CHAPTER 5

SUSTAINABLE AND REVERSE LOGISTICS RISK MANAGEMENT

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ABSTRACT

The purpose of this chapter is to explore the latest research developments in sustainable and reverse logistics risk management (SRLRM) and provide a comprehensive outline for researchers and practitioners attempting to identify the current state of the art in the field of SRLRM. For this aim, first, the general framework of risk management is introduced in three phases, including risk identification, risk assessment, and risk mitigation. Then, some potential risks associated with sustainable and reverse logistics are determined based on a literature review. Afterward, the popular approaches used for risk analysis are investigated. Finally, the risk mitigation stage in the field of study is discussed. The outputs of this study develop new research avenues for future researchers studying the risks related to SRLs.

Keywords: Sustainable logistics practices, reverse logistics, supply chain management, risk management, logistic management

1. Introduction

Due to the recent global disruptions to supply chains (e.g., the Covid-19 pandemic), the role of supply chain management (SCM) and logistics management has been highlighted in improving the living standards of end-costumers. The management of logistics systems involves inventory management, warehouse management, and transportation (1). Logistics systems link the supply chain entities and facilitate the movement of goods from suppliers to manufacturers and eventually to end customers. This, in turn, affects the overall performance of various organizations in responding to market demand. In addition to the positive socio-economic impacts of logistics systems (e.g., job creation and fulfilling demand for mobility and accessibility), these systems may have several negative effects on the environment and societies (2). Dependency on nonrenewable resources, global warming, occupational health and safety of workers (i.e., injuries and accidents), and congestion are some of the negative socio-environmental impacts of logistics systems. Therefore, managers and decision-makers have focused on the integration of sustainability practices with logistics management (e.g., the development of a traceability system) to create sustainable logistics systems. This can minimize the negative socio-environmental impacts while improving the efficiency and profitability of supply chains (3). The incorporation of the concept of sustainable development into logistics systems to create a sustainable and green logistics procedure is shown in Figure 1 (4).

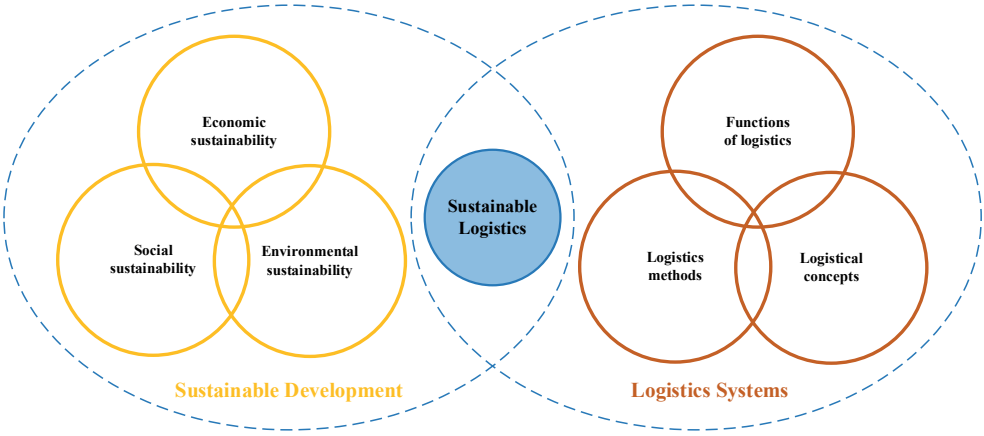


Figure 1. The components of sustainable logistics management

Reverse logistics management is another important topic in the SCM area. Reverse logistics includes all practices and operations related to the upstream movement of products and processes of reusing materials, remanufacturing and disposal of goods at the end-of-life. This type of logistic greatly influences relationships between stakeholders and contribute to the

long-term profitability of supply chain activities by managing the backward currents in the network (5). Sustainable and reverse logistics (SRL) systems help managers get economic benefits and consider the socio-environmental aspects of their activities simultaneously. More precisely, these systems support organizations to establish a socially friendly reputation among stakeholders and protect the environment in addition to achieving a competitive advantage (5,6). Nevertheless, the implementation of SRL systems in various industries is tied to great challenges and barriers (2). One of the main barriers is the complexity of logistics operations and the management of such systems. This complexity results from the need for a substantial level of expertise, infrastructure, and technology (5). Therefore, managers may reluctant to adopt SRL systems due to existing risks posing an economic threat to their businesses (7).

To improve the performance of SRL systems, managers should analyze the risks associated with these systems and implement some mitigation measures to address managerial conservatism. Furthermore, managers are required to control the inherent uncertainty and risk of logistics operations to ensure the success of logistics management and the service delivery process (6). The limited budget to establish the required physical and technological infrastructures for returning residues and managing waste flows, reluctance to change the traditional practices, and lack of government financial incentives can be also considered as the risks affecting the implementation and success of SRL systems (5). Hence, managers need a comprehensive framework to manage and control such risks. A risk management framework can enable managers to prevent severe negative impacts of existing risks on the performance of logistics operations. Sustainable and reverse logistics risk management (SRLRM) aims to identify the potential risks, asses risks based on different factors (e.g., severity and occurrence probability), and define measures to mitigate the adverse impacts of critical risks. Since SRLRM is an emerging field within SCM, this research introduces the risk identification, assessment, and mitigation stages to deal with challenges associated with SRL systems. Then, this study explores the risks affecting the SRL and investigates the approaches developed to analyze these risks. We also discuss the risk mitigation measures proposed to improve the performance of logistics systems.

The rest of this research is organized as follows: In Section 2, the framework of risk management, from risk identification to risk mitigation, focusing on the SRL, is introduced. Section 3 explores the risks associated with SRL systems based on the literature. Then, the analytical and conceptual approaches proposed for risk analysis are investigated in Section 4. Section 5 introduces some risk mitigation measures to improve the performance of logistics systems. The practical and managerial implications of SRLRM are discussed, and research avenue for future researchers is provided in Section 6.

2. Risk management methodology

SRLRM is a comprehensive framework for identifying, assessing, and mitigating the risks associated with SRL systems to guarantee the profitability of supply chains, especially during disruptions. SRLRM aims to manage areas of risk that could adversely influence the success of SRL operations. This section discusses the main SRLRM stages, including risk identification, assessment, and mitigation. The first stage of the SRLRM framework is risk identification. This stage seeks to identify the risk types, risk factors or both (8). Decision-makers can identify the potential risks using conventional techniques (e.g., failure modes and effects analysis) or based on interviews with experienced experts in the field of logistics management. These internal and external can be divided into different categories, such as strategic, tactical and operational risks. In addition to identifying and categorizing the potential risks, the negative consequences of each risk should also be determined in this stage. This can help decision-makers analyze the identified risks and model their relationships more properly in the risk assessment stage.

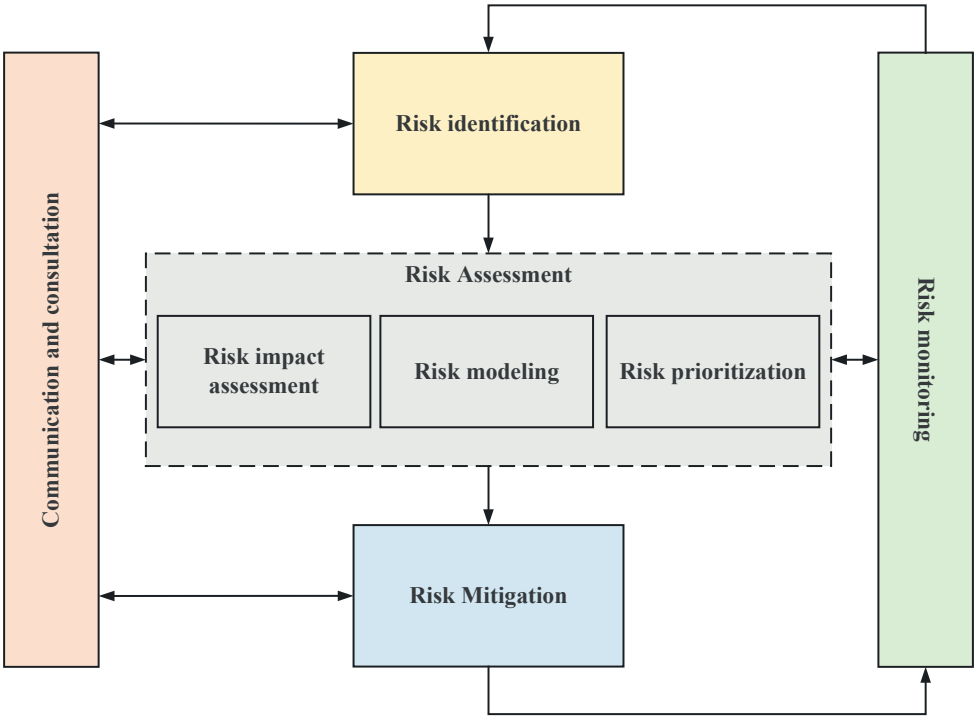


Figure 2. SRLRM framework

Risk assessment is another main pillar of SRLRM to evaluate risks based on their probabilities (6). In fact, risk assessment deals with the probability of an event occurring and its consequences (8). This stage includes risk impact assessment, risk modeling, and risk prioritization to identify critical risks. Several risk assessment methods have been introduced in the literature to analyze the various risks, especially supply chain risks. However, risk assessment methods can be divided into quantitative or qualitative methods. Quantitative methods enable decision-makers to quantify the probability of occurrence and impact of a risk (i.e., severity) based on the recorded data in an organization. On the other hand, qualitative or conceptual risk assessment frameworks focus on the characteristics of risk rather than its probability values. The qualitative risk assessment often employs experts' opinions in the form of linguistic scales to determine the probability of occurrence and impact of a risk. Using linguistic variables for investigating the factors associated with the identified risks can also be beneficial for managers to identify the weaknesses of the systems (9).

After identifying and assessing risks associated with logistics systems, decision-makers should define and implement risk mitigation measures to reduce the adverse impacts of the existing risks (6). Risk mitigation refers to the development of effective mitigation measures to reduce risks and consequently facilitate achieving the determined management goals (e.g., increasing customer satisfaction and profitability). The main aim of the risk mitigation measures can be different and include avoidance, reduction, and transference strategies. However, today's organizations may face various limitations (e.g., budget), and they cannot struggle with all identified risks. Organizations, in this case, should target the most critical risks identified in the risk assessment stage to ensure the success of SRL systems or facilitate the adoption of such systems. More precisely, the mitigation of negative impacts of critical risks may affect other risks, inherently interconnected with these risks. After implementing the risk mitigation measures, managers should also monitor the behaviour of critical or target risks to guarantee performance improvement in the logistics systems.

3. Risk identification in SRLs

It has been stated in the previous sections that the activities of identifying, assessing and mitigating risks are at the center of SRL management. In this section, we will focus on the identification of risk, and the next sections cover assessment and mitigation. Risk identification provides a list of risks that are likely to affect the sustainable and reverse supply chain and, thus, the wider organization (10). When considering risks from a sustainability perspective, it can be seen that in many ways they differ from typical supply chain risks in many ways. Giannakis and Papadopoulos (11) address sustainability-related risks as environmental,

social and financial/economic hazards. For each of these hazard groups, a classification of endogenous (i.e., internal risks arising from the activities of companies along their supply chain) and exogenous (i.e., external risks posed by the interactions of companies with the external environment in which they operate) has been proposed. Regarding the environmental dimension, the risk steering principle is to meet the requirements for the quality of a shared ecosystem. Environmental accidents, natural disasters, pollution, emission of harmful gases, non-conformance to sustainability rules (e.g., unnecessary packaging, unsuitable use of energy, and waste), and water scarcity are the most important risk factors that come to mind initially under the environmental dimension (11). The social dimension refers to the assignment of responsibilities to employees, customers, business partners, governments and communities. Working life-based inequalities (e.g., unfair wages, child labour/forced labour, discrimination, and bad working conditions), unethical treatment of animals, pandemics, and social instability are considered under the social dimension (11). The economic dimension includes the monetary risks brought by the financial environment, the deceptive behaviour of companies and individuals, and the effort for sustainable economic growth. Risk factors such as price fixing accusations, antitrust claims, boycotts, energy price instability and financial crises are also the main risks evaluated under the economic dimension (11).

On the other hand, a comprehensive study on reverse logistics risks (12) revealed 41 different factors. These risk factors are placed in clusters in three main groups: strategic, tactical and operational. The strategic cluster mostly includes the information-oriented aspects of the business and the risks that directly affect the decision-making of top management. This cluster includes 21 risks, such as poor communication, lack of shared goal, poor strategic development, technological change, competitive uncertainty, and corporate social responsibility, that affect an organization's long-term strategic operations. The tactical set consists of 14 risks, such as demand fluctuation, labour instability, and political instability, that affect an organization's medium-term tactical operations. Mostly, inventory and supply management issues are included in this cluster. The operational cluster includes six risks (i.e., financial instability, macroeconomic uncertainty, transportation, security, customer and outsourcing risk) that directly affect daily operations. Any disruption as a result of exposure to such risks has an immediate and direct impact on the performance of reverse logistics systems. Senthil et al. (13) combined a list of nine SRL risk types as follows: environmental, inventory, data managing, time management, managerial, cultural, quantity, outsourcing and distribution risks. In another research by (14), the main risks associated with the operation of SRL are defined under eight items. These include inadequate storage and collection process, lack of a suitable

vehicle for transportation, equipment and communication between the supply chain actors, vehicle routing issues, overstock inventory, and low quality of the residue.

In this context, the methods used to identify risks include risk checklists, taxonomies, risk mapping, subjective evaluation of experts through surveys, interviews, group meetings and the Delphi method, and extensive literature reviews (i.e., content analysis of academic articles, industry reports, and white papers) (10-12). Undoubtedly, the SRLRM process, which struggles with many types and numbers of risks, is very difficult to manage. Different categories can be introduced to focus on the most important types of risk. The standardized triple classification of internal operational risks, risks within the chain, and risks arising from the external environment make it easy for managers to identify risks. Some formal procedures are needed for this identification. The usual way is to divide the chain process into a series of activities, systematically examining each activity in turn and identifying the risks in each. To do this, managers can analyze past events, gather insights or directly analyze operations (10). The risk identification ensures that significant risks of SRL systems are recorded. But problems can always occur. Besides the inherent difficulty of identifying risk, managers may be reluctant to acknowledge that risks exist and must take appropriate action to deal with them. After compiling the most critical risks associated with SRL, managers ensure that they are assessed using logical and scientific methods.

4. SRL risk assessment

In this section, the published papers on SRL risk assessment focusing on their used approaches are analyzed. To evaluate the risks of SRL, there are methods called qualitative, quantitative or semi-quantitative, which are among the risk assessment methods followed by the traditional health and safety perspective. In order to evaluate the risks of SRL, there are methods called qualitative, quantitative or semi-quantitative, which are among the risk assessment methods. It is seen that there are limited studies in academic databases such as Scopus with appropriate key terms (e.g. “sustainable reverse logistics” AND “risk assessment”). However, due to the diversity of the study spectrum, we have determined that the studies in which the risks that occur directly in an SRL system, evaluated in the context of the framework in Figure 2, are limited. In Table 1, we have included some selected focus studies. When these are evaluated, it can be stated that multi-criteria decision making (MCDM), traditional risk analysis techniques such as failure mode and effect analysis (FMEA) and Bayesian network, and fuzzy logic are used.

MCDM is a field that operates on the basis of determining the most appropriate among the options and is frequently used by researchers in risk assessment. It is generally applied

as a combination of two basic stages. The first is the determination of the importance level of the parameters that include the description of the risk. In this part, MCDM methods based on pairwise comparisons such as analytic hierarchy process (AHP), analytic network process (ANP), and best-worst method (BWM) are generally used. The second stage is the stage, where the risk types determined in the SRL process are handled in the light of these parameters, scored with expert opinions, and the risk scores and ranks are determined. At this stage, mostly compromise and outranking-based MCDM methods (e.g., TOPSIS, VIKOR, PROMETHEE, ELECTRE) are used (13, 16-17, 22-23). Fuzzy logic is also frequently used in risk assessment, both to better present the uncertain environment in decision-making and improve the limited flexibility provided by linguistic evaluations expressed in precise numbers (15, 18-21). It can be said that MCDM methods combined with fuzzy logic produce useful solutions compared with traditional risk assessment approaches.

Apart from MCDM, fuzzy logic theory, and traditional approaches, there are different concepts used, especially in the assessment of SRL risks. Among these, it is possible to count optimization-oriented operations research techniques such as linear programming, goal programming, game theory, nonlinear programming and stochastic programming (24). In these models, instead of evaluating the risks, the optimization objectives, mostly economic and environmental objectives, are satisfied with a mathematical model in which the risks will be minimized.

Table 1. Studies and used methods in SRL risk assessment

Study	Focus	Method	Method details
Giannakis and Papadopoulos (11)	Explore sustainability-related supply chain risks	FMEA	A mixed method risk assessment approach including statistical analysis and FMEA
Senthil et al. (13)	Analysis and prioritisation of risks in a reverse logistics network	MCDM	Hybrid AHP-Fuzzy TOPSIS method; Hybrid AHP-PROMETHEE method; Hybrid AHP-Diagraph and Matrix method
Omosa et al. (15)	Reverse logistics supply chain for end-of-life vehicle recycling risk management	Fuzzy set	Fuzzy knowledge representation theory embedded in the risk assessment process that helps to quantify risk ratings
Huizhe and Donglin (16)	Risk assessment of reverse logistics of retailing	MCDM	The unascertained measurement and attribute hierarchy model (AHM) employed to risk assessment of reverse logistics of retail enterprise

Huizhe and Lihua (17)	Effective index of retailing reverse logistics risk factors	MCDM	AHM and index weigh merged
Yan et al. (18)	Retailing reverse logistics risk factors assessment	Fuzzy set	A triangular fuzzy number-based risk assessment approach
Meng (19)	Risk analysis of reverse logistics outsourcing	Fuzzy set	Fuzzy comprehensive analysis method
Zhou et al. (20)	SME reverse logistics outsourcing risk analysis	Fuzzy set	Fuzzy comprehensive evaluation method
Insuasty-Reina et al. (21)	Prioritization of operational risks in a reverse logistics network for the recovery of waste cooking oil	Fuzzy set	Fuzzy quality function deployment
Duran and Zafeirakopoulos (22)	Environmental risk assessment of e-waste	MCDM	ANP, COPRAS
Rostamzadeh et al. (23)	Evaluation of sustainable supply chain risk management	MCDM	TOPSIS, CRITIC
Jayasinghe et al. (25)	Cause and effect relationship risks in reverse logistics supply chains for demolition waste	Bayesian network, Interviews	A mixed method approach (Semi- structured interviews, structured interviews, thematic analysis, and Bayesian belief network)

Another important element in the fuzzy logic integrated MCDM SRL risk assessment studies is the decision-making experts. The fact that their evaluations are stated with fuzzy linguistic expressions, and the formation of a group decision also strengthens the accuracy of the results of the study. Apart from MCDM and fuzzy logic theory, traditional risk assessment approaches such as FMEA and Bayesian networks are also used for assessing SRL risks. Giannakis and Papadopoulos (11) determined the relative importance of a defined set of sustainability-related supply chain risks using FMEA. As a result of their studies, it has been stated that endogenous environmental risks are the main risks. In another study (25), semi-structured and structured interviews were conducted to identify and assess the interdependencies of risks in SRL systems. Data were analyzed using thematic analysis, and a Bayesian network was used to develop a risk model.

5. Risk mitigation for SRL management

Risk mitigation is the final stage of the SRLRM methodology. In this context, managers need to discuss the decisions and actions they will take to deal with the high-scoring risks that emerged in the previous stage. It is necessary to make measures and recommendations for the risks that are less controllable. In the study of Giannakis and Papadopoulos (11), six basic

strategies, including avoid, mitigate, prevent, cooperate, insure, and retain, are mentioned. These measures need to be structured so that at least the SRL system can operate normally or with little disruption, be effective in dealing with risks, allow efficient use of resources, and comply with legal constraints (10). There are several techniques to put such strategies into action. Among them, it is necessary to mention the what-if analysis and cost analysis or cost-benefit analysis (26). In the literature, although not directly for the SRL risk mitigation stage, there are models recommended for the prioritization of control measures in reducing the risks arising from occupational health and safety, especially in the process industries (27). It is important to prioritize these preventive measures and develop models by considering performance, applicability, functionality and integrability, which are the factors that affect the decision process.

6. Conclusion

Logistics systems play a major role in improving customer satisfaction and supply chain network efficiency and, consequently, increasing the profitability of a company. Due to the increasing importance of the sustainability concept in various fields, SRL systems have been created to improve resource utilization, protect the ecological environment, improve social responsibility, and increase the supply chain's profitability simultaneously. However, the success of the implementation of SRL systems in various industries can be challenging because of existing infrastructure requirements and organizational limitations. Therefore, managers should manage risks and barriers associated with SRL systems to improve the performance of such systems. Hence, a comprehensive SRLRM framework can enable managers to deal with potential risks to prevent their negative impacts on the performance of logistics operations. More precisely, SRLRM aims to identify these potential risks, asses risks based on various factors, and propose effective measures to mitigate the adverse impacts of critical risks.

Based on the literature, such risks are identified through checklists, interviews with experts and extensive literature reviews. Furthermore, most existing approaches for SRL risk assessment in the literature are developed based on MCDM techniques and fuzzy sets. To address some shortcomings associated with these frameworks, such as biased comparisons and not considering the interactions among risks, the development of decision support systems based on the advanced versions of MCDM and data analytics techniques can be considered for future research. The SRL mitigation stage can be considered as an intact part, while the definition and prioritization of mitigation measures are of cardinal importance to improve the performance of logistics operations. Accordingly, future researchers can focus on evaluating the effectiveness of the defined risk mitigation measures considering the interactions between

potential risks and the supply chain's objectives. In fact, the adoption of effective risk mitigation strategies can significantly affect the performance of SRL systems to deal with future disruptions.

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