7. Timeline of main approaches of the analysed papers.

topics such as demographic growth, road networks, avian influenza, fuel shortages, international trade, market volatility, food crises, logistical coordination, as well as biological terrorism, interconnectivity and functionality of food systems, and the resilience of the supply chain.

In recent years, starting from 2020, the trend has shifted towards the impact of Covid-19 on the supply chain, inventory management, risks and technology, the sustainability and resilience of the food supply chain, and the analysis of vulnerabilities in production and distribution systems. Fig. 7 depicts the timeline illustrating the evolution of the findings from this review.

The first publication analysed in this review is a study by Crittenden et al. [19], which examined seasonal patterns in gardening activity and their relationship with the body weights of the population. Also, Mcginnis [60] developed a rational choice model that shows how individuals' decisions affect the supply and food demand considering conflicts. Besides, Ozbay and Ozguven [74] proposed a humanitarian inventory management model capable of determining food or medicines safety stock and assessing the disruption risk. Additionally, Memmott et al. [61] studied the impact on food production through a possible alteration between plants and their animal pollinators due to climate change.

Later, the literature focused on humanitarian logistics, population growth, road networks, and avian influenza. For example, Dowty and Wallace [22] formulated a mixed model of social anthropology, economy, and governance in cases of disruption of the humanitarian supply chain after Hurricane Katrina and the World Food Programme interacting with the Southern African Development Community to deliver maise after the floods. Afterwards, Hayward and Mosse [35] analysed the impact on the availability of tuna in Ambon (Indonesia), considering the population growth and consumption of a traditional gastronomic product. Meanwhile, Lertworawanich [48] presented a model for determining an optimal restoration sequence for the road network restoration problem when budgets and resources are unknown. Besides, Malladi et al. [56] studied the incorporation of a waiting time before the movement of the eggs together with directed active surveillance considering the presence of the avian influenza virus.

Between 2014 and 2016, issues such as product shortage, market volatility, and food crises led to the analysis of logistical coordination and international trade within the literature. Research studies, such as the one conducted by Wakeford and Swilling [95], studied fuel supply and its effect on South Africa's food distribution and agricultural production. Furthermore, Baldos and Hertel [7]

Table 4
Types of disruption in FSC.

Type of disruption	Description	Authors
Managerial and operational	Harvest loss	[76]
	Low product quality	[75,89,101]
	Management decisions	[4]
	Production and manufacturing breakdowns	[101]
	Reduced harvest yield	[76]
Biological and environmental	Contamination	[72]
	Covid-19	[1,5,6,8,12,14,16,20,23,30,43,44,46,47,52,58,62,67,68,84,87,90,97,102]
	Crop pests	[72]
	Diseases	[101]
	Ecological interactions	[35,61]
	Plant or animal pathogens	[56,71]
Climatic	Climatic change	[7,10,18,37,55]
	Drought	[10,15,19,64,72]
	Extreme weather	[7,55,60,91]
	Fire	[64]
	Floods	[17,22,48,72,100]
	Hurricane	[22,33,55,72,74]
	Natural Disasters	[49,72,75,99,101]
	Rains	[7,72]
Demand	Consumer preferences	[51,89]
	Market fluctuations	[11,72,86,101]
Logistics and infrastructure	Distribution system	[13,52,72,75,101,106]
	Infrastructure	[25,48,50,72,73,101,104,106]
	Interrupted facilities	[32,50,54,73,75]
	Technology and information system	[4,75,101]
Public regulations	Environmental regulations	[31]
	Government measures	[63,72,80,101]
Social and politics	Biological terrorism	[71]
	Economic recessions	[80]
	Labor strikes	[50,72,75,101]
	Social disparity	[42]
	War and armed conflict	[57,60,96]
Supply	Energy supply	[10,45]
	Fuel supply	[29,73]
	Oil shortage	[95]
	Shortage of supplies	[66,99,101]
	Supply of fertilizers	[66]
	Supply of raw materials	[11,75]
	Water scarcity	[10,18,88]

studied the role of international trade in managing food security risks considering supply volatility. Also, Rude and An [80] examined the impact of export restrictions on grain price volatility to establish the effect on the disruption of FSC. Likewise, Maltz [57] studied the dismantling and reconstruction of food systems in World War I and II, considering the interaction between local production, national coordination, international humanitarian aid networks, and the food policies of Britain, the US, and Germany. Yang and Xu [99] generated a quantitative model to analyse the recovery of a grain processor when a disaster disrupts supply and the impact on grain retailers. Next, Monit et al. [63] studied the 2007–2008 rice price crisis to analyse the adaptation after the world market disruption. Moreover, L'Hermitte et al. [49] conducted a case study of the United Nations World Food Programme to investigate the logistical impact of prolonged operations, risks, and uncertainty.

Bioterrorism emerges as a research topic, and for this reason, highlighted research such as Nthakanio and Jacob [71] explored the threats of bioterrorism in Kenya, considering the generation of laws that protect the food system from the malicious use of plant or animal pathogens in the agricultural sector. Additionally, climate change is examined by Berardy and Chester [10], who developed a dynamic simulation model to assess the impacts of rising temperatures and water and energy supply disruptions on crops in Arizona (USA). Besides, Nyamah et al. [72] analysed the probability and consequences of risks affecting supply operations, considering disruptions' impact on the FSC's performance in Ghana. Meanwhile, Rathore et al. [75] developed a risk assessment proposal for a FSC applying an integrated analytical hierarchy process in India. Other contributions, such as Lamalice et al. [45], studied the interconnectivity and complexities of food and energy systems in Canada. Also, Chodur et al. [15] analysed the functioning of the food system at the community level and mapped its components in terms of accessibility, availability, and acceptability.

Subsequently, the resilience of the supply chain was introduced as a particular subject of study. Research studies, such as Bottani et al. [11], formulated the problem of designing a resilient supply chain to ensure the continuity of business operations in the event of risk or disruption. Besides, Ali et al. [4] developed a model based on a Pareto analysis to identify food supply risks and a Combined Assessment and Decision-Making Laboratory (DEMATEL) model to assess the relationships between the main identified risks in the food supply. Moreover, Chakraborty and Sarmah [13] designed a simulation-based technique to explore the impacts of disruptions on the food store inventory system in India's distribution system. On the other hand, Coffel et al. [18] analysed the effect of drought on food production in the Upper Nile basin in areas such as Ethiopia, Sudan, and Uganda. Also, Gao et al. [29] conducted a case study of twelve large agricultural enterprises in Russia to assess the effectiveness of their logistics operations under the conditions of fragmented grain storage infrastructure. In addition, Maiyar and Thakkar [54] designed a mixed non-linear model to optimise intermodal grain transport in India, considering interruptions of the distribution system.

With the emergence of COVID-19, different research determined a trend for the modelling and analysis of pandemic effects in the supply chain, such as Chowdhury et al. [16], who studied the impacts of the COVID-19 pandemic and strategies to mitigate them in Bangladesh's food and beverage industry. Sharma et al. [84] analysed strategic perspectives on issues generated by COVID-19 through a Twitter data analysis of NASDAQ 100 firms. Also, Marusak et al. [58] explored FSC's improving strategies for the US food supply system, considering the best logistics practices for efficient and reliable distribution to consumers at regular times and during the emergency of COVID-19. Further, Nchanji and Lutomia [67] examined the effects of COVID-19 on sustainable production and consumption of beans, vegetables, fish, and fruits in rural, peri-urban, and urban areas in Eastern and Southern Africa. Likewise, Zhan and Chen [102] analysed China's food system's initial impacts and resilience amid COVID-19 to discuss the government's responses and long-term efforts to promote stability. Meanwhile, Abuabara et al. [1] analysed the diet problem during COVID-19 to provide a diversified weekly meal plan that complies with the nutritional requirements. Finally, Durant et al. [23] examined the resilience and vulnerability of farmers during COVID-19 in California, and Lee et al. [46] analysed the diet quality during COVID-19 among Massachusetts adults with lower incomes.

However, disaster response, supply shortages, and international trade were still being analysed. For instance, Sheu and Kuo [86] proposed a conceptual framework that reflects speculative hoarding behaviour's endogenous and exogenous background in response to disasters. Besides, Tanaka and Guo [90] examined the causality between the price of wheat at the global and regional levels in exporting countries. Nanda et al. [66] studied phosphorus shortages as a disruption to India's FSC. Also, Sjöstrand et al. [88] estimated the time-dependent water supply resiliency factors for economic sectors.

Afterwards, research studies on inventory and risk management have gained greater prominence. In this context, the work of

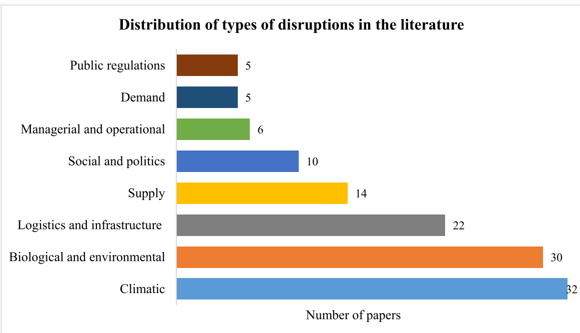

Fig. 8. Distribution of types of disruptions.

Table 5
Relationship between authors and stakeholders, echelons, and response level.

No.	Authors	Year	Actors						Echelon in supply chain					Response approach			
			Env	Hum	Op	Org	Pop	Reg	Sup	Far	Pro	Dis	Cus	Loc	Reg	Nac	Int
1	Crittenden et al. [19]	1988					x			x				x			
2	Mcginnis [60]	2000		x		x		x		x				x			x
3	Memmott et al. [61]	2007	x							x				x			
4	Ozbay and Ozguven [74]	2007		x			x		x			x		x			
5	Dowty and Wallace [22]	2010			x	x		x	x						x	x	x
6	Hayward and Mosse [35]	2012			x				x	x		x	x		x		
7	Lertworawanich [48]	2012						x				x			x	x	
8	Malladi et al. [56]	2012			x			x		x	x		x			x	
9	Wakeford and Swilling [95]	2014			x			x	x	x		x				x	
10	Baldos and Hertel [7]	2015			x					x			x		x		x
11	Maltz [57]	2015		x	x	x	x	x		x		x	x	x		x	x
12	Rude and An [80]	2015			x			x		x			x			x	x
13	Yang and Xu [99]	2015			x			x	x	x	x		x		x		
14	L'Hermitte et al. [49]	2016		x		x						x			x		
15	Monit et al. [63]	2016			x	x		x		x			x				x
16	Berardy and Chester [10]	2017			x					x					x		
17	Nthakanio and Jacob [71]	2017			x			x		x			x			x	
18	Nyamah et al. [72]	2017	x		x			x	x	x	x	x	x			x	
19	Rathore et al. [75]	2017	x		x		x		x	x	x	x	x			x	
20	Chodur et al. [15]	2018			x		x					x		x			
21	Lamalice et al. [45]	2018					x			x				x	x		
22	Ali et al. [4]	2019			x						x					x	
23	Bottani et al. [11]	2019			x				x	x	x	x				x	x
24	Chakraborty and Sarmah [13]	2019			x							x		x			
25	Coffel et al. [18]	2019			x					x					x		
26	Gao et al. [29]	2019			x			x		x					x		
27	Maiyar and Thakkar [54]	2019			x							x			x	x	
28	Yazdani et al. [100]	2019			x					x					x		
29	Chowdhury et al. [16]	2020			x					x	x	x				x	
30	Nanda et al. [66]	2020			x	x		x		x					x		
31	Sharma et al. [84]	2020			x				x			x				x	x
32	Sheu and Kuo [86]	2020			x		x					x	x	x			
33	Tanaka and Guo [90]	2020			x			x	x	x			x	x		x	
34	Ashtab and Campbell [6]	2021			x		x			x		x	x	x			
35	Burgos and Ivanov [12]	2021			x							x					x
36	Das et al. [20]	2021			x							x		x			x
37	Gholami-Zanjani et al. [30]	2021			x							x			x		
38	Gholami-Zanjani et al. [31]	2021			x							x			x		
39	Gholami-Zanjani et al. [32]	2021			x						x	x			x		
40	Jensen and Orfila [42]	2021			x		x			x			x	x			
41	Marusak et al. [58]	2021			x			x		x	x	x			x		
42	Nchanji and Lutomia [67]	2021			x		x			x			x			x	
43	Suryawanshi et al. [89]	2021			x							x	x	x			
44	Ray [76]	2021			x				x						x		
45	Singh et al. [87]	2021			x							x			x		
46	Sjöstrand et al. [88]	2021			x				x							x	
47	Tsiamas and Rahimifard [91]	2021			x					x	x	x			x		

(continued on next page)

Table 5 (*continued*)

No.	Authors	Year	Actors						Echelon in supply chain					Response approach			
			Env	Hum	Op	Org	Pop	Reg	Sup	Far	Pro	Dis	Cus	Loc	Reg	Nac	Int
48	Yadav et al. [97]	2021			x					x				x			
49	Zhan and Chen [102]	2021						x		x	x	x	x			x	
50	Zulkefly et al. [106]	2021			x							x			x		
51	Abuabara et al. [1]	2022					x						x	x			
52	Anis et al. [5]	2022					x						x			x	
53	Balkan et al. [8]	2022			x					x					x		
54	Ermes et al. [25]	2022			x							x				x	
55	Hedlund et al. [37]	2022	x		x					x		x					x
56	Joshi and Sharma [43]	2022			x						x				x		
57	Kazancoglu et al. [44]	2022			x				x	x	x	x	x			x	
58	Leong et al. [47]	2022			x				x	x	x			x			
59	Li et al. [51]	2022			x		x				x	x	x		x	x	
60	Lin et al. [52]	2022			x							x				x	
61	Malik et al. [55]	2022	x		x		x				x	x	x			x	
62	Mishra et al. [62]	2022			x							x		x			
63	Njomane and Telukdarie [68]	2022			x							x				x	
64	Oliver et al. [73]	2022			x					x	x	x		x			
65	Yazdani et al. [101]	2022			x						x	x			x		
66	Zhao et al. [104]	2022			x					x	x	x		x	x		
67	Cheng et al. [14]	2023			x							x				x	
68	Clavijo-Buritica et al. [17]	2023			x					x	x		x		x		
69	Durant et al. [23]	2023			x						x	x		x			
70	Hasnain et al. [33]	2023		x								x			x		
71	Lee et al. [46]	2023		x									x		x		
72	Li et al. [50]	2023			x				x			x				x	
73	Murphy et al. [64]	2023			x					x	x	x	x			x	
74	Weldegiargis et al. [96]	2023					x						x		x		

Env: Environmental Agents.
Hum: Humanitarian actors.
Op: Operational actors.
Org: International organizations.
Pop: Population.
Reg: Regulatory entities.
Sup: Suppliers.
Far: Producers and farmers.
Pro: Processors.
Dis: Distributors.
Cus: Customers.
Loc: Local.
Nac: National.
Reg: Regional.
Int: International.

Gholami-Zanjani et al. [30] is highlighted when they proposed a Benders decomposition model considering several resilience strategies to optimise the operating cost of FSC. In addition, Gholami-Zanjani et al. [31] formulated a meat supply model under uncertainties around environmental problems and disruptions. Also, Gholami-Zanjani et al. [32] developed a generic mathematical model with mixed integers to integrate inventory placement, allocation, and supply decisions, seeking maximisation of expected total utility and minimising total operating costs. Also, Yazdani et al. [100] identified flood risk drivers and their impact on the sustainability of an agricultural supply chain concerning a circular economy strategy. Other works proposed optimization models for a supply chain of perishable products and supply interruptions considering intermediaries agents in risk management [20], and optimal risk management strategies to maximise expected utility on uncertain demand [76]. Other researchers, such as Jensen and Orfila [42], developed an empirical study focusing on food production in Leeds (UK) to analyse its population's sustainable supply.

In contrast, Zulkefly et al. [106] extended a mathematical model to illustrate the problem of a cold chain system subject to transportation disruption. Then, Ashtab and Campbell [6] analysed the impact of consumers' buying decisions in local markets in Canada's food production and distribution systems. As well as Balkan et al. [8] studied the complex causal and feedback relationships for the FSC using the system dynamics methodology.

Moreover, the modelling of food supply systems considering digital tools of industrial 4.0 is becoming more visible. For example, Yadav et al. [97] modelled a multi-level system based on sustainability for the agri-FSC, which is managed through different emerging applications of Internet of Things (IoT) technology, using interpretive structural modelling and Fuzzy-DEMATEL. On the other hand, Burgos and Ivanov [12] used discrete-event simulation to examine supply chain operations with the help of a digital supply chain in COVID-19. Additionally, Tsiamas and Rahimifard [91] proposed a decision-support approach based on simulations to assist manufacturers in mitigating the impact of various unexpected disruptions associated with climate change. Also, Singh et al. [87] developed a simulation model of the public distribution system network with different scenarios to demonstrate the impact of the disruptions in the FSC. Furthermore, Suryawanshi et al. [89] presented an example of e-commerce based on a distribution planning problem to minimise the supply chain cost simulating online grocery business. In contrast, Joshi and Sharma [43] used multicriteria methods to identify the critical success factors for adopting digital technologies in food security across the FSC.

Sustainability and resilience of the food supply chain are considered fundamental research topics. For this reason, modelling and analytical approaches are determining a significant projection that can be addressed in various works, including the study by Kazancoglu et al. [44], who determined the sustainability factors of FSC using an interpretive structural modelling method to state the relations between the sustainability factors of FSC. Moreover, Oliver et al. [73] developed a methodology for performing supply chain impact assessments to identify the impacts of critical infrastructure disruptions. In addition, Leong et al. [47] proposed a multicriteria model to evaluate suppliers considering resilience criteria. Other research, such as Hedlund et al. [37], proposed a network model to project how climate change impacts crop yields and may be translated into changes in trade. Moreover, Yazdani et al. [101] developed a decision-making model to measure the resiliency of critical players in a case study of the agricultural FSC in Andalucia (Spain). Meanwhile, Li et al. [51] investigated the operation management of a dual-channel fresh-food supply chain under disruption.

Also, Zhao et al. [104] analysed the disruption propagation in a supply chain network and evaluated the strength of agri-FSC networks. Then, Ermes et al. [25] explored the factors influencing disruption propagation in South Africa's fast-moving consumer goods food and beverage manufacturing sector. Meanwhile, Njomane and Telukdarie [68] compared the adaptation of retailers' business models to remain resilient during Covid-19. Furthermore, Anis et al. [5] evaluated the effect of quality and nutritional attributes on consumer food behaviour. Also, Mishra et al. [62] examined the current situation that hindered daily operations and created difficulty in achieving operational excellence during COVID-19. Lastly, Lin et al. [52] analysed the consumers' perception and acceptance of China's retail food delivery system during the COVID-19 disruption. Besides, Malik et al. [55] estimated the spillovers regarding social and health impacts resulting from extreme weather in FSC.

Finally, research has evolved to include the analysis of vulnerabilities in production and distribution systems without dismissing other topics. In 2023, research studies such as the one conducted by Weldegiargis et al. [96] have stood out, examining the impact of armed conflict on household food insecurity in Tigray (Ethiopia). Besides, Li et al. [50] proposed a mathematical model to optimise the transport system in a green containerised grain supply chain in Ukraine, considering disruption scenarios. Next, Hasnain et al. [33] explored the behaviour of the Socio-ecological System of the Food Bank of Central and Eastern North Carolina during Hurricane Florence. Furthermore, Clavijo-Buritica et al. [17] studied the resilience of the perishable FSC in emerging countries, considering disruptive events in Colombian coffee production and distribution. Also, Murphy et al. [64] investigated how forest fires and pandemic shocks affected the agri-food system in Melbourne (Australia). Lastly, Cheng et al. [14] applied the complex network theory to construct an evolutionary model of the Chinese fresh cold chain network.

4. Category selection

4.1. Types of disruptions

We classified the types of disruptions analysed in the literature (Table 4) according to the categories proposed by Nyamah et al. [72]: managerial and operational; biological and environmental; climatic; demand; logistics and infrastructure; public regulations; social and politics; and supply. Fig. 8 shows the number of publications according to the type of disruption; each disruption can be addressed in several papers.

In addition, we classified the items according to the actors involved in each type of disruption, supply chain links and response level. The stakeholders include the categories: environmental, humanitarian, international organizations, food producers and distributors, the population, and regulatory entities. Moreover, the links in the FSC have the supply of raw materials and inputs, production, processing, distribution, and food consumption. Response levels involve the type of entity involved in decision-making, e. g., local, regional, national, and international. Table 5 shows the relationship between authors and the characteristics of each disruption and Table 6 shows the relationship between the categories of actors involved and the literature.

4.2. Solution methods

In this section, we present the classification around the approaches for analysing disruptions in food systems. Fig. 9 shows the number of applications of each method within the literature. The classification considered that each paper could address several methods.

The authors widely used qualitative, statistics and stochastic methods. There are also applications of other alternatives that include exact methods, multicriteria techniques, econometric and analytical tools, metaheuristics, and information technologies. Table 7 describes the categories of methods used and their relationship with the authors.

4.3. Goals of the models

In this section, we present objective functions, indicators or variables of interest considered by the authors to address disruptions in the FSC. This categorisation applies the proposal of [72] to classify model goals. Fig. 10 presents the distribution of model targets in disruption analysis.

The goals of the models cover mainly administrative aspects and operations, considering a lesser proportion of political variables; other alternatives are logistics, socio-cultural, demand, biological and environmental and supply. Table 8 describes the categories of goals used and their relationship with the authors.

Table 6
Stakeholders involved in disruptions in FSC.

Category	Description	Authors
Environment	Nature	[55,61,72,75]
Humanitarian actors	Aid Agencies	[49,57,60]
	Food banks	[33,46]
	Shelters	[74]
International Organizations	International community	[57,60,63,66]
	ONU	[22,49]
Operative actors	Companies	[15,22,29,58,72,88]
	Customers	[5–7,35,42,44,51,57,67,72,75,86,90,99]
	Distributors	[8,12–14,16,25,30,32,44,50,51,58,62,64,68,73,87,89,91,95,101,104,106]
	Logistics Operators	[14,20,29,50,54,72,75,89]
	Processors	[4,11,16,44,47,56,64,72,73,75,91,99,104]
	Producers	[6–8,10,11,14,17,18,23,29–32,35,37,42–44,47,51,56–58,64,66,67,71–73,75,76,90,91,95,97,99–101, 104]
	Providers	[8,10,30,31,42,47,58,72,75,95]
	Traders	[4,7,11,35,37,57,63,72,80,84,86,90]
Population	Families	[1,19,57]
	General populations	[6,15,42,46,51,57,74,75,86,96]
	Indigenous communities	[45]
Regulatory entities	Governments	[22,29,48,56–58,60,63,66,71,72,80,90,95,99,102]

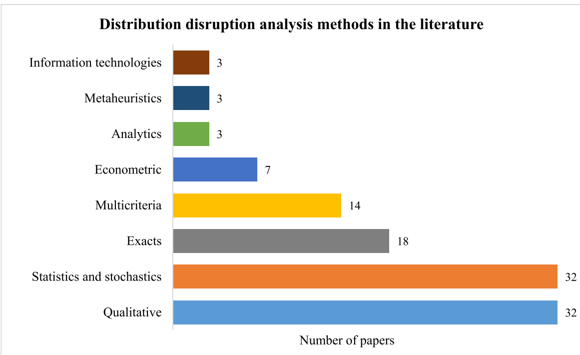

Fig. 9. Distribution of disruption analysis methods.

Table 7
Relationship between methods and authors.

Method	Description	Authors
Analytics	Fault tree analysis	[15]
	Performance assessment	[72]
	Rational choice model	[60]
Econometric	Analysis of material flow accounts	[63]
	Generalized method of moments	[80]
	Generalized self-regressive methods conditional heteroscedasticity	[90]
	Network model	[14,37]
	Simple model	[7]
	Stackelberg game	[51]
Exacts	Bender's decomposition	[30]
	Dynamic Programming	[13,48]
	Economic order quantity model	[29]
	Integer non-linear programming	[54,106]
	Mathematical Model	[74,104]
	Mixed integer linear programming	[1,11,17,20,32,50,76,89]
	Quantitative models	[99]
	Structural modelling of equations	[86]
Information technologies	System modelling	[73]
	Twitter data analysis	[6,84]
Metaheuristics	Ant colony optimization	[11]
	Optimization of the particle swarm with differential evolution	[54]
	Particle optimization	[48]
Multicriteria	Analytical hierarchy process	[1,75]
	Best worst method	[47,101]
	DEMATEL	[4,43,97]
	Fuzzy measurement alternatives and ranking according to the compromise solution (MARCOS)	[101]
	Grey relational analysis	[47]
	Hybrid multicriteria methodology	[47,100]
	Interpretive structural modelling	[44]
	TOPSIS	[47,75]
Qualitative	Actor process-learning action performance	[62]
	Case study	[13,22,23,35,45,57,58,64]
	Empirical models	[4,16,18,33,35,42,45,49,58,66,68,71,72,80,84,86,90,95,102]
	Ethnographic research	[35]
	Integrated modelling framework	[55]
	Semistructured interviews	[25,33]
Statistics and stochastics	Analysis of variance	[19]
	Simulation	[10,12,13,30–32,50,56,61,73,80,87,89,91]
	Stochastic models	[74]
	Surveys	[5,6,16,19,23,46,49,52,64,67,72,88,96]
	System dynamics modeling	[8]
	Tchebycheff weighted lexicographic methods	[31]
	Univariate structural series of time	[80]

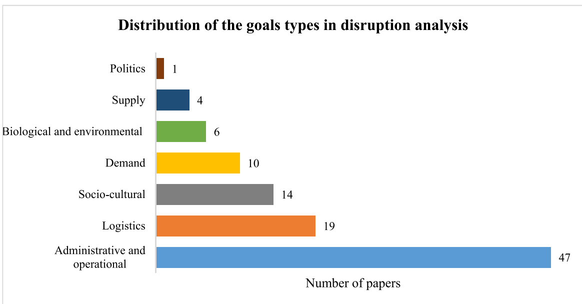

Fig. 10. Distribution of the goal types in disruption analysis.

4.4. Constraints and considerations

In this section, we present the classification of the main restrictions and considerations analysed in the literature related to disruptions in FSC. The categories are logistics and infrastructure, managerial and operational, socio-cultural, demand and market,

Table 8
Relationship between goals of models and authors.

Category	Description	Authors
Managerial and operational	Adaptability of strategies	[23,33,43,62,64,68,84,102]
	Costs	[12,13,17,20,29,30,32,50,54,74,87,89–91,106]
	Crop Yield	[18]
	Cultivated area	[19]
	Digital technologies adoption	[43,52,68]
	Disruption propagation risk	[25]
	Failure rate	[15]
	Food productivity	[10,37,42,45,67,99]
	Freeman centralization	[104]
	Level of coordination	[57]
	Organizational Culture	[22]
	Risk index of crop areas	[100]
	Supplier selection	[47]
	Utility	[11,31,32,60,76,99]
Biological and environmental	Bio-environmental sustainability index	[35]
	Emissions to the environment	[31]
	Food Waste	[4]
	Phenological change	[61]
	Propagation rate	[56]
	Reducing waste	[97]
Demand	Backorders	[12]
	Causality	[90]
	Consumption level	[8,67]
	Herfindahl-Hirschman Index	[63]
	Price volatility	[7,29,51,80,90]
Logistics	Average daily available inventory	[12]
	Impact of disruptions	[16,49,55,58,64,67,71]
	Inventory level	[51,73]
	Lead Time	[11,12]
	Loss of travel demand	[48]
	Product quality	[51]
	Resilience Index	[20,101]
	Service level	[12]
	transport distance	[14]
	Value risk index	[75]
Politics	Policy responses	[102]
Socio-cultural	Consumers' decisions to buy	[6]
	Diet selection	[1,5,46]
	Human nutritional status	[5,19,42,46,55,96]
	Multiple deprivation rate	[42]
	Nutritional contributions	[42,45]
	Speculative hoarding induced by disasters	[86]
Supply	Oil shortage	[95]
	Phosphorus vulnerability index	[66]
	Risk in the supply chain	[72]
	Time of water dependency	[88]

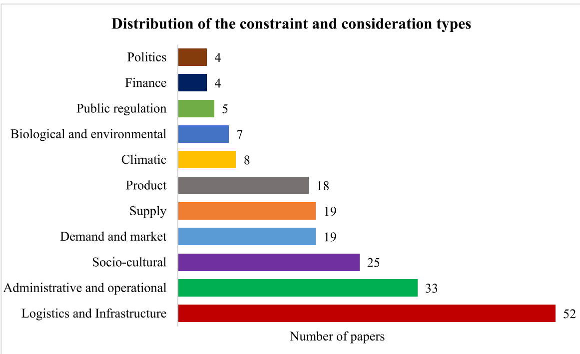

Fig. 11. Distribution of the constraint or consideration types in disruption analysis.

supply, product, climatic, biological and environmental, public regulation, finance, and politics. Fig. 11 presents the distribution of restrictions or consideration types in the literature. Table 9 shows the relationship between the considerations and the authors.

5. Discussion

Disruptions consolidate as external events that are challenging to foresee and control, significantly impacting the operational performance of the supply chain. These disruptions can influence resource supply, demand, and distribution, affecting the operational system's flow of products, money, and information. In the case of food supply chains, disruptions affect the availability of safe products for the population, ranging from situations of product scarcity to instances where consumers exhibit resistance to acquiring certain items. This implies that the product flow is affected at any stage, whether in production, distribution, or consumption, directly impacting the supply and demand for products, access to information, and the profitability of organizations.

Furthermore, disruptions significantly increase the level of uncertainty in food supply chains, introducing key elements such as the intensity of the event's impact, propagation speed, geographic proximity [30], and the overall effect of the disruption at each link [32]. Moreover, the nature of food products adds complexity to food systems. Variables such as freshness degree, nutritional content [42], lifecycle [32], availability, and price further contribute to the intricacies to be considered within the analysis of these supply chain behaviours.

Similarly, the operational infrastructure of food supply chain links can be affected by installed capacity, node prioritization [11], inventory levels, and operational policies and procedures depending on the level of exposure to disruption effects. These disruptions can also impact the market, adding more complexity to supply and demand uncertainty [30], resulting in price fluctuations, changes in product quality perception, and shifts in consumer consumption strategies and attitudes.

The changing and globalised nature of the world has amplified the complexity and vulnerability of FSC. Besides, the growing global population and increasing demand for food significantly impact the sustainability of these supply chains [44]. For example, the war in Ukraine is causing significant disruptions to global agri-food systems, which are still recovering from the effects of the COVID-19 pandemic; this is compounded by climate change, which has caused forest fires, floods, and droughts worldwide [64].

During disruptions such as Covid-19, food processing and production had problems such as closing and restricting borders and production plants to contain the spread of the virus [68]. In humanitarian organizations such as food banks, the flexible and dynamic network of relationships and exchange of information and resources allows a recovery of stability to continue working towards long-term resilience. These relationships are characterised by social capital based on social trust, collaborative action, social effectiveness, reciprocity, and citizen participation [63].

In disruptions that affect vital supplies such as water, the economic losses will be significant for businesses and society, affecting food production, distribution, and consumption [88]. According to Malik et al. [55], catastrophes resulting from climate change and extreme weather events hurt agricultural and livestock production. Disruptions, such as natural disasters and water supply failures, generate critical and unstable environments under extreme conditions for which companies are often unprepared. Research on FSC companies has prioritised resilience through risk management, recovery speed and cooperation with suppliers. However, improving production flow, maintaining customers, and satisfying stakeholders are essential ways to strengthen resiliency [101].

Also, according to Zhan and Chen [102], there are three key elements to mitigate disruptions, firstly the use of innovative methods to ensure the normal functioning of FSC; next, the establishment of targeted policies to support businesses and households, finally, the increase and prioritization of investments to build resilient food systems. Furthermore, Kazancoglu et al. [44] add that it is essential to consider drivers such as information sharing and management approaches, as well as relevant factors, focused on food safety, knowledge transfer, logistics networking, risk mitigation, employee engagement, innovation, traceability, and responsiveness.

On the other hand, in the food production echelon, where farmers are the main actors, disruptions can cause short, medium, and long-term effects. Considering that perishable products have a short life cycle and high complexity in their handling, in the short term, there are difficulties concerning the capacity to harvest and transport goods, acquire inputs and employ labour due to blocking measures and travel restrictions, which generates an increase in food loss and waste. In the medium term, changes in consumer behaviour, such as a greater preference for non-perishable items, have contributed to fewer customers and less profit, reducing the capacity to invest in future inputs and offer competitive wages to secure labour. This situation may lead to increased unemployment and farm closures in the long term [8].

Finally, disruptions can affect food retailing in times of crisis with surges in demand and supplier closures, as well as in product transport and storage capacity, government measures, and the dynamics of retail inventory orders and customer behaviour [12]. In addition, food quality and nutritional attributes affected consumers' food choices [5]. Among other things, Covid-19 also affected consumer behaviour patterns, leading to local producers' sales being influenced by consumer sentiments regarding shopping at farmers' markets and buying locally [6]. Regarding transport, critical aspects such as carrying capacity have a significant effect on the recovery phase of disruptions, as higher capacity allows for a reduction in the frequency of deliveries, thereby reducing transport costs, as well as carbon emissions from fuel consumption and the cooling system [106].

6. Insights and future research directions

We have identified various research opportunities according to the categories analysed in this review. These include analysing the impact of government policies and climate change on food supply chains, coordinating different actors, and utilising hybrid methods for decision-making. We also consider evaluating the impact of product and supply shortages as an essential research perspective, integrating stakeholders, and considering multi-objective methods that incorporate resilience and sustainability in the FSC.

Table 9
Relationship between authors and restrictions or considerations.

Category	Description	Authors
Managerial and operational	Agility	[49]
	Agricultural practices	[95,97]
	Best practices	[58]
	Coastal processes	[100]
	Crop yields	[17,37]
	Gardening space	[45]
	Groundwater systems	[100]
	Labor capacity	[8,62]
	Managerial decision-making	[25,101]
	Multiple period	[30–32,50,54]
	Operational risks	[22,44,72,101]
	Production capacity	[102]
	Production processes	[42,45,57,60]
	Prolonged humanitarian operations	[49]
	Responsiveness	[13,47,74,88,104]
Biological and environmental	Carbon dioxide	[45,106]
	Extinction of species	[61]
	Interactions between species	[61]
	Sickness mortality	[56,71]
	Transmission of diseases	[56]
Climatic	Climate Change	[7,10,18,37,55,61,100]
	Seasonal effect	[19]
Demand and market	Acceptability	[15]
	Accessibility	[15,42,45,88]
	Competitors	[71]
	Demand uncertainty	[62,76]
	Exports and imports	[37,63,71,90]
	International trade	[7,11,80]
	Price uncertainty	[76]
	Seasonal nature	[29,45]
	Substitute goods	[90]
Finance	Financial risk	[47,100]
	Operational cost	[8,47]
Logistics and Infrastructure	Associates	[22,72]
	Auto-adaptation	[11]
	Coordination tactics	[12,22,43,72]
	Distributions strategies	[51,52,68,89]
	Flexibility	[47,62]
	Fresh cold chain network	[14]
	Intermodal transport	[17,50,54]
	Inventory	[12,17,20,25,30–32,73,74,101]
	Lead time	[47]
	Logistics effectiveness	[44,102]
	Market channels	[23,89]
	Modernization	[35]
	Recovery Rate	[99]
	Relocation/Location	[31,32,60,95]
	River systems	[100]
	Storage and transport	[8,12,17,20,29,62,75,76,87,95]
	Timeout	[56]
	Urban Systems	[100]
	Visibility	[47]
Politics	Coercion	[60,86]
	Peacekeeping operations	[60]
	Terrorist groups	[71]
Product	Availability	[10,15,42,45,67,91,99]
	Multiproduct	[11,20,42]
	Perishability	[32,76]
	Product Diversity	[42]
	Quality	[4,47,97]
	Rate of deterioration	[32]
	Utility	[45]
Public regulation	Food policies	[57]
	Government aid	[33,99]
	Government policy	[100]
	Socio-economic conditions	[75]
Socio-cultural	Anthropometric data	[19]
	Human behaviour	[5,6,67,100]

(*continued on next page*)

Table 9 (*continued*)

Category	Description	Authors
	Human psychology	[6,86]
	Hunger human status	[96]
	Indigenous peoples' way of life	[13,45]
	Nutritional status	[19,42,57]
	Population growth	[18,35,55]
	Population income	[46]
	Social networks	[84]
	Socio-cultural change	[35,42,45]
	Theory of social cognition	[86]
	User Perception	[1,16,48]
Supply	Donations	[33]
	Relationship between supply and demand	[8,12,25,30,31,37,42,62,67,72,73,75,76,91,102]
	Replenishment process	[13]
	Supply of fertilizers	[66]
	Supply probabilities	[74]

Additionally, designing strategies to mitigate disruptions and developing new technological tools for decision-making are other areas of research to consider. In Fig. 12, we synthesise the research opportunities identified in this review.

Resilient food supply networks are early in developing countries and could incorporate social issues [30]. Therefore, approaches to FSC sustainability coupled with resilience considerations can provide more comprehensive decision-making tools for decision-makers. Similarly, implementing robust scenario-based optimization methods could incorporate the attitudes of decision-makers. In addition, it is essential to expand research on resilience by considering realistic environments with a more significant number of customers, suppliers, and distributors in global supply chain disruption situations [20].

The growth of modern cities involves more support for the local production of nutritious food. Therefore, much work remains to be done on options for optimizing the food system in general within the local, national, and global context, particularly in reducing the punitive environmental impacts of the system and improving the diets and health of communities [42].

The existing literature on risk modelling and perishable factors needs to be expanded. Therefore, it is possible to open the field of research to the exploration of other risk management strategies and the implementation of digital technologies such as Artificial Intelligence, the Internet of Things, Cloud Computing, Big Data Analysis and Blockchain technology, among others [44,76]. According to Clavijo-Buritica et al. [17], it is essential to address information processing and mitigation of future risks associated with the effects of natural disasters, thus providing an opportunity to improve food systems through the development of information systems that allow farmers to record small, medium, and high impact disasters daily.

In this order, the development of decision support systems considering modelling approaches and structural dynamics could be expanded to promote further the adaptability of the network structure in time for future scenarios [32]. Moreover, the operation could also be investigated in an international environment subject to other types of disruptions and limitations of globalisation [31].

The field of study on the design of supply networks could be expanded with an approach associated with food traceability problems as another resilience strategy requiring new modelling techniques [30]. More resilience-seeking strategies can also be proposed and modelled to compare solutions with their efficiency and effectiveness [31], such as investment in technology for food traceability [30],

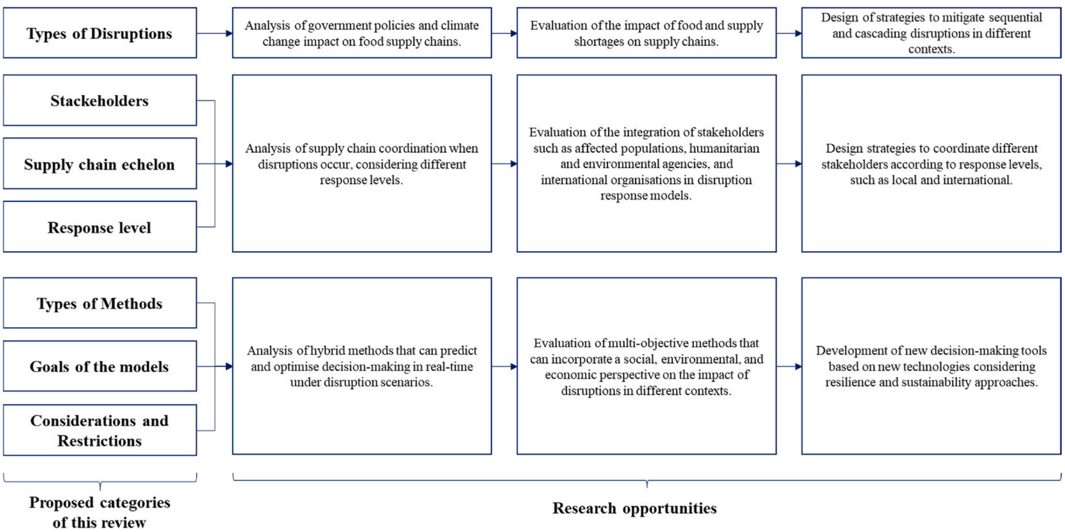

Fig. 12. Research opportunities.

climate change and social contexts. Another research perspective is to analyse the potential viability of farmers' markets during and after disruptions [6].

Another direction for future research may be to explore further preparedness, response and recovery from disruptions in water availability for agri-food systems, leading to an understanding of how businesses are affected by disruptions to understand societal vulnerability, estimate losses to businesses and society, and mitigate the effects of future disruptions by considering water supply planning and management so that trade-offs between performance, risk and finance can be established in a structured and transparent way [88].

Studies on optimizing FSC in an integrated manner are an option for expansion in the scientific field, seeking to manage disruptions by considering variables related to transportation time with expiration dates, penalty systems, and the consideration of CO2 emissions as an objective function [50]; and developing an efficient and robust food delivery network can be vital to the last-mile supply chain for food delivery during certain types of crises where customers are confined for extended periods [52].

Short FSCs have the potential to support rural and urban livelihoods in the face of adverse effects caused by pandemics while contributing to sustainable production and consumption. Therefore, local input and food distribution models and inclusive institutional and legal support for urban agriculture are crucial in reducing food and nutrition insecurity, poverty and gender inequality [67]. It would also be interesting to address the distribution of perishable and long-life food in direct market distribution contexts and the presence of intermediaries [23].

According to Mishra et al. [62], further descriptive studies are needed to understand the impact of contextual variables such as firm size, industry type, leadership style, and degree of external uncertainty on the ability of organizations to develop supply chain resilience to maintain operational excellence. There is an imperative need to increase the level of understanding of ways to strengthen the resilience of food systems in the face of multiple shocks and stresses that occur sequentially or alternately, such as international conflicts, pandemics, and climate change, among others [64].

Finally, we highlight the importance of addressing studies that contribute to generating policies that guarantee food security to mitigate the impact of FSC disruptions. Future research can address the integration of different actors considering local, regional, and international levels of response, as well as the integration of actors such as the affected population, humanitarian and environmental agencies, and international organizations in models of disruption care. Within the significant research gaps are opportunities to analyse sequential and cascading disruptions. The field of research could also be extended to the analysis of less studied categories of disruptions such as demand, public, administrative, and operational regulations. Similarly, supply chain coordination is relevant, mainly when disruptions occur, considering different response levels. Finally, another perspective research is designing hybrid methods to predict and optimise real-time decision-making under disruption scenarios.

7. Conclusions

This paper provides a literature review to identify, discuss and generate future research directions about disruptions in FSCs. This study analyses the types of disruptions, methods, goals, and research considerations in FSC. Results showed that the most common disruptions in the FSC are climatic, biological and environmental, logistics and infrastructure, and supply. Other disruptions include social and political, managerial and operational, demand, and public regulations. Regarding the actors involved in supply chain disruptions, we found that the most representatives are the environment, humanitarian actors, operative actors, international organizations, population, and regulatory entities.

The broadest range of stakeholders examined includes operative actors such as companies, customers, distributors, logistics operators, processors, producers, providers, and traders. Furthermore, nature represents the most significant environmental stakeholder. Also, humanitarian agencies like aid agencies, food banks, and shelters are included in the literature. Moreover, international organizations are analysed, e.g., the United Nations and the international community. Furthermore, the population comprises a representative stakeholder group, encompassing families, general people, and the communities affected by disruptions. Lastly, governments represent the stakeholder that wields national power.

Furthermore, qualitative, exact, statistical, and stochastic techniques are the most used methods for analysing disruptions in FSCs. The goals of the models most studied consider a focus on managerial and operational, logistics, and socio-cultural. On the other hand, the most common considerations involved in the models are logistics and infrastructure, demand, managerial and operational; other considerations analysed will focus on categories socio-cultural, supply, biological and environmental, climatic, finance, political, product, and public regulations.

Finally, the limitations of this study involve the inclusion of scientific papers focused on food-related contexts, as well as the development of a descriptive analysis of the findings. Other reviews may consider correlation analysis of variables and other documents, such as book chapters and proceedings, among others. This review can be extended to other perspectives, such as the impact of disruptions on each supply chain link (production, processing, distribution, consumption). It can also consider a deeper insight into the role of each type of actor and their influence on the preparedness, mitigation, and recovery phases of disruptive events. Besides, future research may seek clear clustering patterns among types of disruptions and food systems and explore specific policy implications. Methodologies can also be proposed to characterise disruptions according to their impact in specific contexts. Finally, the proposed review methodology can be applied to update the findings.

Data availability statement

The data associated with the articles included in this review are available in the original sources.

CRediT authorship contribution statement

Juan J. Rojas-Reyes: Methodology, Conceptualization, Project administration, Resources, Writing – original draft. **Leonardo Rivera-Cadavid:** Supervision, Resources, Writing – original draft, Writing – review & editing. **Diego L. Peña-Orozco:** Validation, Supervision, Methodology.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Juan J. Rojas-Reyes reports financial support was provided by University of the Valley. Leonardo Rivera-Cadavid reports financial support was provided by University of the Valley. Diego L. Peña-Orozco reports financial support was provided by Corporación Universitaria Minuto de Dios (Colombia).

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