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Risk Management in Reverse Supply Chain for Sustainable Agri-food Industry: A Systematic Literature Review and Future Research Agenda

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ABSTRACT

In implementing a Reverse Supply Chain (RSC) for food waste products, several risks must be borne by producers or third parties. This research aims to identify risks in RSC operations, analyze existing methods and approaches, and improve a further framework model for managing the risk of RSC for the sustainability of the agricultural food industry. Using the PRISMA protocol, data was collected from a systematic review and synthesis of 78 articles published between 2012 and 2021. The result showed that although several research have been carried out on RSC risk, there is still very little research on risk management in the agri-food industry. It also found the potential aspects for future research in managing RSC risk in the agri-food industry, include process risk by considering product damage, supply-demand uncertainty, quantity and quality product return uncertainty, transportation and technology, and financial and environmental risk. According to the literature, MILP and integration with other approaches are frequently used in decision-making to manage the risk of RSC. Exploration of future research requires developing RSC risk management in the integrated agri-food industry. Furthermore, it is important to optimize the risk management of the RSC by considering the complexity of the risk and designing the sustainability of the RSC network in the agri-food industry. Focus is presently on the Hybrid Intelligent Decision Support System (HIDSS) approach for the development of a concept is the most appropriate new concept to reduce various types of risks in the RSC of the agri-food industry.

Keywords: *agri-food, hybrid intelligent decision support system, reverse supply chain risk, risk management, sustainability*

1. INTRODUCTION

Agri-food products face various risks and vulnerabilities before reaching consumers. Poor road conditions often lead to distributing defective or damaged products to retailers. Damaged or distant transportation routes and fluctuations in temperature and humidity during transit tend to cause a significant decline in the quality of processed goods. Additionally, extended turnover times can result in a notable reduction in product quality (Noor *et al.*, 2016). It is imperative to actively address these challenges by implementing effective measures to re-manage food waste products not absorbed by the market, thereby adding value to them. Ensuring the sustainability of these products is of utmost importance. The process of re-managing these waste products is commonly referred to as RSC (*Govindan et al.*, 2015; *Kazemi et al.*, 2018).

In the past ten years, the adoption of RSC has witnessed a remarkable expansion in supply chain management across diverse industries. Businesses are compelled to reconsider their customer relationship management and supply chain strategies due to various emerging factors such as market dynamics, environmental concerns, regulations pertaining to its protection, and social considerations (Couto *et al.*, 2016).

The closed-loop supply chain (CLSC) consists of two primary streams, namely the forward supply chain (SC) and the RSC. In the CLSC model, consumers have the opportunity to return products or materials to the original producers, thereby creating a feedback loop (Liu & Chang, 2017; Banasik *et al.*, 2017). On the other hand, the open-loop supply chain model does not involve the return of goods to the initial producer. Instead, it relies on a third party to recover (Ene & Öztürk, 2014; Kalverkamp & Young, 2019).

While implementing a reverse supply chain (RSC), retailers, manufacturers, and third parties receiving returned products from consumers must contend with disturbances and risks (Gooran *et al.*, 2018). Risks associated with RSC activities encompass financial and management aspects (Rahimi & Ghezavati, 2018; Zhao & Zhu, 2018), product collection, supply and demand uncertainty, environmental threats (Jabbarzadeh *et al*., 2018), as well as others that necessitate further exploration in the existing literature. It is important to note that risks encountered in RSC operations differ between industries such as electronics, plastics, and other manufacturing sectors compared to RSC activities in the agri-food industry. In the agri-food industry, process activities are essential, such as control over the safety of food products (Septiani *et al.*, 2016). Various risks accompany the remanufacturing process activities, such as the quality risk of the returned product material, which will later be used as raw material in RSC activities, and the quality of the resulting remanufacturing product. Consequently, additional investigation of the existing literature is required to identify the most critical risks in RSC operations specific to the agri-food industry and examine the methods employed in research to address these issues.

Reverse Supply Chain is needed as one of the company's responsive efforts in sustainability. Sustainability is currently a concern for society such as increasing economic, social, technological, and environmental improvements such as preventing environmental damage due to waste, how to minimize the generation of waste, and how to increase the added value of waste, which is the subject of research in the RSC (Liu & Chang, 2017; Morgan *et al*., 2018; Kalverkamp & Young, 2019). The issue of sustainability is essential because there are doubts about the implementation of RSC in the agri-food industry. Therefore, exploring the literature on Reverse Supply Chain sustainability is necessary.

This research aims to identify risks inherent in RSC operations, analyze trends and gaps in the reviewed literature and existing approaches and methods, and ultimately develop a novel framework model for effectively managing RSC risks in the sustainable agri-food industry.

2. METHODOLOGY

In order to achieve a methodical and objective understanding of the existing literature, it is important to conduct a systematic literature review (SLR) (Kitchenham *et al.*, 2010). An SLR enables a comprehensive assessment of relevant findings and their interpretation in relation to the research topic while addressing predetermined research questions. This approach helps to maintain consistency, minimize bias, and provide a reliable basis for analysis.

The research employed a two-step approach, initially, a systematic literature review (SLR) was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. Preliminary researchers often rely on the PRISMA method and utilize online databases like SCOPUS and ScienceDirect, which have specific criteria for publication date and language perimeter (López-Santos st sl., 2020). The adoption of an SLR technique was motivated by the diverse content in each publication (Bastas & Liyanage, 2018). This process encompassed planning, conducting and reporting, and dissemination stages. The literature review applied a methodology proposed by Briner and Denyer (2012).

2.1 Literature Search

The first phase of the literature review involved identifying the bibliographic databases, descriptors or keywords, and search methods. According to Buchanan and Bryman (2009), utilizing peer-reviewed publications is recommended to monitor the quality of the papers in the sample. Another approach to ensure the quality and relevance of information sources is to restrict the search to publications that adhere to journal rankings.

Moreover, to ensure a comprehensive review, articles related to the research topic were searched in popular literature databases. The inclusion of these databases aimed to provide a broad perspective and extensive coverage of the literature. The following list includes the digital databases that were searched:

- Scopus
- ScienceDirect
- Google Scholar

A search was conducted for scientific papers and journals on Management Risk in RSC for Sustainable Agri-food over the past ten years, from 2012 to 2021. The search yielded 635 papers, with 300 from ScienceDirect, 171 from Scopus, and 164 from Google Scholar. **Table 1** shows the following search string.

Table 1 Search strings used in each of the databases

Database	Keyword with string	Search
Google Scholar	Risk AND "management" AND "in" AND" reverse" AND "supply" AND "chain"	100
	"sustainable" AND "Reverse" AND "Supply" AND "Chain" AND "agri-food"	64
Scopus	"Risk" AND "management" AND "in" AND" reverse" AND "supply" AND "chain"	137

Database	Keyword with string	Search
	"sustainable" AND "agri-food"	34
ScienceDirect	"Reverse" AND 'Supply' AND "Chain" OR "reverse" AND "logistics" OR "closed" AND "loop" AND "supply" AND "chain" AND "risk" AND "management"	300
Total		**635**

2.2 Paper selection and assessment

The previously mentioned search strings were utilized across three scientific databases, identifying 635 full-text publications. These publications were then subjected to a well-structured screening method for evaluation. The steps involved in data collection and the subsequent selection process are shown in **Figure 1.**

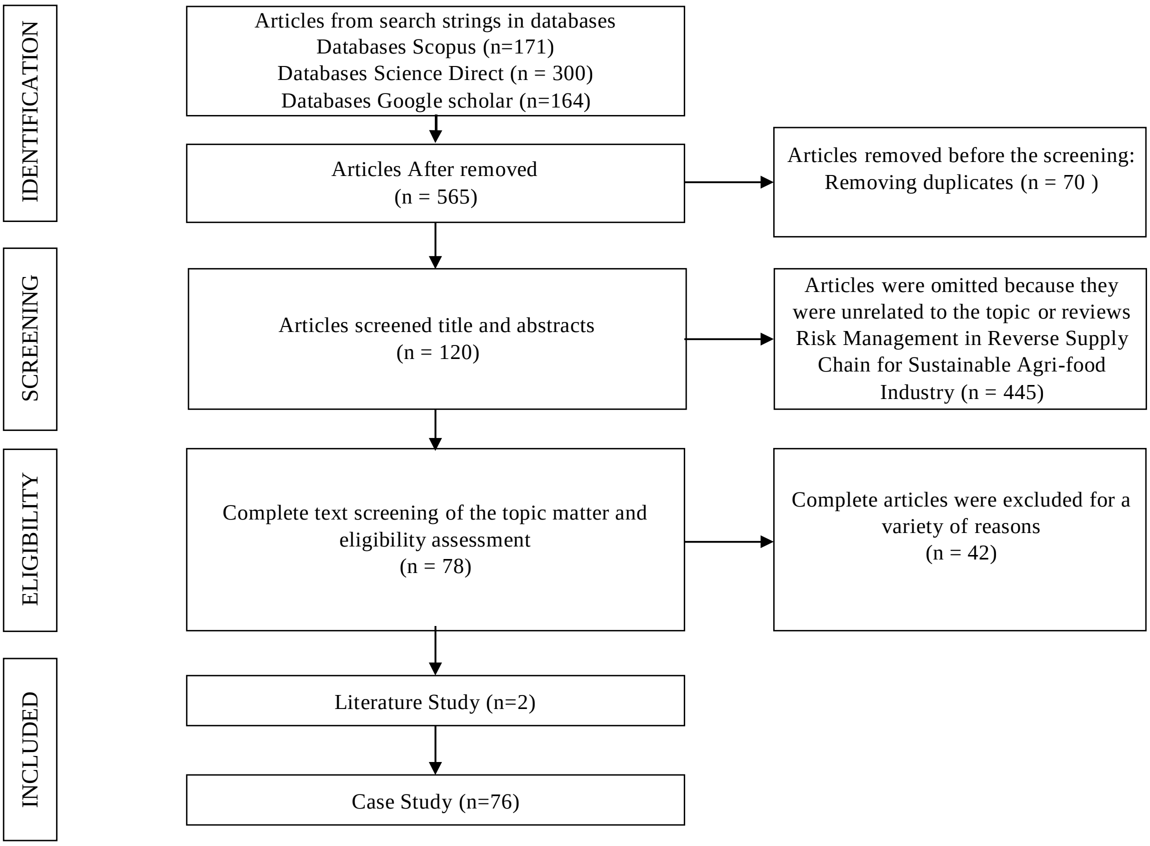

Figure 1 Data collection and selection process using PRISMA protocol
From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372: n71. doi: 10.1136/bmj. n71

3. ANALYSIS AND SYNTHESIS

Given the broad scope of discussions related to RSC (Responsible Supply Chain), it was necessary to employ clustering techniques. Based on the literature review findings, the discussions were categorized into four primary groups, namely Agri-food RSC, RSC Risk, Risk Management, and Sustainability of RSC. These groups are visually represented in **Figure 2.** The industrial area that is the topic of discussion in the RSC can be seen in **Figure 3.**

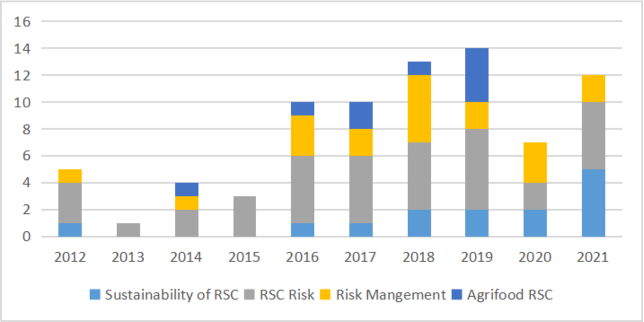

Figure 2 Temporal distribution of the articles

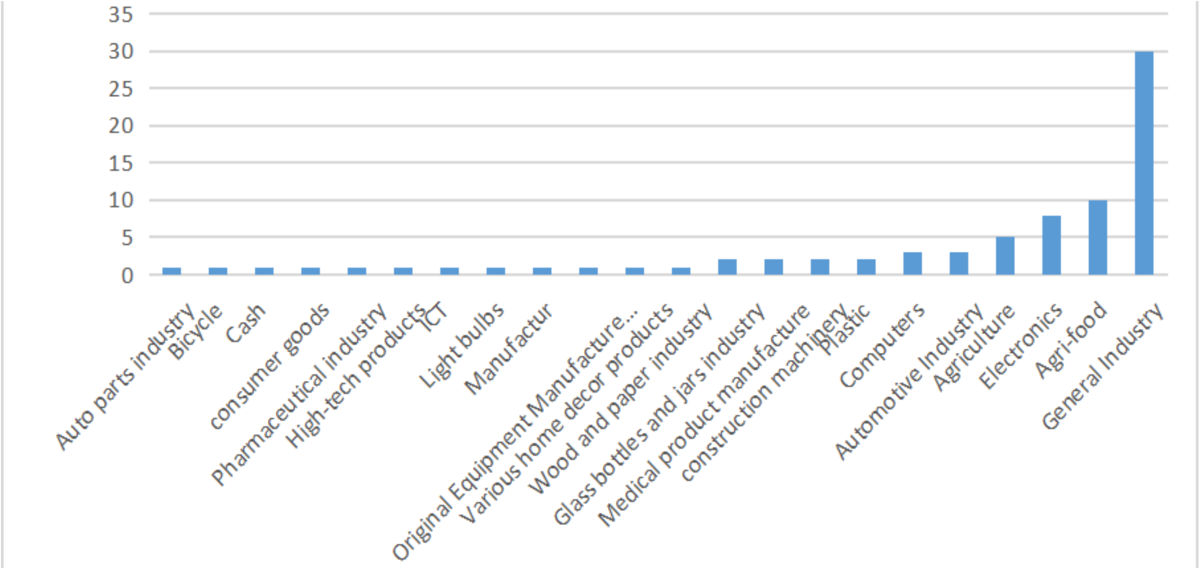

Figure 3 Industrial RSC area

From the graph in **Figure 3**, ten articles discuss RSC in agri-food, and five discuss RSC in agriculture. Some RSC research discusses more in general industrial areas.

3.1 Agri-food RSC

The numerous challenges faced by stakeholders when implementing Reverse Logistics (RL) in the food industry are shown in **Table 2**. One significant challenge in RL activities within this industry is the need for fast and efficient logistics operations to ensure the security of food products and preserve the shelf life of agricultural goods (Vlachos, 2014).

Each year, a significant volume of organic waste is buried or incinerated, resulting in environmental challenges and additional transportation costs. According to Cheraghalipour *et al*. (2018), converting organic waste into fertilizer is one possible approach to address these issues. In the case of CLSC (Closed-Loop Supply Chain) for citrus fruit, any damaged fruit is treated as organic waste and promptly returned to the fertilizer manufacturing center for further processing into organic fertilizer (Roghanian & Cheraghalipour, 2019).

The CLSC (Closed-Loop Supply Chain) network faces specific issues when dealing with perishable foods like milk. These challenges stem from the unpredictability and the varying quality of the returned rate and goods (Yavari & Geraeli, 2019). Failure to address these conditions promptly can lead to environmental pollution. Therefore, it is crucial to develop a robust CLSC network model (Yavari & Zaker, 2019).

Table 2 Agri-food RSC

Authors	Scope	Year	Method/ approach
(Cheraghalipoura *et al*., 2018)	Optimization for citrus CLSC	2018	Metaheuristic
(Roghanian and Cheraghalipour, 2019)	Optimization for citrus CLSC considering CO2 emissions	2019	Metaheuristic
(Yavari and Geraeli, 2019)	Green CLSC network architecture for perishable goods: robust optimization	2019	Robust-MILP
(Yavari and Zaker, 2019)	constructing a robust green CLSC for perishable goods in a disruptive environment	2019	MILP (mixed-integer linear programming)
(Banasik *et al*., 2017)	CLSC in agricultural mushroom	2017	MILP
(Noor *et al*., 2016)	RL in food industries	2016	Empirical Study
(Vlachos, 2014)	the product life cycle of RL food	2014	survey

3.2 RSC Risk

One of the risks encountered in RSC (Reverse Supply Chain) activities is the potential decline in product value within a specified timeframe (Moubed *et al*., 2021). Furthermore, a financial risk is involved in the planning and design of CLSC (Closed-Loop Supply Chain) operations.

In the process of determining the location, capacity size, and production quantity in the CLSC (Closed-Loop Supply Chain) network, it is essential to consider the risks associated with uncertain demand and unpredictable product returns in terms of both quantity and quality (Biçe & Batun, 2021). Furthermore, **Table 3** shows several other risks that arise during RSC activities.

Table 3 RSC risks

No	**Authors**	**Network Type**	**Type of Risk**																				**Solution approach**
			Uncertainty					**Pd**	**DTP**	**FS**	**Pr**	**I**	**O**	**Tp**	**M**	**Financial**		**Tc**	**T**	**HR**	**DP**	**E**	
			D	**C**	**QRP**	**Q**	**S**									**C**	**P**						
1	(Asim *et al*, 2019)	CLSC	*				*	*						*					*				Fuzzy
2	(Moubed *et al.*, 2021)	CLSC							*														System Dynamic
3	(Zhang *et al.*, 2021)	CLSC					*						*										DOA and MINLP
4	(Polo et al., 2019)	CLSC	*													*							MINLP
5	(Biçe and Batun, 2021)	CLSC	*		*	*																	Two stage Stochastic MIP
6	(Shekarian *et al.*, 2021)	CLSC			*												*					*	Game Theory
7	(Zhou et al., 2017)	CLSC			*							*							*				System dynamic
8	(Wang Han *et.al.*, 2019)	CLSC			*			*							*								Mathematic model
9	(Mohajeri and Fallah, 2016)	CLSC	*	*	*																	*	Fuzzy Mathematics
10	(Cardoso *et al.*, 2016)	CLSC	*													*							MILP
11	(Almar aj and Trafalis, 2019)	CLSC				*																	Robust MILP
12	(Vahda ni and Ahmadzadeh, 2019)	CLSC										*					*						Metaheuristic
13	(Ma *et al.*, 2019)	CLSC																				*	Mathematic model
14	(Amin and Zhang, 2013)	CLSC	*				*									*							Stochastic MILP
15	(Zeball os *et al.*, 2018)	CLSC			*	*																	two stage Stochastic MILP
16	(Maiti and Giri, 2015)	CLSC				*																	Game Theory
17	(Soleimani and Govindan, 2014)	RL			*												*						Two-stage Stochastic MILP
18	(Alumur *et al.*, 2012)	RL		*																		*	MILP
19	(Govin dan and Bouzon, 2018)	RL													*	*		*					Literature review
20	(Gooran *et al.*, 2018)	RL	*		*	*																	Metaheuristic
21	(Chileshe *et al.*, 2015)	Rl			*								*			*							Statistic
22	(Yu and Solvang, 2016)	RL	*											*		*							MILP
23	(Jabbarzadeh *et al.*, 2018)	CLSC					*					*	*	*								*	Heuristic
24	(Asl-Najafi *et al.*, 2015)	CLSC											*										Metaheuristic
25	(Paydar *et al.*, 2017)	CLSC			*															*			Robust MILP

No	**Authors**	**Network Type**	**Type of Risk**																				**Solution approach**
			Uncertainty					**Pd**	**DTP**	**FS**	**Pr**	**I**	**O**	**Tp**	**M**	**Financial**		**Tc**	**T**	**HR**	**DP**	**E**	
			D	**C**	**QRP**	**Q**	**S**									**C**	**P**						
26	(Jindal and Sangwan, 2014)	CLSC	*		*	*										*							Fuzzy MILP
27	(Enteza minia *et al.*, 2017)	CLSC	*					*								*						*	Robust MILP
28	(Han *et al.*, 2016)	CLSC			*		*						*			*							Game Theory
29	(Xiao *et al*., 2012)	CLSC					*	*				*		*				*		*	*	*	Fuzzy Mathematics
30	(Heydari and Ghasemi, 2018)	RSC		*	*																		Mathematic model
31	(FazliKhalaf and Hamidieh, 2017)	CLSC	*	*												*							Robust Stochastic
32	(Lundin, 2012)	CLSC												*		*							Network flow modeling
33	(Papen and Amin, 2019)	CLSC				*													*			*	MILP
34	(Bakhshi & Heydari, 2023)	RSC	*	*																			Game Stackelberg
35	(Rezaei, *et al*., 2020)	CLSC	*				*																Two-stage Stochastic
36	(Sun *et al*., 2019)	RSC			*				*					*		*			*				Mathematic model
38	(Hatefi and Jolai, 2014)	RL	*		*	*																	Robust MILP
39	**This research**	**RSC**	*		*	*	*			*	*			*		*		*				*	**HIDSS**

D: demand, C: Capacity; QRP: Quantity return product; Q: Quality return product, S : Supply, Pd : Production, DTP : deteriorated products, FS : food safety, Pr : Processing, I : Inventory, O : Operational, Tp : Transportation, M : Marketing, C : Cost, P : Price, Tc : Technology, T : Time, HR : Human Resources, DP: Data Processing, E : environment

3.3 Risk Management

Table 1 shows an overview of risk management in RSC (Reverse Supply Chain) activities, as documented in various literature sources. Senthil *et al*. (2018) stated that RL (Reverse Logistics) risk management starts with the identification of different risks. These risks are then compiled and prioritized based on their magnitude of potential losses and probabilities of occurrence. It was recommended to address the risks with higher probabilities and significant losses first, while those with lower probabilities and losses can be handled subsequently (Lahane & Kant, 2021).

Managing uncertainty in a CLSC (Closed-Loop Supply Chain) poses a significant challenge for managers. It requires effectively coordinating the forward and backward flow of the supply chain while navigating uncertainties in demand, production costs, and product returns (Baptista *et al*., 2018). According to He (2017), supply uncertainty typically arises in RSC activities, whereas demand manifests in the forwarding supply chain. Regarding site selection and CLSC allocation, risk management should focus on two key aspects, namely the non-deterministic nature of demand and price for new and returned products and the optimization of profits (Soleimani *et al*., 2014).

Table 1 Risk management

Authors	Scope	Year	Method/Approach
(Senthil *et al*.,2018)	Risk assessment and prioritization in a RL network	2018	AHP - Fuzzy TOPSIS, AHP - PROMETHEE, AHP-Digraph matrix
(He, 2017)	Supply risk sharing in a CLSC	2017	Game Theory
(Baptista *et al*., 2019)	Risk management for the issue with CLSC design	2019	Time Stochastic Dominance (TSD
(Hosseini-Motlagh *et al*., 2020)	Management of collection disruptions in CLSC	2020	Game Theory
(Sirisawat and Kiatcharoenpol, 2018)	Prioritizing solutions for RL constraints	2018	Fuzzy AHP - TOPSIS
(Lahane and Kant, 2021)	Solutions for reducing the risks of a circular supply chain	2021	Pythagorean fuzzy AHP-VIKOR
(Wang Han *et al*., 2019)	RL Demand Matching	2018	AHP-Entropy Weight (EW)
(Zhao and Zhu, 2018)	a remanufacturing supply chain strategy for market fluctuations	2018	Mean-Variance
(L J Zeballos and Me, 2016)	Risk Management in Product Design and Closed-Loop Supply Chain Structure	2016	Two-stage stochastic MILP
(García-Sánchez, Guerrero-Villegas, & Aguilera-Caracuel, 2019)	What Are the Benefits of Technological Skills for RL	2019	Regression multivariate
(Chakraborty *et al.,* 2016)	Creating a causal model to assess the key difficulties in RSC implementation	2016	Fuzzy set theory, DEMATEL, ANP
(Morgan *et al*., 2016)	The impact of collaboration and information technology on developing a RL competency	2016	Structural equation modeling
(Soleimani *et al.,* 2014)	Designing a CLSC network with risk measures in mind	2014	mixed-integer two-stage stochastic programming model
(Prakash *et al.,* 2017)	Risk evaluation and mitigation in the SC for perishable foods	2017	ISM, RPN, and RMN
(Paksoy *et al*., 2012)	Risk management in a green supply chain network	2012	Fuzzy AHP and fuzzy TOPSIS
(Ke *et al.,* 2018)	In an uncertain CLSC, competitive pricing and remanufacturing are a challenge.	2018	Game theory
(Kumar *et al.,* 2021)	Determine the obstacles the agriculture SC faces in adopting Industry 4.0 and the circular economy.	2021	ISM ANP
(Bogataj *et al.,* 2021)	Meat supply chain risk mitigation using redirection possibilities	2020	MRP
(Panjehfouladgaran and Lim, 2020)	Risk management in RL	2020	Clustering by Self-organizing map
(Wang Wenbin, *et al.*, 2019)	Sharing collecting duties in a multi-tiered CLSC	2019	Game theory

3.4 Sustainability of RSC

Sustainability has emerged as a crucial concern in community development, as shown in **Table 2**. The research on RSC (Reverse Supply Chain) addresses several complex issues related to sustainability, encompassing economic, social, and environmental improvements. These efforts focus on preventing ecological harm from waste, reducing its generation, and maximizing the value derived from such unwanted substances (Gholizadeh et al., 2021) (Gholizadeh *et al*., 2021). Effective utilization of resources plays a vital role in logistics network design, necessitating efficient management across all facilities (Moheb-Alizadeh *et al*., 2021).

The planning of RL (Reverse Logistics) systems is more intricate than that of forwarding supply chains due to the uncertainties associated with reverse goods flow, fluctuating product quality, and price changes of remanufactured items (Yu and Solvang, 2018). The research findings indicate that an increase in environmental criteria leads to a decrease in the profitability of an RL system. Additionally, Yu and Solvang (2020) have developed a decision-making model for closed SC (Supply Chain) network design that optimizes economic growth, resource utilization, and sustainability.

Table 2 Sustainability of RSC

Authors	Scope	Year	Method/Approach
(Gholizadeh *et al.*, 2021)	The dairy industry's sustainable CLSC	2021	Robust-MILP
(Zhen *et al.*, 2019)	Designing a sustainable and environmentally friendly CLSC network in the face of uncertainty	2019	Stochastic-MILP
(Moheb-Alizadeh, *et al.*, 2021)	CLSC network design that is both efficient and sustainable	2021	Stochastic-MINLP
(Khorshidvand *et al.*, 2021)	A hybrid modeling approach for a sustainable and green CLSC	2021	Robust-MILP
(Yu and Solvang, 2020)	Designing sustainable CLSC network flexibility under uncertainty	2020	Fuzzy Stochastic Multi-Objective Mathematical Model (F-SMOMM)
(Taleizadeh *et al.*, 2019)	Modeling and resolution of a sustainable CLSC problem involving pricing choices and discounts for returned goods	2019	Fuzzy mixed integer optimization model (F-MIOM)
(Yu and Solvang, 2018)	Designing a sustainable RL network with variable capacity in an uncertain environment	2018	Stochastic Multi objective mixed integer programming S-MOMIP
(Lee *et al.*, 2012)	Managing RL to improve industrial marketing's sustainability	2012	Literature review
(Govindan *et al.*, 2016)	Network design for sustainable RL	2016	Fuzzy Multi-Objective Particle Swarm Optimization (F-MOPSO)
(Feitó-Cespón *et al.*, 2017)	Redesigning a sustainable RSC in the face of uncertainty	2017	Stochastic Multi-Objective Mixed Integer Non-Linear Problem (SMO-MINLP)
(Usama and Ramish, 2020)	A sustainable RL system based on RFID	2020	Literature review
Salehi-amri *et al.*, 2021)	Establishing a sustainable CLSC network for the Walnut industry	2021	MILP
(Adams *et al.*, 2021)	Developing food manufacturing operations and SC that are sustainable	2021	SLR
Mangla *et al.*, 2018)	Enablers for agri-food SC sustainability initiatives	2018	ISM and Fuzzy DEMATEL

Methods and approach for Risk Management of RSC and sustainable agri-food industry.

3.4.1 Methods and Approaches for RSC Risk Management

Preliminary research adopted diverse approaches to tackle risk reduction in RSC (Reverse Supply Chain) activities. Their focus lies in optimizing RSC by specifically addressing the risks associated with these activities. Hybrid multi-criteria decision-making (Hybrid-MCDM) methods are employed in RSC risk management, including approaches such as ANP, AHP Fuzzy TOPSIS, AHP PROMETHEE, AHP Digraph matrix, fuzzy VIKOR, Interpretive Structural Model (ISM), and ISM-ANP. Several research employed the MCDCM (Multi-Criteria Decision-Making) approach to identify, rank, and mitigate risks in RSC, prioritizing them accordingly (Sirisawat & Kiatcharoenpol, 2018). An overview of the applied approaches and methods is shown in **Table 3** and **Table 4**.

Preliminary research employed diverse methodologies and approaches to optimize RSC (Reverse Supply Chain) management. These encompassed mathematical models (Wang Han *et al.*, 2019), game theory (Shekarian *et al.*, 2021), stochastic methods (Baptista *et al.*, 2018), MILP (Mixed-Integer Linear Programming) in conjunction with other techniques (Cardoso *et al.*, 2016; Biçe & Batun, 2021; Jindal & Sangwan, 2014), as well as MINLP (Mixed-Integer Nonlinear Programming) combined with other procedures (Polo *et al.*, 2019). Furthermore, in subsequent developments, heuristic approaches and metaheuristic algorithms are utilized for CLSC/RL/RSC risk management, aiming to achieve near-optimal results (Vahdani & Ahmadzadeh, 2019). Gooran *et al.* (2018) proposed a GA (Genetic Algorithm) approach along with Monte Carlo simulation, while Asl-Najafi *et al.* (2015) designed a method that addresses inventory risk by combining MOPSO (Multi-Objective Particle Swarm Optimization) with the Non-Dominated Sorting Genetic Algorithm (NSGA).

3.4.2 Methods and Approach for Sustainability of RSC

Table 5 summarizes the different methods used in designing and developing RSC sustainability models in the agro-industry. Existing literature primarily adopted an optimization model approach to address RSC sustainability in this sector. Some researchers have utilized and integrated the MILP method with other techniques in their RSC sustainability models (Gholizadeh *et al.*, 2021). Other approaches employed include the stochastic MINLP technique (Moheb-Alizadeh *et al.*, 2021), S-MIOMP (Yu &

Solvang, 2018), F-SMOMM (Yu & Solvang, 2020), F-MIOM (Taleizadeh *et al.*, 2019), F-MOPSO (Govindan *et al.*, 2016), SMO-MINLP (Feitó-Cespón *et al.*, 2017) and ISM - fuzzy DEMATEL (Mangla *et al.*, 2018).

4. RESULT AND DISCUSSION

4.1 Research Gap

Figure 4 shows that extensive research has been conducted by numerous scholars in the field of RSC (Robotics and Smart Control) and RL (Robotics and Automation). Nevertheless, further exploration is required in terms of investigating risks, specifically within the agri-food industry.

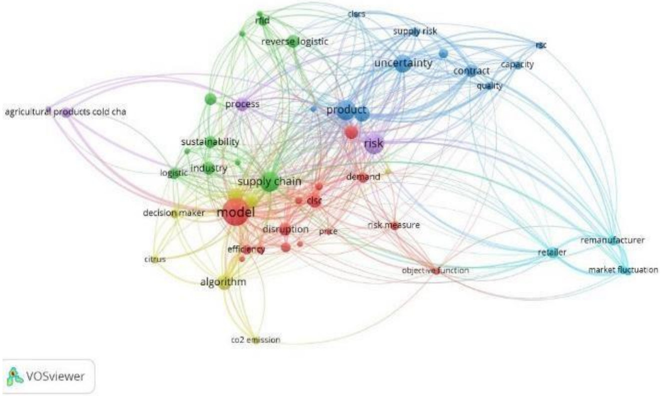

Figure 1 Keyword reference network visualization

By analyzing the VOSviewer mapping interaction results shown in **Figure 5**, it is evident that research on RSC risk pertaining to remanufacturer activities is closely linked to threats involving product quality, capacity, demand, and process. Consequently, there is a need to assess and devise RSC risk management models. Referring to the visualization of research novelty in **Figure 6** investigations on supply chain models and risks, including their measurement, have been explored prior to reviews on RSC. It is important to note that the research on sustainability is relatively new.

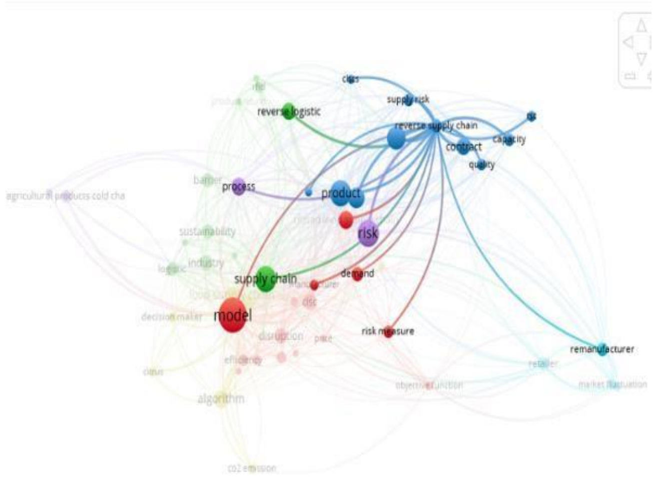

Figure 2 Visualization of the relationship between RSCA risk and other topics

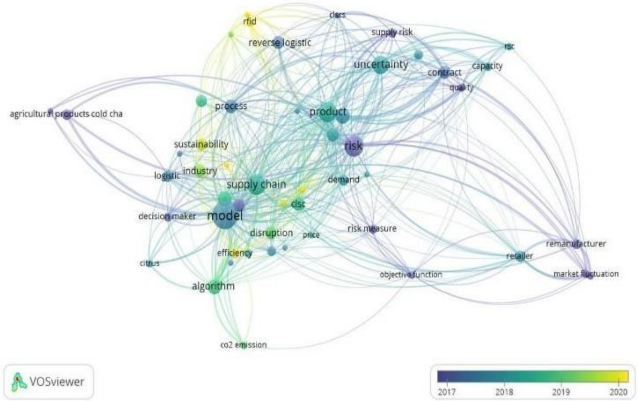

Figure 3 Visualization of keyword reference novelty

The analysis of **Figure 6** shows that significant research efforts have been devoted to the model, product supply chain, and risk. However, observations reveal that topics related to RSC (Reverse Supply Chain) sustainability have relatively smaller nodes and densities, indicating a lack of extensive research in these areas. There is a need for further investigation of risk assessment and management in RSC activities, particularly within the context of sustainable agro-industry.

The risks associated with the RSC Agri-food Industry differ from those found in other sectors, such as electronic products, plastics, and manufacturing industries. The literature review highlights that multiple risks are frequently encountered in RSC activities, encompassing both internal and external factors (**Table 3**).

Based on **Figure 7** process risk is a significant factor frequently overlooked in RSC activities. It is closely linked to the uncertainty surrounding the quantity and quality of returned goods (Zeballos L. J *et al.*, 2018). Supply and demand uncertainties also contribute to process risk, particularly in relation to reprocessing or remanufacturing technologies (Zhao & Zhu, 2018). Issues associated with information systems and flow can further lead to delays in the supply and demand of RSC products (Kazemi *et al.*, 2018). In the agri-food sector, ensuring food safety is of utmost importance (Zupaniec *et al.*, 2022). Consequently, the remanufacturing procedure must be supported by hygienic practices, appropriate technologies, and safety measures to guarantee the reprocessing of new products.

In order to bridge the research gap mentioned earlier, it is crucial to address the various aspects of RSC risk management within the agri-food industry. These aspects include process risk, encompassing supply and demand uncertainties, product damage, uncertainties associated with the quantity and quality of returned products, transportation, as well as financial and environmental factors. Effective management and mitigation of these risks are essential to ensure the smooth functioning of RSC activities. In order to achieve this, supportive tools such as reprocessing, and information technologies are required to optimize RSC operations in the agro-industry as well as produce safe and value-added products. It is imperative to compile and prioritize the threats associated with RSC, followed by implementing risk mitigation actions based on their priorities (Senthil *et al.*, 2018).

Sustainability has emerged as a prominent public concern in RSC, encompassing economic, social, and environmental improvements. This entail preventing ecological damage resulting from waste, reducing its production, and exploring opportunities to enhance the value through research. While numerous research has examined the sustainability of RSC, there is a noticeable dearth of research specifically addressing this issue in the agri-food industry.

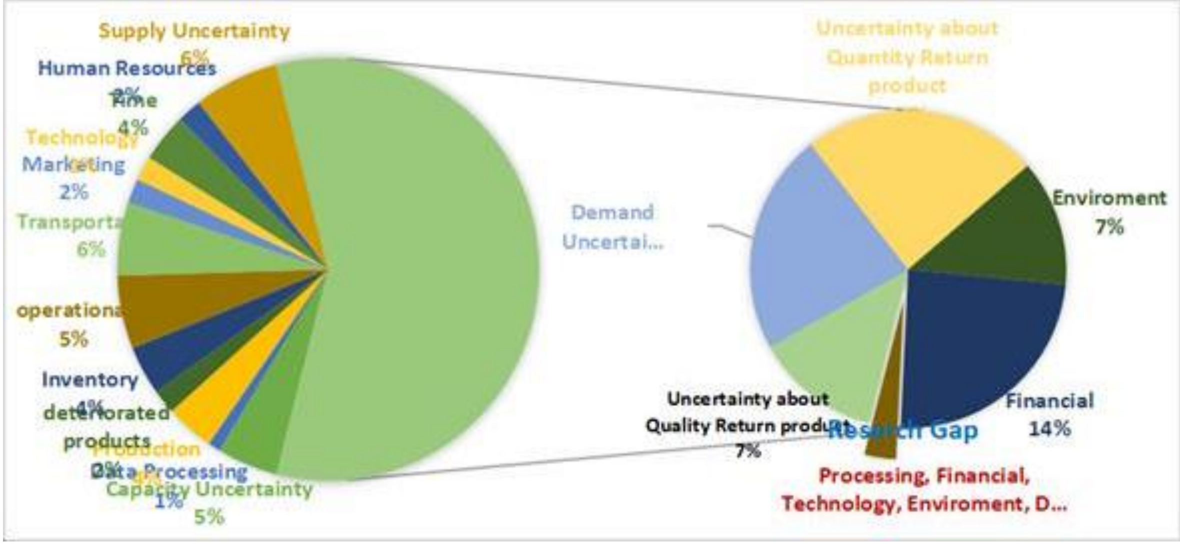

Figure 4 Research gap in the risk management of RSC

Apart from addressing the research gaps related to RSC risk and sustainability in the agro-industry, it is essential to examine the methodologies utilized and identify areas for further investigation. Existing literature reported that RSC risk management was carried out using a hybrid MCDM (Multi-Criteria Decision Making) method involving a combination of AHP (Analytic Hierarchy Process) and Fuzzy-TOPSIS-PROMETHE (Senthil *et al.*, 2018). However, this method does not directly prioritize risks and requires additional steps to obtain a rating graph matrix. In order to advance future research, the determination of risk priority was accomplished using the following approaches interpretive structural modeling (ISM), ISM-ANP (ISM-Analytic Network Process) combination (Kumar *et al.*, 2021), or the integration of ISM Fuzzy Dematel (Mangla *et al.*, 2018).

The House of Risk (HOR) methodology combines FMEA (Failure Mode and Effects Analysis) with the House of Quality (HOQ) model to prioritize risks effectively. By employing HOR, decision-makers can identify the most critical risks that require mitigation to reduce the potential harm stemming from the identified sources (Pujawan & Geraldine, 2009). This methodology incorporates the ARPj (Aggregate Risk Potential of risk agent j) value to assist in determining risk priorities. Additionally, the ISM (Interpretive Structural Modeling) technique was employed to map the relationships between risks and identify the primary threats that act as triggers for other associated ones. When making decisions regarding immediate and delayed risk mitigation actions, decision-makers utilize the combination of HOR and ISM techniques while considering budgetary and resource constraints (Nguyen *et al.*, 2018).

A systematic review of research articles (**Figure 8**) shows that the dominant approach used to optimize RSC management is a combination of MILP (Mixed Integer Linear Programming) and other methods. The MILP approach is particularly effective in addressing uncertainty issues by employing a two-stage stochastic framework (Zeballos *et al.*, 2018; Biçe & Batun, 2021). Additionally, fuzzy MILP approaches have been used to tackle uncertainties (Jindal & Sangwan, 2014). These two-stage stochastic MILP and fuzzy MILP models provide optimal solutions for risk management while considering uncertainty. These approaches are limited in their ability to adapt to changes over multiple periods. Metaheuristic approaches such as GA (Genetic Algorithm), NSGA II (Non-dominated Sorting Genetic Algorithm II), and MOPSO (Multi-objective Particle Swarm Optimization) is used to design optimization models for RSC risk management while considering uncertainty (Jabbarzadeh *et al.*, 2018; Vahdani & Ahmadzadeh, 2019). This research aims to develop a comprehensive optimization model for RSC management, considering multi-purpose and multi-period aspects, as well as supply and demand uncertainties and reservations associated with the quantity and quality of returned goods. The proposed model integrates the Hybrid Fuzzy MILP approach with NSGA-II.

Daultani *et al.* (2022) used the MINLP (Mixed Integer Non-Linear Programming) approach to develop a sustainable Forward and Reverse Logistics Network Design for new and refurbished products. Meanwhile, Feitó-Cespón *et al.* (2017) focused on constructing a product recycling supply chain using the SMO-MINLP (Sequential Multi-Objective Mixed Integer Non-Linear Programming) method. This approach integrated economic and environmental objectives to determine facility location, material flow, and transport selection. It did not address social implications and neglected important factors such as recycled product prices, production costs, and quality. In order to address these limitations, further research is needed to design an RSC sustainability framework in the agri-food industry. This should involve the inclusion of additional parameters such as price, production costs, and product quality within the economic considerations. The integration of four key sustainability aspects in the agri-food industry, namely financial, social, environmental, and technological elements, can be achieved through the utilization of the Fuzzy-MOPSO (Fuzzy Multi-Objective Particle Swarm Optimization) algorithm (Govindan *et al.*, 2016).

Based on the findings from the research gap analysis shown in **Figure 7** and **Figure 8**. **Figure 8**, it is clear that complex risks characterize the RSC of the sugar palm agro-industry. Therefore, there is a pressing need for a comprehensive approach to managing RSC risks. In order to address this, integrating intelligent decision support systems becomes crucial in designing an effective risk management model. This was accomplished by utilizing a Hybrid Intelligent Decision Support System (HIDSS).

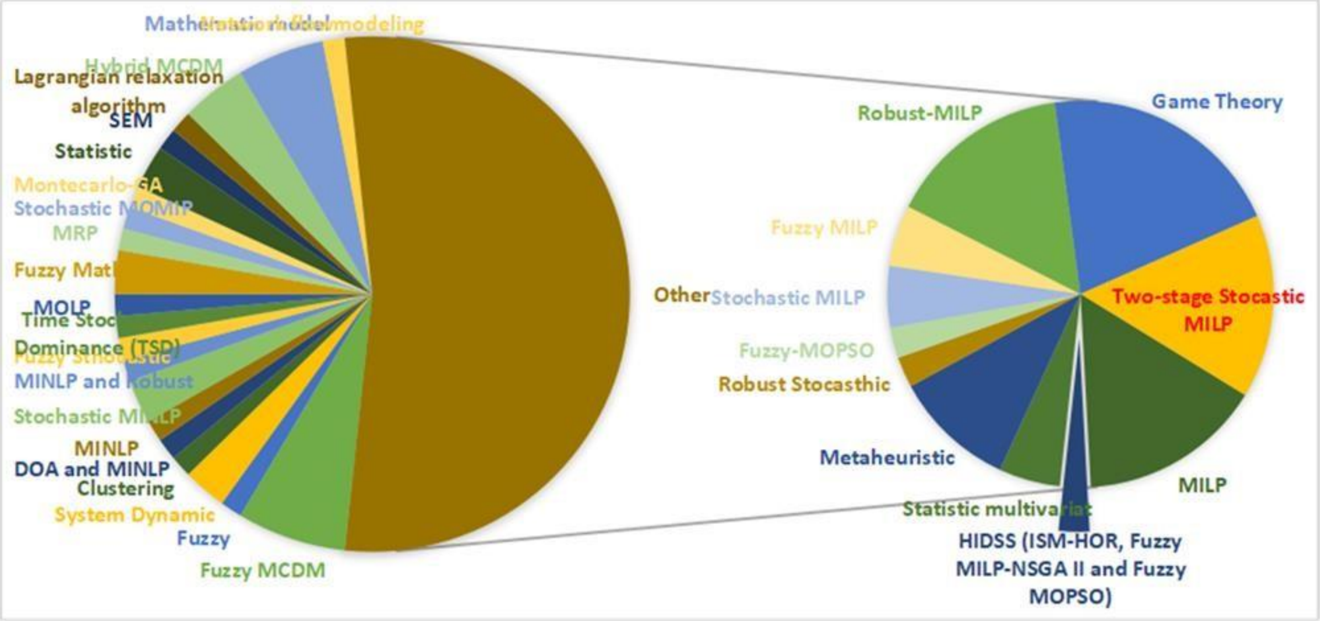

Figure 8 Gap methods in RSC risk management

4.2 Potential Future Research for RSC Risk

Based on a systematic review of research articles, it was reported that approximately 20 risk types occurred in RSC activities. These include supply uncertainty, production, inventory, marketing, transportation, etc, as shown in **Table 4**. Interestingly, one risk that has received comparatively less attention is process risk, as shown in **Figure 8**. Process risk holds significant importance within the context of RSC activities in the agro-industrial sector, as it directly influences the generation of value-added products. In situations where it is executed effectively, the RSC process can potentially enhance the value of the returned products.

However, in-depth research on process risk encountered within RSC activities in the agri-food industry is needed, particularly regarding supply and demand, product quantity and quality uncertainties, transportation, cost, and technological and environmental risks. This research gap presents a valuable opportunity for future investigation. By better understanding the risks associated with RSC activities, decision-makers can proactively implement strategies to manage these threats, ensuring smooth and optimal operations effectively. In order to support such endeavors, the agri-food industry should leverage reprocessing and information technologies, thereby enabling the efficient and safe production of value-added products through RSC activities.

Numerous research has explored the sustainability of the Reverse Supply Chain (RSC) (Feitó-Cespón *et al.*, 2017; Govindan *et al.*, 2016). However, when existing literature was examined, it was evident that limited attention has been given to the sustainability of RSC, specifically within the agri-food industry. The current one primarily evaluates economic, social, and environmental factors pertaining to RSC sustainability. It is crucial to ascertain that the technological component is significant in achieving RSC sustainability in the agri-food sector. This research gap presents an opportunity for further investigations into the sustainability of RSC in the earlier-mentioned industry, particularly in integrating the four key aspects, namely economic, social, environmental, and technological factors. Such comprehensive reviews tend to contribute to developing sustainable Reverse Supply Chain practices in the agri-food industry.

A comprehensive review of research articles has revealed the utilization of multiple methods in sustainable risk management and optimization of the Reverse Supply Chain (RSC). These encompass diverse approaches such as Fuzzy-AHP-TOPSIS-PROMETHEE, ISM Fuzzy-DEMATTEL, MILP (Mixed-Integer Linear Programming), fuzzy-MILP, Robust MILP, Stochastic MILP, Fuzzy-MOPSO, SEM (Structural Equation Modeling), Multivariate Statistics, etc. Each method is selected based on its specific purpose and objectives regarding this context.

The intricate nature of risks in the reverse supply chain of the agro-industry necessitates a holistic management approach. Integrating intelligent decision support systems is crucial in designing and implementing an effective reverse supply chain risk management model. By utilizing the Hybrid Intelligent Decision Support System (HIDSS), the sustainable agri-food industry can effectively mitigate various risks within the RSC. This approach is different from previous research, wherein in previous research, the risk management approach was carried out partially and not integrated. This approach distinguishes itself from previous research, which often adopted partial and non-integrated risk management approaches. The HIDSS approach encompasses the following components:

1. Prioritizing risks and determining mitigation strategies based on their order of importance using the ISM (Interpretive Structural Modeling) and HOR (House of Quality) methods.
2. Optimizing RSC risk management by addressing supply and demand uncertainties by applying Hybrid Fuzzy-MILP (Mixed-Integer Linear Programming) and NSGA II (Non-dominated Sorting Genetic Algorithm II) methods.
3. Designing the sustainability of the RSC network using the Hybrid Fuzzy-MOPSO (Multi-Objective Particle Swarm Optimization) technique.

The development framework of RSC risk management with respect to the sustainable agri-food industry is shown in **Figure 9** and **Figure 10**. These figures provide an overview of the essential elements and sequential steps involved in establishing robust risk management practices for this sector.

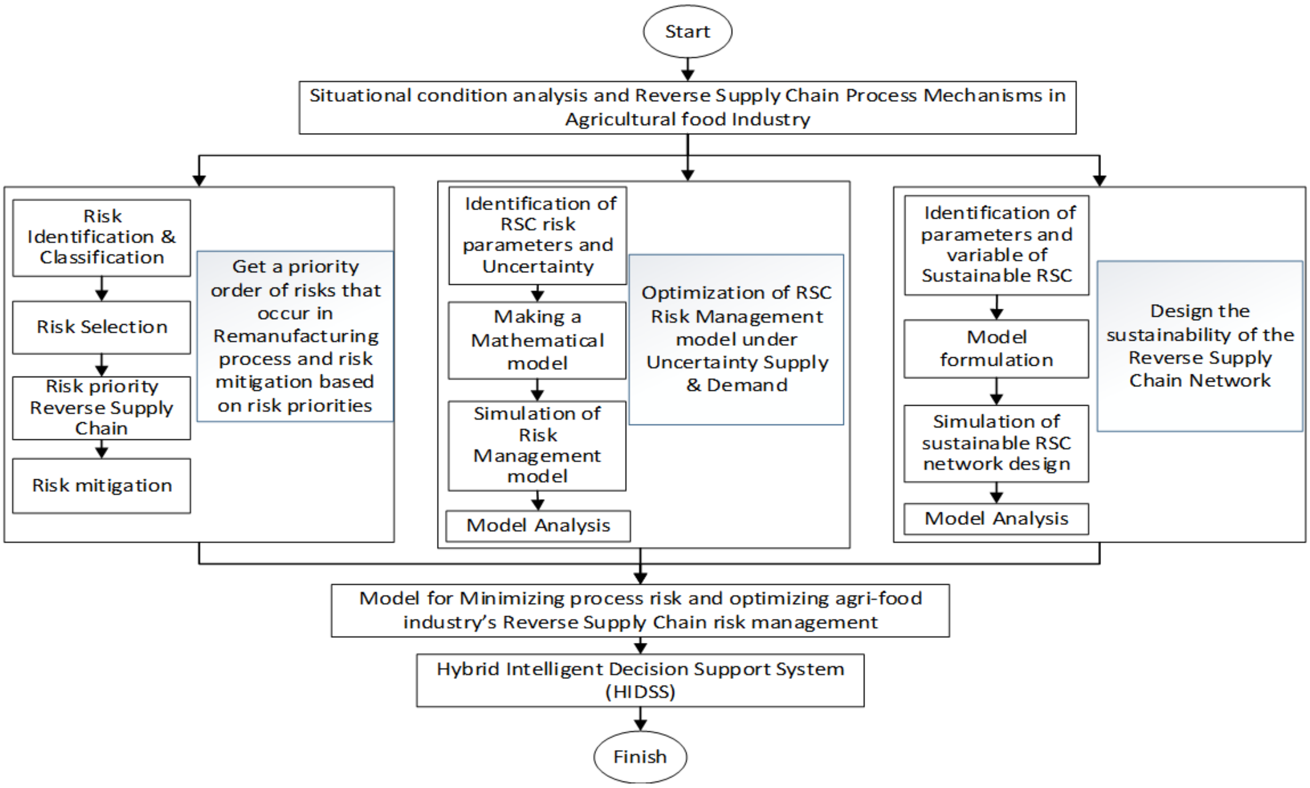

Figure 9 Risk management framework in RSC for the sustainability of agri-food industry

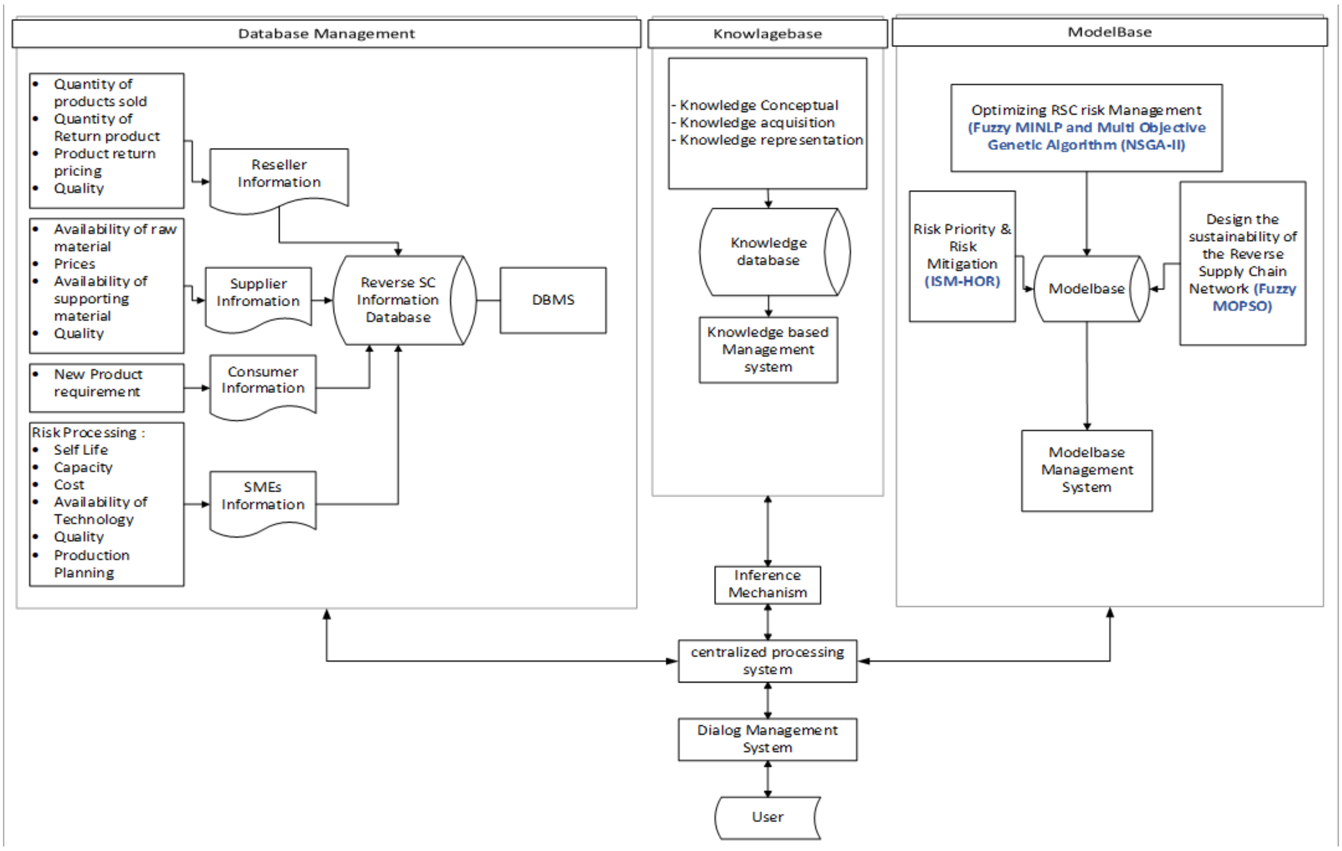

Figure 10 HIDSS for minimizing process risk and optimizing the RSC risk management in agri-food industry

5. CONCLUSIONS AND RECOMMENDATIONS

After reviewing 78 articles, it is evident that RSC risk management for a sustainable agri-food industry can be classified into four main groups. These include Agri-food RSC, RSC Risk, Risk Management, and RSC Sustainability. While some research has addressed RSC risk management, there is still a lack of review specifically on the agri-food industry. A systematic literature review has identified several fundamental aspects of RSC risk management in the agri-food industry, including process risk related to product damage, supply-demand uncertainty, uncertainties in quantity and quality of product returns, transportation, and technology, as well as financial and environmental threats. These aspects warrant further exploration in future research endeavors. Previous research has explored various approaches to mitigate RSC risks, such as utilizing MILP in combination with other methods to address optimization challenges. Given the unpredictability of product returns, demand, and supply within the agri-food RSC context, there is a need for adaptive optimization models that can effectively handle uncertainty. Future research directives should aim to develop integrated RSC risk management practices for this industry while considering its sustainability. The proposed approaches for future investigations include HIDSS utilizing the ISM-HOR method, Fuzzy-MILP-NSGA II, and Fuzzy-MOPSO. These innovative concepts tend to reduce various risks in the agri-food RSC effectively. By mitigating threats in the remanufacturing process and optimizing RSC risk management, it is anticipated that the remanufacturing process can successfully add value to food waste products and deliver high-quality new items that meet market demands.

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