



**POLITECNICO**  
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE  
E DELL'INFORMAZIONE

# Supply Chain Risk Management: A Literature Review, Case Studies, and the Role of Technological Innovation

TESI DI LAUREA MAGISTRALE IN  
MANAGEMENT ENGINEERING  
INGEGNERIA GESTIONALE

Author: **Mattia Meli**

Student ID: 225702

Advisor: Prof. Giovanni Miragliotta

Co-advisor: Nataliia Roskladka, PhD

Academic Year: 2024-25



# Abstract

Risk management has become an essential component of modern business strategy, particularly in the context of increasingly complex and interconnected supply chains. While existing literature extensively discusses the categorization of risks, the key phases of risk management, and the strategies available to mitigate risks, there remains a gap in understanding how companies decide which strategy to adopt in different scenarios. This thesis begins with a comprehensive literature review, analyzing various risk classifications, the structured phases of the risk management process, and the strategic approaches proposed by researchers. Building on this theoretical foundation, the study extends its scope to real-world case studies, identifying the key factors that influence companies' decision-making when selecting a risk management strategy—an aspect previously underexplored in the literature. These factors include geographical location, regulatory environment, technological capabilities, financial constraints, corporate risk tolerance, and supply chain interdependencies. Furthermore, this research investigates the potential risks and corresponding mitigation strategies at different stages of supply chain planning, providing a structured framework for businesses to proactively manage vulnerabilities. Beyond risk prevention, the study also explores how the implementation of risk management strategies transforms a company's supply chain, affecting operational efficiency, supplier relationships, inventory management, and overall resilience. Finally, this thesis examines the role of emerging technologies in reshaping risk management practices. It highlights how innovations such as Artificial Intelligence (AI), Machine Learning, Digital Twins, and Blockchain can be leveraged to enhance risk identification, predictive modeling, and decision-making processes. As businesses strive to navigate an increasingly uncertain global landscape, the integration of these technologies represents a significant opportunity to shift from reactive to proactive risk management, ensuring long-term competitiveness and stability. By combining theoretical insights with empirical analysis, this research provides a holistic perspective on risk management, bridging gaps in the existing literature and offering practical recommendations for organizations aiming to develop more structured, data-driven, and technologically advanced risk management strategies.

**Key-words:** Supply Chain, Risk Management, Technological Innovation



## Abstract in italiano

La gestione del rischio è diventata una componente essenziale della moderna strategia aziendale, in particolare nel contesto di catene di fornitura sempre più complesse e interconnesse. Sebbene la letteratura esistente discuta ampiamente la categorizzazione dei rischi, le fasi chiave della gestione del rischio e le strategie disponibili per mitigare i rischi, rimane una lacuna nella comprensione di come le aziende decidono quale strategia adottare nei diversi scenari. Questa tesi inizia con una revisione completa della letteratura, analizzando varie classificazioni del rischio, le fasi strutturate del processo di gestione del rischio e gli approcci strategici proposti dai ricercatori. Basandosi su queste basi teoriche, lo studio estende il suo ambito a casi di studio del mondo reale, identificando i fattori chiave che influenzano il processo decisionale delle aziende nella scelta di una strategia di gestione del rischio, un aspetto precedentemente sottoesplorato in letteratura. Questi fattori includono la posizione geografica, il contesto normativo, le capacità tecnologiche, i vincoli finanziari, la tolleranza al rischio aziendale e le interdipendenze della catena di fornitura. Inoltre, questa ricerca indaga i potenziali rischi e le corrispondenti strategie di mitigazione nelle diverse fasi della pianificazione della catena di approvvigionamento, fornendo un quadro strutturato affinché le aziende possano gestire in modo proattivo le vulnerabilità. Oltre alla prevenzione del rischio, lo studio esplora anche il modo in cui l'implementazione delle strategie di gestione del rischio trasforma la catena di fornitura di un'azienda, influenzando l'efficienza operativa, le relazioni con i fornitori, la gestione delle scorte e la resilienza complessiva. Infine, questa tesi esamina il ruolo delle tecnologie emergenti nel rimodellare le pratiche di gestione del rischio. Evidenzia come innovazioni come l'intelligenza artificiale (AI), il machine learning, i digital twin e la blockchain possono essere sfruttate per migliorare l'identificazione del rischio, la modellazione predittiva e i processi decisionali. Mentre le aziende si sforzano di navigare in un panorama globale sempre più incerto, l'integrazione di queste tecnologie rappresenta un'opportunità significativa per passare da una gestione del rischio reattiva a quella proattiva, garantendo competitività e stabilità a lungo termine. Combinando approfondimenti teorici con analisi empiriche, questa ricerca fornisce una prospettiva olistica sulla gestione del rischio, colmando le lacune nella letteratura esistente e offrendo raccomandazioni pratiche per le organizzazioni che mirano a sviluppare strategie di gestione del rischio più strutturate, basate sui dati e tecnologicamente avanzate.

**Parole chiave:** Catena di fornitura, Gestione del Rischio, Innovazione Tecnologica







# Contents

<b>Abstract .....</b>	<b>i</b>
<b>Abstract in italiano .....</b>	<b>iii</b>
<b>Contents .....</b>	<b>vii</b>
<b>1 Introduction.....</b>	<b>1</b>
1.1. Importance of SC risk management in the global context and current challenges .....	1
1.2. Research objectives and research question .....	3
1.3. Methodology.....	5
1.4. Summary of results .....	6
<b>2 Literature review.....</b>	<b>7</b>
2.1. Risk categories .....	7
2.1.1. Supply risk .....	7
2.1.2. Demand risk .....	8
2.1.3. Operational risk .....	8
2.1.4. Environmental risk .....	8
2.1.5. Collaboration risk .....	9
2.1.6. Financial risk .....	9
2.1.7. Logistic and security risk .....	9
2.1.8. Strategic risk.....	9
2.1.9. Synthesis of categories.....	10
2.2. Phases of risk management .....	11
2.2.1. Internal environment and objective settings .....	11
2.2.2. Risk identification.....	13
2.2.3. Risk measurement and assessment .....	16
2.2.4. Risk mitigation.....	18
2.2.5. Control and monitoring .....	20
2.3. Risk management strategies.....	23
2.3.1. Avoidance.....	23
2.3.2. Acceptance.....	24
2.3.3. Prevention .....	25
2.3.4. Mitigation.....	26

2.3.5.	Transfer and sharing .....	26
2.4.	Case studies .....	27
2.4.1.	Avoidance .....	27
2.4.2.	Prevention .....	28
2.4.3.	Mitigation.....	30
2.4.4.	Transfer and sharing .....	31
2.4.5.	Acceptance .....	32
2.5.	Decisions factors .....	34
2.5.1.	Geographical area.....	34
2.5.2.	Legislations .....	35
2.5.3.	Technological resources and skills.....	36
2.5.4.	Reputation and cost.....	38
2.5.5.	Risk tolerance.....	39
2.6.	Risk and solutions in the planning process .....	40
2.6.1.	Supply planning .....	40
2.6.2.	Production planning .....	42
2.6.3.	Inventory planning.....	44
2.6.4.	Transportation planning .....	46
2.6.5.	Demand planning.....	47
<b>3</b>	<b>Methodology .....</b>	<b>49</b>
<b>4</b>	<b>Findings .....</b>	<b>53</b>
4.1.	Analysis of the possible impact on the supply chain of the chosen strategy 53	
4.1.1.	Product redesign.....	53
4.1.2.	Logistical and production network redesign .....	55
4.1.3.	Strategic partnership .....	57
4.1.4.	Nearshoring .....	58
4.1.5.	Supply chain digitalization.....	59
4.2.	New technologies and software for supply chain risk management ...	59
<b>5</b>	<b>Conclusions and recommendations .....</b>	<b>63</b>
5.1.	Summary of the main results emerging from the research .....	63
5.2.	Contribution of the thesis.....	66
5.3.	Future researches .....	68
<b>6</b>	<b>References.....</b>	<b>70</b>
<b>Appendix A – Iltom interview .....</b>		<b>75</b>
	AZIENDA .....	75
	ESIGENZA .....	75

ORGANIZZAZIONE E PROCESSO DI RISK MANAGEMENT .....	75
<b>Appendix B – Tecniplast interview .....</b>	<b>77</b>
AZIENDA.....	77
ESIGENZA .....	77
ORGANIZZAZIONE E PROCESSO DI RISK MANAGEMENT .....	77
<b>List of Figures .....</b>	<b>81</b>
<b>List of Tables .....</b>	<b>83</b>
<b>Acknowledgments .....</b>	<b>87</b>



# 1 Introduction

## 1.1. Importance of SC risk management in the global context and current challenges

In the contemporary global economy, supply chains have emerged as a fundamental pillar of business success, playing a pivotal role in ensuring competitiveness, profitability, and resilience. Over the past few decades, the scope and complexity of supply chains have expanded exponentially, driven by factors such as globalization, technological innovation, and evolving consumer demands. These supply chains are no longer isolated networks; they are intricate systems marked by interdependencies between a wide array of actors, both within a single supply chain and across multiple interconnected ones. This increasing scale and interconnection have amplified the challenges of managing them effectively, particularly in an environment where both opportunities and risks are abundant.

Several trends have reshaped the structure and functioning of supply chains. On the one hand, internal operational strategies such as outsourcing, just-in-time inventory management, agile supply chains, and supply base reduction have created avenues for efficiency and cost optimization (Fan & Stevenson, 2018). On the other hand, external forces—including technological advancements, sustainability imperatives, and shifting consumer behaviors—have introduced new dimensions of both opportunity and complexity. While these developments enable companies to innovate and thrive in competitive markets, they also expose organizations to an expanding array of risks. The broader the scope of a supply chain and the greater its interdependence with external factors, the more vulnerable it becomes to disruptions that can compromise its stability and resilience.

The nature of these risks is diverse, unpredictable, and often severe. Natural disasters, pandemics, geopolitical conflicts, and economic downturns are just a few examples of disruptive events that can ripple through supply chains, causing widespread consequences. For instance, the 2011 tsunami in Japan devastated supply networks for numerous industries, most notably the automotive sector, where flooding of critical warehouses disrupted production timelines. Similarly, the COVID-19 pandemic led to unprecedented global lockdowns, halting production in many sectors and sharply reducing demand for various goods, pushing countless companies toward insolvency. More recently, the ongoing conflict between Russia and Ukraine has disrupted the

flow of essential resources like Russian natural gas and Ukrainian grain, creating bottlenecks in global trade and challenging companies to navigate heightened uncertainty.

These examples underscore a pressing reality: the ability to anticipate, prepare for, and respond to risks is no longer a peripheral consideration but a central strategic priority for businesses. Modern companies must adopt a proactive approach to risk management, one that addresses not only traditional risks but also emerging threats that may be harder to predict. A robust and integrated risk management system is essential to navigate the volatile and interconnected global landscape. Such a system must be capable of identifying vulnerabilities, mitigating their impact, and adapting dynamically to new challenges as they arise.

However, despite the growing complexity and frequency of supply chain disruptions, only a limited number of companies have implemented structured and comprehensive risk management frameworks. Many organizations still rely on reactive approaches, addressing risks only after disruptions have occurred rather than proactively preparing for them. As we see in Figure 1, three companies out of four have not a structured process for risk management. This lack of structured risk management exposes businesses to greater vulnerabilities, increasing the likelihood of severe operational and financial consequences. Bridging this gap requires a fundamental shift in corporate risk culture, where risk management is embedded into decision-making processes and prioritized at all levels of the organization.

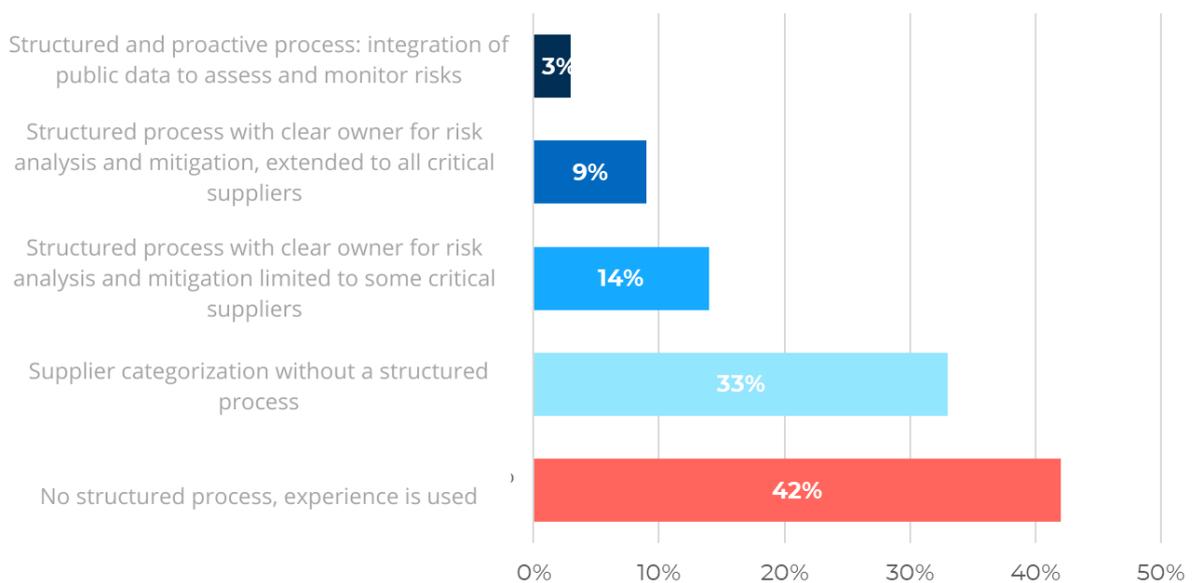


Figure 1: survey on the risk management approach of a large number of companies.

At the core of effective risk management lies the active involvement of stakeholders across all levels of the organization and beyond. Internal teams, suppliers, customers, and external partners must work collaboratively to ensure the seamless functioning of supply chains. This collaboration is vital not only for minimizing potential disruptions but also for transforming risks into opportunities for growth and innovation. By fostering a culture of risk awareness and encouraging collective problem solving, businesses can build resilient supply chains that are equipped to thrive in even the most adverse conditions.

In addition to stakeholder engagement, leveraging advanced technologies has become an indispensable component of modern risk management. Emerging tools such as artificial intelligence (AI), machine learning, and digital twins are revolutionizing how companies identify, assess, and mitigate risks. AI and machine learning algorithms can process vast datasets to detect patterns, predict disruptions, and optimize decision-making processes. Digital twins, which create virtual replicas of physical systems, enable companies to simulate potential scenarios and evaluate their impact in real-time. These technologies empower organizations to shift from reactive to proactive risk management, enhancing their ability to safeguard operations and seize opportunities in a rapidly changing environment.

As businesses increasingly recognize the transformative potential of these technologies, they must also address the challenges associated with their adoption. Implementing advanced tools requires significant investments in infrastructure, expertise, and data integration. However, the benefits of enhanced predictive capabilities, greater operational efficiency, and improved agility far outweigh the initial costs, making these tools a critical asset in the pursuit of supply chain resilience.

In conclusion, the ever-evolving nature of global supply chains necessitates a comprehensive and forward-looking approach to risk management. Organizations must not only protect themselves against potential disruptions but also harness risks as catalysts for innovation and competitive advantage. By fostering collaboration among stakeholders, embracing technological advancements, and cultivating a culture of resilience, businesses can create supply chains that are both robust and adaptable.

## 1.2. Research objectives and research question

This research aims to explore and develop a structured approach to risk management for end-to-end supply chains, addressing both theoretical and practical aspects of this critical discipline. In today's increasingly interconnected and volatile global environment, companies face unprecedented challenges that require innovative and

adaptive solutions. Recent disruptions such as the COVID-19 pandemic, geopolitical tensions and inflation have highlighted the vulnerabilities of supply chains and underscored the need for robust risk management strategies. By combining a thorough review of the academic literature with an in-depth analysis of real-world practices, this study seeks to bridge the gap between existing theoretical frameworks and their practical implementation.

The research investigates how risk management is conducted across the entire supply chain, from upstream suppliers to downstream customers, emphasizing the importance of holistic approaches that consider the complex interdependencies between various supply chain actors. A particular focus is placed on understanding how organizations have adapted their risk management practices in response to recent perturbations. These disruptions have tested the resilience of supply chains globally, prompting businesses to reevaluate traditional risk management methodologies and adopt innovative solutions to ensure operational continuity and long-term sustainability.

The central research question guiding this study is: How is risk management conducted for end-to-end supply chains, and how have approaches evolved in response to recent disruptions such as the COVID-19 pandemic, geopolitical tensions, and inflation?

To address this question, the research adopts a dual approach that combines theoretical analysis and practical exploration. The theoretical foundation is built through an extensive review of academic literature, which provides a detailed understanding of existing risk management models and methodologies. The practical dimension of the study, which involves the analysis of case studies and interviews with supply chain managers, complements this. These real-world insights reveal how companies navigate the complexities of risk management in their day-to-day operations, highlighting both strengths and areas for improvement.

The ultimate goal of this research is to design a structured risk management process that integrates the insights gained from theory and practice. This process is intended to be both adaptable and actionable, providing companies with a framework to proactively identify, assess, and mitigate risks while leveraging opportunities for innovation and growth. By addressing the gap between theoretical models and their practical application, the study aims to contribute not only to the academic field but also to the business community. It seeks to offer practical tools and recommendations that can enhance the resilience and competitiveness of supply chains in an ever-changing global landscape. Through this holistic approach, the research aspires to create a meaningful impact on the way organizations perceive, approach, and manage risks within their supply chains.

### 1.3. Methodology

The methodology of this research is grounded in a comprehensive and multidisciplinary approach, combining both theoretical and practical perspectives to gain a well-rounded understanding of risk management in supply chains. The study draws upon several sources of information and employs diverse methods of data collection and analysis to ensure the robustness and reliability of its findings.

The first phase of the research involved an extensive review of academic literature on risk management, encompassing a wide range of papers, journal articles, and industry reports. This theoretical foundation provided a deep understanding of existing models, frameworks, and methodologies related to identifying, assessing, and mitigating risks in supply chains. The literature review also highlighted key gaps in current knowledge, which informed the subsequent phases of the research and shaped the focus of the study.

To complement the theoretical insights, the research incorporated the analysis of real-world case studies. By examining how various companies have managed risks in practice, the study identified patterns, best practices, and challenges that arise in different industrial contexts. These cases offered valuable lessons about the application of risk management frameworks, as well as insights into the unique dynamics and complexities of supply chain operations.

Another crucial component of the research methodology was conducting interviews with supply chain managers from diverse industries. These interviews provided firsthand accounts of how risk management is approached in day-to-day operations, allowing for a deeper exploration of practical challenges and innovative solutions. The managers shared their experiences with recent disruptions such as the COVID-19 pandemic and geopolitical tensions, shedding light on how organizations are adapting their strategies to remain resilient in the face of uncertainty.

Additionally, the research benefited from participation in workshops and seminars focused on risk management and supply chain resilience. These events brought together academics, practitioners, and industry experts, creating opportunities for knowledge exchange and collaborative learning. The workshops provided a platform to engage with cutting-edge developments in the field and gather insights into emerging trends, technologies, and best practices.

By integrating these diverse sources of information, the research employed a qualitative and exploratory methodology designed to bridge the gap between theory and practice. The combination of academic literature, real-world cases, interviews, and workshops allowed for a holistic understanding of risk management in supply chains,

enabling the development of a structured and actionable framework that aligns with both theoretical principles and practical realities. This methodological approach ensures that the findings of the study are not only academically rigorous but also highly relevant and applicable to the challenges faced by organizations in today's complex and dynamic business environment.

## 1.4. Summary of results

This thesis explores the complexities of risk management, offering a structured framework for understanding the different types of risks, the fundamental stages of risk management, and the strategic approaches companies adopt to mitigate potential threats. Through a detailed examination of existing literature, case studies, and industry practices, this research highlights the factors influencing corporate risk management decisions and the growing role of emerging technologies in this field.

A key aspect of the study is the analysis of how companies structure their risk management processes. While different models exist, this research confirms the importance of a systematic and proactive approach, which typically follows a series of well-defined steps. By establishing a clear process, organizations can enhance resilience, improve decision-making, and minimize operational disruptions.

Additionally, the study identifies critical decision-making factors that influence how companies select risk management strategies. While the literature extensively discusses different risk mitigation techniques, little attention has been given to the rationale behind their selection. This research aims to fill this gap by identifying key factors such as geographical location, regulatory requirements, technological capabilities, corporate reputation, cost-benefit analysis, and risk tolerance. Understanding these elements allows businesses to tailor their risk management approaches to their specific operational context.

Furthermore, the thesis examines how risk mitigation actions extend beyond individual companies, affecting the entire supply chain. The adoption of certain strategies can create both additional risks and new opportunities, reinforcing the need for businesses to remain agile and adaptive. The study emphasizes the importance of strategic flexibility, enabling companies to transform challenges into competitive advantages.

Finally, the research explores the transformative impact of emerging technologies on risk management. Technologies such as Artificial Intelligence (AI), Digital Twins, and Machine Learning are increasingly being integrated into corporate risk strategies, providing companies with real-time risk assessment, predictive modeling, and automated decision-making capabilities. Organizations that successfully adopt and implement these innovations are expected to gain a substantial competitive advantage,

as they will be better equipped to anticipate and mitigate risks in an increasingly volatile business environment.

By addressing these key areas, this research contributes to both academic discourse and practical applications, offering valuable insights into the evolution of risk management and the role of technology in shaping its future.

## 2 Literature review

### 2.1. Risk categories

All the papers and the literature analyzed provide an extensive and detailed exploration of the different categories of risk in supply chain management, emphasizing the multifaceted and interconnected nature of these risks. While there are overarching similarities in how these risks are categorized, the nuances within each study allow for a deeper understanding of the diverse factors that can disrupt supply chain operations. Below, a more detailed examination of these risk categories is provided, capturing the distinctive contributions of each study and the commonalities across the literature.

#### 2.1.1. Supply risk

Supply risks are universally recognized as one of the most critical categories. These risks arise from disruptions in the inbound flow of materials or services that affect an organization's ability to meet customer demand. Manuj & Mentzer (2008) defines supply risk as events like supplier opportunism, poor inbound product quality, and transit time variability, all of which can lead to incomplete orders. Um (2021) echoes this perspective but adds that supply risks can include threats to customer life and safety, emphasizing supplier accountability. Shahbaz (2019) further categorizes these risks as "supply-side risks," pointing to market-wide issues or individual supplier problems, such as material shortages or outdated supply processes. Across the literature, supply risks are framed as a direct threat to operational continuity and

customer satisfaction, requiring robust supplier relationship management and contingency planning.

### 2.1.2. Demand risk

Demand risks pertain to disturbances in the outbound flow of goods and services and the challenges associated with meeting customer needs. Manuj & Mentzer (2008) defines this category as "delivery risk," focusing on forecast errors, demand variability, and competitor strategies that affect customer ordering patterns. Shahbaz (2019) highlights delays in new product development, inaccurate demand forecasting, and rapid fluctuations in customer preferences as significant contributors to demand-side risks. Um (2021) provides a similar view, emphasizing how these risks disrupt schedules, inventory management, and technology access. Across the studies, demand risks are consistently linked to market uncertainty and the difficulty of accurately predicting customer behavior, which can lead to overstocking or stockouts, eroding profitability and customer trust.

### 2.1.3. Operational risk

Operational risks encompass internal disruptions within an organization that hinder its ability to produce goods or services efficiently. Manuj & Mentzer (2008) highlight risks related to inventory ownership, asset and tools management, and internal production quality issues. Schlegel & Trent (2015) expand this category to include service failures from poorly managed inventory, forecasting inaccuracies, and internal quality control problems. Bandalay (2013) uses the term "internal operations risk" to describe disruptions stemming from process inefficiencies, labor uncertainties, and information system failures. Um (2021) builds on this by linking operational risks to adverse events affecting production quality, timeliness, and profitability. Across the literature, operational risks are framed as the backbone of supply chain disruptions, emphasizing the need for robust internal processes and adaptable operational systems.

### 2.1.4. Environmental risk

Environmental risks are characterized as low-probability but high-impact events originating from external, uncontrollable factors. Shahbaz (2019) highlights natural disasters, diseases, and political instability as key examples. Bandalay (2013) categorizes these risks as part of the broader "environmental" domain, including major accidents, regulatory changes, and sociopolitical conditions. Similarly, Schlegel & Trent (2015) refer to "hazard risks," which include natural disasters, fires, and even acts of terrorism. Environmental risks are distinct from other categories because they

typically arise outside the organization's immediate control yet have profound implications for supply chain resilience. These risks underscore the importance of disaster preparedness and scenario planning in risk management frameworks.

#### 2.1.5. Collaboration risk

Collaboration risks, as described by Shahbaz (2019), focus on the challenges of maintaining cooperative relationships within the supply chain. These risks include a lack of trust between partners, inaccurate information sharing, and system security breaches. Waters (2007) expands on this by discussing how issues in supply chain interactions, such as delivery problems or misaligned objectives, can exacerbate collaboration risks. The emphasis on collaboration risks highlights the interconnected nature of modern supply chains and the importance of fostering transparent, trustworthy partnerships to mitigate potential disruptions.

#### 2.1.6. Financial risk

Shahbaz (2019) defines financial risks as events with immediate financial consequences, such as price fluctuations, currency exchange volatility, and financial instability within the supply chain. Schlegel & Trent (2015) frame these risks as critical to an organization's ability to maintain profitability and liquidity. The inclusion of financial risks in the literature underscores the importance of integrating financial metrics and monitoring tools into supply chain risk management processes to safeguard against unexpected economic shocks.

#### 2.1.7. Logistic and security risk

Logistics risks, emphasized by Shahbaz (2019), involve uncertainties in transportation and distribution systems, such as delays, interruptions, or inefficiencies in the logistics network. Um (2021) discusses "security risks," which encompass threats like data breaches, vandalism, theft, and sabotage. These risks are particularly significant in the context of globalized supply chains, where the reliance on technology and digital infrastructure has introduced new vulnerabilities. The literature emphasizes the need for robust logistics and cybersecurity strategies to address these risks effectively.

#### 2.1.8. Strategic risk

Strategic risks, discussed by Schlegel & Trent (2015), are those that threaten an organization's long-term objectives, business strategy, and brand value. These risks

are closely tied to high-level decision-making and can result from market shifts, competitor actions, or regulatory changes. Strategic risks are distinguished from operational risks by their broader scope and long-term implications, requiring a proactive approach to identify and mitigate them effectively.

### 2.1.9. Synthesis of categories

While the papers use different terminologies and categorizations, there is significant overlap in how risks are conceptualized. Core categories like supply, demand, and operational risks are universally recognized, forming the foundation of supply chain risk management. Other categories, such as environmental, financial, and collaboration risks, represent more specialized dimensions that highlight specific challenges faced by modern supply chains. This diversity in risk categorizations reflects the evolving nature of supply chain management and the need for a comprehensive, integrative approach to risk identification and mitigation.

Table 1: Classification of risks in literature

	Manuj & Mentzer (2008)	Um (2021)	Schlegel & Trent (2015)	Shahbaz (2019)	Waters (2007)	Bandalay (2013)
<b>Supply risk</b>	X	X		X		
<b>Demand risk</b>	X	X		X		
<b>Operational risk</b>	X	X	X			X
<b>Environmental risk</b>			X	X		X
<b>Collaboration risk</b>				X	X	
<b>Financial risk</b>			X	X		
<b>Logistic and security risk</b>		X		X		
<b>Strategic risk</b>			X			

In conclusion, the literature provides a multifaceted view of supply chain risks, underscoring the complexity and interconnectivity of modern supply chains. By synthesizing these categories, organizations can develop a robust risk management framework that addresses both traditional and emerging challenges, ensuring resilience and adaptability in an increasingly volatile global environment.

## 2.2. Phases of risk management

The literature on risk management generally presents a consistent and structured approach to the process, with most frameworks converging on a series of well-defined phases.

Building on this established body of research, this thesis adopts a structured classification of the risk management process, aligning with widely recognized models while ensuring a comprehensive and practical perspective. The following sections outline the key phases that constitute an effective risk management framework, providing a systematic approach that businesses can implement to enhance their resilience and decision-making capabilities.

### 2.2.1. Internal environment and objective settings

The internal environment and objective setting form the foundational phase of the supply chain risk management (SCRM) process. Before identifying, assessing, and mitigating risks, organizations must establish a solid internal framework that defines their approach to risk management, clarifies roles and responsibilities, and aligns objectives with their overall strategic mission. This phase shapes an organization's risk culture, determining how risks are perceived, addressed, and integrated into decision-making processes.

The internal environment refers to the overall tone, structure, and philosophy that an organization adopts regarding risk management . It includes elements such as:

- **Risk Management Philosophy:** The organization's overarching approach to risk—whether it adopts a conservative stance, prioritizing risk avoidance, or a more aggressive stance, tolerating higher risks for potential rewards.
- **Risk Appetite:** The level of risk an organization is willing to accept while pursuing its strategic goals. This varies across industries and firms, depending on market conditions, regulatory constraints, and competitive pressures.
- **Integrity and Ethical Values:** The ethical framework guiding decision-making, ensuring that risk management aligns with corporate governance principles.

- **Governance and Leadership:** The role of senior management and the board in fostering a risk-aware culture and setting accountability mechanisms.

By defining these components, the internal environment ensures that risk management is embedded in the organization's culture, rather than being treated as an isolated function. This phase also involves setting up internal policies, procedures, and communication channels that facilitate proactive risk identification and response.

A critical aspect of the internal environment is context analysis, which involves defining the scope of the supply chain and understanding key stakeholders, their roles, and responsibilities. This analysis provides a structured view of:

**The main actors in the supply chain:** Identifying suppliers, manufacturers, logistics providers, distributors, and customers.

**Roles and responsibilities:** Clarifying which entities are responsible for specific activities, ensuring accountability.

**Existing risk management measures:** Assessing what controls, safeguards, and contingency plans are already in place.

Risk management efforts should focus on actors whose actions could cause substantial losses—whether for themselves, another member of the chain, or the entire supply network. This selective approach prevents unnecessary resource allocation to low-impact risks while ensuring that critical vulnerabilities are addressed.

Context analysis serves as a boundary-setting mechanism, helping organizations determine the scope of risk management efforts. Once this scope is defined, firms can focus on the most relevant risks and develop targeted mitigation strategies.

After establishing the internal environment and conducting context analysis, organizations move to the objective setting phase. Effective supply chain risk management must align with the company's broader strategic mission and risk appetite. This step ensures that:

The firm's risk management objectives support its long-term business strategy.

Objectives are realistic and measurable, considering the organization's capacity to manage risks.

There is consistency between operational goals and the level of risk the company is willing to tolerate.

A well-defined objective-setting process provides clarity on what risks should be managed and to what extent, ensuring that risk management efforts are proportionate to the company's strategic priorities. For instance, a firm focused on cost leadership may tolerate higher risks in supplier selection, while a company prioritizing reliability may invest heavily in redundancy and risk mitigation.

The internal environment and objective-setting phase ensures that risk management is not a reactive process, but rather a proactive and structured approach aligned with the organization's mission. Companies that invest in defining a strong internal framework can:

Enhance supply chain resilience by fostering a risk-aware culture.

Improve coordination among supply chain partners through clear roles and responsibilities.

Optimize resource allocation by prioritizing risks that align with strategic objectives.

By setting the right foundation, firms can transition smoothly to the next phases of risk management—risk identification, assessment, and mitigation—ensuring that their supply chains remain robust and competitive in an increasingly uncertain business environment.

### 2.2.2. Risk identification

Risk identification is a crucial phase in the supply chain risk management (SCRM) process, as it lays the groundwork for all subsequent risk management actions, including risk assessment, mitigation, and monitoring. Without a comprehensive identification of potential risks, an organization cannot effectively evaluate their consequences, design appropriate mitigation strategies, or proactively manage supply chain vulnerabilities. Several scholars and practitioners emphasize the importance of this phase, recognizing it as fundamental to the success of the entire risk management process.

The primary goal of the risk identification phase is to systematically determine and catalogue the potential risks that could affect supply chain operations. According to Ghadge et al. (2013) and Manuj & Mentzer (2008), the key deliverable of this phase is a "profile" for each identified risk, which allows for later evaluation of their consequences (Tummala & Schoenherr, 2011). This profile typically includes a description of the risk, its potential sources, its potential impacts, and the context in which it might manifest.

The identification process is vital for several reasons:

**Proactive Risk Management:** By identifying risks early, companies can address them before they escalate into significant disruptions, thus minimizing potential losses and business interruptions.

**Resource Allocation:** A detailed understanding of risks helps organizations prioritize their risk mitigation efforts, ensuring resources are allocated to the most pressing threats.

Strategic Alignment: Proper risk identification ensures that the risks considered are aligned with the organization's risk appetite and objectives, allowing for better strategic decision-making.

A variety of techniques and tools are used in the risk identification phase to help organizations uncover potential supply chain risks. These methods vary from simple tools to more complex, quantitative techniques, and may include:

- **Supply Chain Mapping:** One of the first steps in identifying risks involves creating a visual map of the supply chain, detailing the flow of goods, information, and money from upstream suppliers to downstream customers. This map helps organizations identify bottlenecks, dependencies, and points of failure within the supply chain (Gardner & Cooper, 2003). Mapping makes it easier to spot risks related to supply chain nodes, transportation routes, or even regulatory issues.
- **Checklists and Check Sheets:** These are standardized tools used to record specific failures or irregularities observed within the supply chain, such as late deliveries or quality issues. By documenting the frequency and type of failures, organizations can pinpoint areas that may be prone to risks (Chase et al., 2006). This method is particularly useful for capturing historical risk data and identifying recurrent issues that may require attention.
- **Event Tree and Fault Tree Analysis:** These graphical methods help visualize potential outcomes following a disruptive event. Event trees map out all possible consequences triggered by an event (e.g., supply chain failure), while fault trees illustrate the root causes of those events. Both methods assist organizations in anticipating potential disruptions and planning for alternatives or mitigation strategies (Pate-Cornell, 1984; Hollnagel, 2004).
- **Failure Mode and Effect Analysis (FMEA):** FMEA helps identify risks at the design stage, analyzing what could go wrong during product manufacturing or while the product is in use by the customer. This tool is particularly useful for identifying risks early in the product development lifecycle, allowing organizations to take corrective actions before risks materialize (McDermott et al., 1996).
- **Ishikawa Cause-and-Effect Diagram (Fishbone Diagram):** This brainstorming tool is used to explore the potential relationships between causes and effects in the supply chain. It is particularly effective in identifying root causes of issues or disruptions, helping organizations understand how various factors (e.g., materials, processes, people, equipment) contribute to supply chain risks (Chase et al., 2006).
- **Value-Focused Process Engineering (VFPE):** Proposed by Neiger et al. (2009), VFPE offers a structured approach to identifying risks by treating risk as a

process objective. This methodology helps organizations align risk identification efforts with their strategic objectives and value drivers. By framing risks within the context of value creation and risk reduction, VFPE provides a comprehensive lens through which to view potential disruptions.

Understanding the underlying drivers of supply chain risks is essential for accurate risk identification. Drivers can be classified into two types:

- **Probability Drivers:** These factors influence the likelihood of a risk occurring, such as competitive pressures, supply chain complexity, or a focus on cost reduction. For example, a company that heavily relies on lean practices may be more vulnerable to disruptions due to its minimal inventory levels (Thun & Hoenig, 2011).
- **Impact Drivers:** These drivers affect the severity of a risk's consequences, such as supplier dependence, lack of redundancy, or poor contract management. Understanding these drivers helps organizations assess the potential impact of a risk if it materializes (Wagner & Bode, 2006).

By identifying both the probability and impact drivers, companies can create a more detailed and comprehensive risk profile, allowing for better risk mitigation strategies (Ritchie & Brindley, 2007).

Despite the importance of risk identification, this phase is not without challenges:

- **Complexity of Risks:** Supply chains are often global and multi-tiered, making the identification of risks across different regions, suppliers, and stakeholders a complex task.
- **Dynamic Nature of Risks:** Risks evolve over time, with new risks emerging and existing risks changing in scope or impact. Keeping up with these changes requires continuous monitoring and updating of risk profiles.
- **Data Availability:** Accurate risk identification often relies on having access to timely and reliable data. Gaps in data or poor visibility into the supply chain can hinder the identification of emerging risks.

Risk identification is a critical first step in the supply chain risk management process. It requires a comprehensive, structured approach to uncover all potential threats and vulnerabilities that could disrupt supply chain operations. Through the use of mapping techniques, risk categorization, and analysis tools, organizations can better understand the risks they face and prepare to address them proactively. By accurately identifying risks, companies can ensure that their risk management efforts are aligned with their strategic objectives and are effective in reducing exposure to future disruptions.

### 2.2.3. Risk measurement and assessment

After identifying potential risks within the supply chain, the next essential phase in the risk management process is risk measurement and assessment. This phase plays a fundamental role in understanding and quantifying risks, allowing companies to evaluate their potential impact on operations, financial performance, and strategic objectives. Several scholars (Crockford, 1986; Raiffa, 1982; Zsidisin et al., 2004; Cohen & Kunreuther, 2007) emphasize that risk assessment revolves around two core dimensions: the likelihood of occurrence of an adverse event and the severity of its consequences. A comprehensive risk measurement and assessment process enables organizations to anticipate potential disruptions, allocate resources effectively, and implement appropriate mitigation strategies to enhance supply chain resilience.

Risk measurement involves determining the consequences of all identified supply chain risks and evaluating the extent to which these risks can affect an organization's resources, operations, and overall performance (Crockford, 1986). The effects of these risks can be diverse, ranging from financial losses, supply delays, and cost overruns to operational inefficiencies, reputational damage, and even legal liabilities. Some common manifestations of supply chain risks include loss of or damage to assets, interruptions in service levels, schedule delays, poor process performance, and injury-related costs (Crockford, 1986). The magnitude of these consequences varies based on the nature of the risk and the industry context in which a firm operates.

To systematically assess and classify risks, scholars propose different categorization frameworks based on frequency, severity, and predictability. One of the most widely recognized classifications comes from Crockford (1986), who identifies four distinct levels of risk consequences:

- **Trivial Consequences:** These occur with very high frequency, have minimal severity, and are highly predictable. They are expected losses that firms can typically absorb within their normal operating budgets.
- **Small Consequences:** These have a relatively high frequency, low severity, and reasonable predictability. Although their individual impact may be minor, their cumulative effect could become significant over time.
- **Medium Consequences:** These happen with lower frequency, have moderate severity, and a reasonable degree of predictability. If they occur at regular intervals, their costs can be estimated annually, allowing firms to plan for them.
- **Large Consequences:** These are rare but highly severe and often unpredictable. When they occur, they can have catastrophic implications for the firm, potentially threatening its financial stability and long-term survival.

This classification helps organizations prioritize risks by distinguishing between routine disruptions that can be managed through operational adjustments and major risks that require strategic planning and robust contingency measures.

Once risks and their potential consequences are identified, the next step is to assess their likelihood of occurrence. Risk assessment, as described by Raiffa (1982), is closely tied to the evaluation of uncertainties, requiring organizations to determine the probability of each risk materializing. This step is essential for making informed decisions about risk mitigation and response strategies.

When historical data is available, firms can adopt quantitative approaches to assess risk probabilities using statistical models, probability distributions, and frequency analysis. Sheffi and Rice (2005) suggest that past data can provide valuable insights into the likelihood of “random events” and “accidents” within supply chains. However, certain risks, particularly intentional disruptions (e.g., cyberattacks, fraud, sabotage), pose a greater challenge because their occurrence is less predictable based on historical trends.

In cases where objective data is scarce, subjective estimation techniques can be used. These may include:

- Expert Judgment and Delphi Method: Structured group discussions or expert focus groups can help derive probability estimates.
- Monte Carlo Simulation: A probabilistic modeling technique that generates possible outcomes based on multiple risk scenarios.
- Five-Point Estimation and Probability Encoding: Methods that involve assigning qualitative probability categories (e.g., rare, occasional, frequent) to different risk events.

A notable approach used in supply chain risk assessment is Failure Mode and Effects Analysis (FMEA), which incorporates a third variable: detection of failure (Stamatis, 2003). This method evaluates not only the probability and severity of a risk event but also the likelihood of detecting the risk before it causes disruption. However, in supply chain management, it is often assumed that most macro-level risks (e.g., demand fluctuations, natural disasters, political instability) are visible, leading some researchers to omit this detection variable (Zsidisin et al., 2004).

One of the key objectives of risk assessment is to prioritize risks based on their potential impact on supply chain vulnerability (Elleuch et al., 2014; Ghadge et al., 2013; Giannakis & Louis, 2011). By systematically evaluating risks, firms can identify the most critical vulnerabilities in their supply networks and determine where to focus mitigation efforts. According to Cohen and Kunreuther (2007) and Knemeyer et al. (2009), risk assessment also involves pinpointing the weakest links in the supply chain, where disruptions are most likely to occur or have the most severe consequences.

Several researchers propose integrating financial, operational, and strategic measures when assessing risk impact. Financial impacts can be measured in terms of revenue loss, value at risk, or cash flow disruption. Operational consequences may include production delays, increased lead times, and customer service failures. Strategic

implications involve loss of goodwill, erosion of competitive advantage, and potential regulatory penalties (Huang et al., 2009). The severity of an impact may also determine the appropriate risk mitigation strategy, as different levels of risk require different management responses (Bandaly et al., 2012).

Ritchie and Brindley (2007) expand upon the concept of risk assessment by introducing a third dimension beyond occurrence probability and impact magnitude: the causal pathway leading to the risk event. This dimension highlights the source of risk—whether internal (e.g., process inefficiencies, supplier failures) or external (e.g., geopolitical instability, economic downturns). Understanding the root causes of risks allows firms to design more proactive risk mitigation strategies, rather than reacting only after disruptions occur.

The ultimate goal of risk measurement and assessment is to provide decision-makers with a clear understanding of which risks require immediate attention and what level of resources should be allocated to managing them. Managers must not only focus on risks with the highest impact but also consider other factors, such as the feasibility of mitigation actions and the cost-effectiveness of risk reduction measures (Aqlan & Lam, 2015; Kern et al., 2012).

By assessing risk comprehensively, organizations can develop risk-adjusted decision-making frameworks that align with their broader business objectives. This process also supports the development of risk-aware supply chain strategies, enabling firms to build resilience against disruptions while maintaining efficiency and competitiveness in a volatile global market. Furthermore, risk measurement and assessment serve as the foundation for subsequent phases in supply chain risk management, including risk evaluation, mitigation, and response planning (Tummala & Schoenherr, 2011).

In conclusion, risk measurement and assessment are vital for ensuring the robustness of supply chains. By quantifying risks, evaluating their potential impact, and prioritizing vulnerabilities, firms can implement more effective risk management strategies, reduce exposure to disruptions, and enhance their long-term sustainability in an increasingly uncertain business environment.

#### 2.2.4. Risk mitigation

The risk mitigation phase is a critical component of the supply chain risk management (SCRM) process, following the identification and assessment of risks. This phase involves determining and implementing strategies to address the risks identified in previous stages. The goal of mitigation is to minimize the likelihood and impact of these risks or reduce their effects on the organization, thus enhancing resilience and ensuring business continuity.

Risk mitigation strategies are essential because they provide a way for organizations to proactively manage identified risks. Rather than waiting for risks to materialize, mitigation strategies allow businesses to reduce exposure to potential threats or minimize the consequences if they occur.

The importance of mitigation can be highlighted in several ways:

- **Minimizing Disruption:** Effective risk mitigation helps prevent supply chain disruptions, which can be costly and damaging to an organization's operations.
- **Enhancing Resilience:** By implementing robust mitigation strategies, companies build more resilient supply chains that can better withstand unexpected events, such as natural disasters, market shifts, or supplier failures.
- **Cost Efficiency:** Well-chosen mitigation strategies can provide a cost-effective way to handle risks. Although implementing these strategies may incur some costs, the benefits—such as reduced downtime, lower operational losses, or enhanced supplier relationships—often outweigh the investments made.
- **Aligning with Organizational Objectives:** Risk mitigation strategies must align with the company's overall objectives, ensuring that risk management efforts are consistent with the company's risk appetite and business goals.

Several tools and techniques can be employed to aid in the mitigation of supply chain risks, ensuring that strategies are applied in an effective and efficient manner. One such tool is the Hazard Totem Pole (HTP) Analysis, which is helpful for assessing the severity and probability of risks and integrating this information into risk planning (Tummala et al., 1994). This tool allows organizations to develop action plans that contain and control risks by categorizing them according to their severity and likelihood, thus enabling more targeted responses.

Another important technique is risk planning, where detailed response actions are created based on the identified risks. Risk planning helps organizations stay prepared for potential disruptions by outlining clear steps to take in case of a risk event (Tummala & Mak, 2001).

The process of selecting a risk mitigation strategy must take into account the strategic fit with the organization's overall objectives and risk appetite. In addition, a cost-benefit analysis is essential to ensure that the selected strategy provides value to the organization by balancing the benefits of risk reduction with the costs of implementing the strategy (Ghadge et al., 2013; Tuncel & Alpan, 2010).

The selected strategy should be tailored to the specific characteristics of the supply chain and the risk in question. For instance, a company with a robust risk management system might prefer risk-sharing or transfer strategies, while others might lean towards risk reduction or avoidance strategies, depending on their risk tolerance.

Once risk mitigation strategies are selected, organizations should develop detailed mitigation plans that define specific actions to reduce risk exposure. Contingency planning is an integral part of this process, preparing the company to respond effectively if the risk materializes despite mitigation efforts. Contingency plans often include alternative supply chain routes, additional suppliers, emergency response protocols, and predefined communication strategies.

The risk mitigation phase is a vital component of the supply chain risk management process, involving the selection and implementation of strategies to address identified risks. By evaluating various mitigation options and selecting the most appropriate strategies based on cost, severity, and likelihood, organizations can reduce their vulnerability to supply chain disruptions. While the primary goal of this phase is to mitigate risks, the specific strategies and tools used will be further explored in the subsequent section.

### 2.2.5. Control and monitoring

The control and monitoring phase represents the final stage in the supply chain risk management process (SCRM), ensuring that the risk mitigation strategies are effectively executed and continuously updated to account for emerging risks and deviations. This phase involves evaluating the progress of implemented risk responses, making necessary adjustments, and ensuring that corrective actions are taken if risks materialize or evolve unexpectedly. It is also about monitoring the entire supply chain environment to identify new risks, observe trends, and make proactive changes to the overall risk management process.

Control and monitoring are vital to ensure that the organization remains resilient in the face of both existing and emerging risks. These activities allow management to oversee the implementation of risk strategies, ensure compliance with established policies, and adjust strategies when required. Furthermore, they are integral for maintaining the continuous improvement of risk management practices.

The importance of control and monitoring in SCRM can be seen in several key areas:

- **Ensuring Effective Strategy Implementation:** Control mechanisms are critical to verifying whether the risk response strategies are being executed as planned and whether they are achieving the desired outcomes. If discrepancies are detected, corrective actions can be taken.
- **Identifying New Risks:** Continuous monitoring of the supply chain environment allows organizations to detect emerging risks, new vulnerabilities, or shifts in risk dynamics. This ensures that the company is always prepared to respond to evolving challenges.

- **Optimizing Decision-Making:** By constantly evaluating risk management performance, companies can make data-driven decisions to fine-tune strategies, ensuring a more effective and efficient risk management approach.
- **Facilitating Continuous Improvement:** The control and monitoring process helps build a culture of continuous improvement by providing the necessary feedback and insights to enhance risk management practices over time.

The first step in the control phase is to ensure that the implemented risk response plans are being followed effectively. This is done by establishing policies and procedures to verify that actions are carried out according to the defined plans. These activities help ensure that the supply chain risk management (SCRM) process is robust, and that the risk responses are aligned with the organization's objectives and operational capabilities.

Key elements of control activities include:

- **Policies and Procedures:** These provide clear guidelines on how risk responses should be carried out. By setting standards and expectations, they ensure consistency and alignment with the organization's overall risk management strategy.
- **Internal Audits:** Regular checks and audits help identify whether the risk strategies are being implemented correctly, and whether the desired outcomes are being achieved. Any deviations from the plan can be flagged and addressed.

For control to be effective, relevant information must be communicated clearly and in a timely manner. This includes reporting on the status of implemented risk responses, the identification of new risks, and any potential deviations from the expected outcomes. Effective communication ensures that the right people in the organization are aware of potential issues and can take the necessary steps to resolve them.

The communication flow should be seamless across all levels of the organization, with information flowing upward, downward, and horizontally. This ensures that stakeholders at all levels have the information they need to take action when necessary.

The monitoring phase involves the ongoing observation and evaluation of the entire risk management system. This is not a one-time process but a continuous activity that ensures the SCRM system remains effective and responsive to changes in the environment. Monitoring is essential for identifying emerging risks, evaluating the effectiveness of risk responses, and determining whether any adjustments are needed to adapt to evolving supply chain conditions.

Key aspects of monitoring include:

- **Supervising Risk Responses:** Regular monitoring of risk responses ensures that strategies continue to address the risks they are meant to manage. Monitoring

also identifies any weaknesses or gaps in the existing strategy that may need to be addressed.

- **Detecting New Risks:** Supply chain environments are dynamic, and new risks may emerge as operations evolve or external factors change. Continuous monitoring helps identify these new risks early, allowing the organization to adjust its risk management plan proactively.
- **Trend Analysis:** By observing trends in risk occurrences, companies can identify patterns that may indicate underlying issues or potential vulnerabilities. Monitoring trends enables the organization to anticipate risks and adjust strategies before problems escalate.

Monitoring activities help detect changes in the supply chain that may warrant updates to the risk management plan. These include shifts in market conditions, regulatory changes, technological advancements, or new geopolitical factors.

If any deviations are identified—whether they pertain to the progress of risk treatment, the effectiveness of implemented strategies, or the emergence of new risks—corrective actions should be taken. These actions may involve adjusting existing strategies, reallocating resources, or implementing new measures to ensure that risks are appropriately managed.

The process of continuous improvement is facilitated through regular assessments of the risk management system's performance. By continuously evaluating the effectiveness of strategies and incorporating feedback, the organization can ensure that its SCRM efforts evolve and adapt over time. This allows the company to not only maintain a state of readiness but also improve its risk management processes for the future.

Modern risk management systems often rely on data management systems and software tools to aid in the control and monitoring processes. These systems store and update critical risk-related data, enabling real-time analysis and decision-making. Examples of such tools include:

- **Risk Catalogs:** A centralized database that tracks identified risks, severity levels, probabilities, and other key risk factors. This data can be used for ongoing monitoring and for making adjustments to risk management strategies.
- **Hazard Totem Pole Analysis:** A tool for assessing the severity and probability of various risks, which can be regularly updated to monitor risk trends over time.
- **SaaS-based Risk Management Solutions:** Commercially available software-as-a-service platforms provide businesses with customizable risk management tools that facilitate monitoring, reporting, and real-time risk assessments.

These tools provide organizations with the necessary infrastructure to support ongoing monitoring, facilitate communication, and ensure that corrective actions are taken swiftly.

The control and monitoring phase is the final and ongoing component of the supply chain risk management process. It is crucial for ensuring that risk mitigation strategies are effectively implemented and continuously updated to address new risks, changes in the environment, and any deviations from expected outcomes. By establishing control activities, facilitating effective communication, and monitoring the entire system, organizations can maintain a proactive and dynamic approach to managing risks. This phase not only addresses current risks but also helps organizations adapt to emerging challenges and improve their risk management practices in the long term.

## 2.3. Risk management strategies

The literature offers a wide range of risk management strategies, each tailored to address different types of risks and organizational contexts. While various frameworks classify these strategies in different ways, most approaches share common principles aimed at minimizing threats, reducing uncertainties, and ensuring business continuity. Given the diversity of perspectives, this thesis consolidates existing classifications and proposes a structured categorization that captures the core strategic responses to risk.

The following sections outline the key risk management strategies, providing a clear framework for understanding how organizations can effectively navigate uncertainties and enhance their resilience in an increasingly complex business environment.

### 2.3.1. Avoidance

Risk avoidance is a proactive strategy aimed at eliminating exposure to specific risks by removing the root cause of potential threats. Unlike other risk management approaches that focus on reducing or mitigating risks, avoidance seeks to completely eliminate the possibility of an adverse event occurring. This is achieved by withdrawing from activities, markets, or operations that pose unacceptable levels of risk.

Avoidance involves making strategic decisions that prevent a company from being exposed to potentially harmful situations. This can include:

Discontinuing certain products or services that are associated with high levels of uncertainty (Jüttner et al., 2003; Hajmohammad & Vachon, 2016), exiting markets or industries that present excessive risk (Ritchie & Brindley, 2007), avoiding unreliable suppliers to ensure stability in the supply chain (Aqlan & Lam, 2015), refusing to invest

in unstable regions where political, economic, or environmental risks are too high or delaying or abandoning projects that introduce excessive uncertainty in demand volume and demand mix.

By employing these strategies, companies can significantly reduce their risk exposure and maintain operational stability.

Risk avoidance is particularly useful when the cost of exposure outweighs potential benefits or when a company deems a particular risk unacceptable. This strategy is most effective in situations where:

The risk presents a high probability of occurrence with severe financial or operational consequences.

There are alternative strategies or markets available that offer safer opportunities.

The cost of mitigation outweighs the potential benefits of engaging in the risky activity.

The company wants to uphold ethical or sustainability standards, such as avoiding partnerships with environmentally harmful suppliers.

While avoidance eliminates direct exposure to risk, it is not always a feasible strategy. Completely avoiding risk may limit growth opportunities, as some high-risk ventures also offer significant rewards or restrict market expansion, preventing companies from entering emerging economies or engaging with new customer segments. Additionally it may increase dependency on fewer suppliers, which may introduce new risks related to supply chain concentration.

For these reasons, organizations often combine avoidance with other risk management strategies to strike a balance between safety and opportunity.

Risk avoidance is a powerful risk management strategy that helps companies eliminate exposure to critical threats by removing their root causes. Through strategic decision-making—such as exiting risky markets, discontinuing vulnerable products, and steering clear of unreliable suppliers—organizations can protect themselves from severe disruptions. However, while avoidance minimizes direct exposure, it may also limit opportunities for innovation and expansion. Therefore, companies must carefully evaluate when and how to apply this strategy to ensure long-term success.

### 2.3.2. Acceptance

Risk acceptance is a strategy in which a company acknowledges and assumes a risk without taking specific preventive actions. This approach is often adopted when risk management is not a priority, leading to acceptance by default. However, risk acceptance is also a conscious decision in cases where a cost-benefit analysis reveals that the expense of mitigating a risk outweighs its potential impact.

In some instances, acceptance is the only viable option, particularly when no practical way exists to prevent, transfer, or mitigate the risk. This may occur when alternative strategies are either ineffective or too costly to implement. Companies generally reserve risk acceptance for low-impact risks or situations where the likelihood of occurrence is minimal.

A common example of risk acceptance is in market volume and cost risk, particularly in new or uncertain markets where demand fluctuations are unpredictable. In such cases, businesses choose to absorb the potential impact rather than invest in costly mitigation measures. The key principle behind this strategy is that the total cost of addressing the risk must not exceed the potential damage that could result from it.

Ultimately, risk acceptance allows companies to focus resources on managing higher-priority threats while acknowledging that certain risks are an inherent part of doing business. However, organizations must continuously monitor accepted risks to ensure that changes in the business environment do not make them more severe or unmanageable over time.

### 2.3.3. Prevention

Prevention is a proactive risk management strategy that focuses on reducing the probability of an adverse event occurring rather than merely responding to it. Unlike avoidance, which involves eliminating exposure to risk by exiting a certain activity, prevention seeks to anticipate and minimize risk while continuing operations.

This approach is particularly useful for known risks, where companies can take preemptive actions to ensure that a potential risk event either does not occur or has only a minimal impact if it does. For example, firms may source from multiple suppliers for a critical component to reduce dependency on a single supplier and lower the risk of supply chain disruptions. Other common preventive measures include quality control processes, which detect defective products before shipment, and buffer inventory or excess capacity to absorb fluctuations in supply and demand.

In modern supply chain management, there is a growing emphasis on prevention rather than just mitigation, as businesses recognize the value of avoiding disruptions before they happen. Many organizations are adept at responding to risks but are now shifting their focus towards anticipating and averting potential threats.

Prevention strategies are often supported by advanced information systems that allow for real-time risk detection and management. Additionally, techniques such as catastrophe models help firms assess and prepare for extreme events. By implementing these measures, companies can significantly reduce both the likelihood and consequences of risk, ensuring greater stability and resilience in their operations.

#### 2.3.4. Mitigation

Mitigation refers to the set of strategies aimed at reducing the impact of adverse events, either by lowering their probability or by minimizing their consequences when they occur (Norrman and Jansson, 2004). Unlike prevention, which focuses on stopping risks before they materialize, mitigation is often used as a reactive approach to manage risks that cannot be entirely avoided or eliminated (Aqlan and Lam, 2015).

Mitigation strategies are particularly relevant for operational risks that have a high probability but low impact. Organizations must carefully assess whether to accept, avoid, share, or transfer a risk before opting for mitigation (Tummala and Schoenherr, 2011). Additionally, since risks are often interconnected, mitigation actions should be designed to minimize unintended consequences, as addressing one risk may inadvertently increase another (Chopra and Sodhi, 2004; Sarker et al., 2016).

Examples of mitigation strategies include flexible process strategies, which allow companies to quickly adjust to disruptions, and postponement, which delays certain production steps to better respond to demand changes. Other approaches involve localized sourcing to reduce lead times and redundancy, such as maintaining backup suppliers or additional inventory to ensure continuity in case of disruptions.

It is worth noting that some discussions in the literature use "risk mitigation" as an umbrella term for various risk management approaches, including prevention. However, a more precise definition distinguishes mitigation as a response strategy to minimize the effects of risk rather than prevent it entirely (Chopra and Sodhi, 2004). This distinction is crucial, especially when dealing with unknown risks that cannot always be anticipated or avoided. Therefore, mitigation plays a vital role in ensuring supply chain resilience and responsiveness, allowing organizations to navigate uncertainties effectively.

#### 2.3.5. Transfer and sharing

Risk transfer and risk sharing are strategies that aim to reduce the direct impact of risks on a single organization by distributing responsibility to other parties (Diabat et al., 2012). These approaches are particularly effective for low-probability, high-impact risks, such as natural disasters or financial disruptions, rather than for everyday operational risks (Aqlan and Lam, 2015).

Risk transfer occurs when an organization assigns responsibility for managing a risk to a third party. This is commonly done through insurance policies, such as business interruption insurance (Zhen et al., 2016), which help protect companies against unforeseen disruptions. Another form of risk transfer involves outsourcing critical processes to external suppliers or service providers who are better equipped to handle specific risks.

Risk sharing, on the other hand, involves distributing the impact of a risk across multiple stakeholders. This is often achieved through contracts with risk-sharing clauses, which allocate responsibilities and potential financial burdens between buyers and suppliers (Buzacott and Peng, 2012). Suppliers may also engage in risk-sharing practices by pre-ordering inventory or expanding capacity in response to guaranteed customer demand (Lai et al., 2009; Scheller-Wolf and Tayur, 2009). Another key mechanism is risk pooling, where multiple companies or insurance providers collectively manage the financial burden of rare but severe events, such as natural disasters.

In the financial sector, risk sharing is commonly observed in hedging strategies, where traders spread commodity and currency risks across multiple participants. Additionally, collaborative agreements, such as joint product development with suppliers and co-creation with customers, serve as innovative risk-sharing approaches in supply chain management (Camuffo et al., 2007).

Ultimately, both risk transfer and risk sharing allow organizations to mitigate financial exposure and improve resilience by leveraging external partnerships, legal agreements, and financial instruments. These strategies provide a way to navigate uncertainty while maintaining operational stability and customer service levels.

## 2.4. Case studies

While theoretical frameworks provide a structured understanding of risk management, their true effectiveness is demonstrated through real-world implementation. Organizations across various industries face diverse and unpredictable risks, requiring them to apply tailored risk management strategies to safeguard their operations, maintain stability, and sustain competitive advantage.

This section presents concrete examples of how companies have successfully implemented different risk management strategies in response to supply chain disruptions, financial uncertainties, cybersecurity threats, and other operational challenges. By examining these case studies, this analysis highlights the practical implications, challenges, and outcomes associated with different approaches, offering valuable insights into how businesses can enhance their resilience and adaptability in an increasingly volatile environment.

### 2.4.1. Avoidance

In recent years, several multinational companies have strategically relocated their manufacturing operations from China to countries like Thailand and Vietnam. This shift aims to mitigate risks associated with geopolitical tensions, particularly between

China and the United States, and to manage rising operational costs. This approach aligns with the supply chain risk management strategy known as "avoidance," where companies proactively circumvent potential risks by altering their operational frameworks.

Panasonic Industrial Devices Thailand Co., Ltd., a subsidiary of the Japanese conglomerate, has transitioned its production base from China to Thailand. The company specializes in manufacturing electronic measuring instruments and automation equipment, including programmable logic controllers. This move is part of Panasonic's global restructuring strategy to enhance competitiveness and leverage Thailand's skilled labor force. The relocation has led to increased utilization of local raw materials and a significant rise in employment within Thailand.

Nike has progressively reduced its manufacturing dependence on China over the past decades. In 2006, approximately 35% of Nike's footwear was produced in China. By 2021, this figure had decreased to 21%, with Vietnam emerging as a primary manufacturing hub, accounting for 51% of Nike's shoe production. This strategic shift is driven by the desire to diversify manufacturing locations and mitigate risks associated with geopolitical tensions and supply chain disruptions.

The relocations by Panasonic and Nike exemplify the implementation of the avoidance strategy in supply chain risk management. By moving manufacturing operations to countries like Thailand and Vietnam, these companies aim to:

- Mitigate Geopolitical Risks: Reducing exposure to potential trade conflicts and tariffs resulting from China-U.S. tensions.
- Control Operational Costs: Leveraging lower labor and production costs in Southeast Asian countries.
- Enhance Supply Chain Resilience: Diversifying manufacturing locations to prevent over-reliance on a single country, thereby reducing the impact of localized disruptions.

This strategic relocation underscores a proactive approach to supply chain risk management, enabling companies to maintain operational stability and safeguard against potential disruptions in an increasingly complex global trade environment.

#### 2.4.2. Prevention

Coca-Cola and Toyota have both adopted prevention strategies within their supply chain risk management frameworks to mitigate potential disruptions and ensure long-term operational stability. The prevention strategy in risk management involves taking proactive steps to reduce the likelihood of risks materializing, rather than merely reacting to them after they occur. These two companies have implemented forward-

thinking initiatives aimed at safeguarding their operations against environmental and logistical challenges.

Coca-Cola has placed significant emphasis on water stewardship as part of its broader sustainability efforts. Given that water is the primary ingredient in its products, ensuring sustainable water use is critical to the company's long-term viability. To prevent water shortages that could disrupt production and negatively impact local communities, Coca-Cola has committed to replenishing the water it uses in highly stressed regions. The company has set ambitious goals, including achieving 100% regenerative water use across 175 key facilities by 2030. This initiative focuses on reducing, reusing, and recycling water within its production processes, as well as replenishing local water sources through conservation projects. In partnership with various non-governmental organizations, Coca-Cola is working to restore watersheds and improve water accessibility in communities facing scarcity.

Furthermore, Coca-Cola has invested in advanced water-efficient technologies to enhance its production processes. These include state-of-the-art filtration systems and closed-loop water recycling techniques, which significantly reduce overall water consumption. The company has also launched global education initiatives to promote responsible water use, collaborating with governments and local organizations to implement sustainable water management practices. By adopting these preventative measures, Coca-Cola not only secures its own operational continuity but also contributes to the broader goal of water sustainability, positioning itself as a leader in corporate environmental responsibility.

Toyota, on the other hand, has focused its prevention strategy on mitigating risks associated with natural disasters, particularly in response to the 2011 earthquake and tsunami in Japan. This catastrophic event severely disrupted Toyota's supply chain, leading the company to reassess its vulnerability to such disasters. As a result, Toyota implemented a robust Business Continuity Plan (BCP) designed to prevent similar disruptions in the future. The company conducted a thorough analysis of its entire supply chain, extending beyond first-tier suppliers to include second, third, and even fourth-tier suppliers. This allowed Toyota to identify critical supply chain weaknesses and implement measures to mitigate risks. These measures included diversifying production facilities to reduce dependency on a single location, decentralizing sources for at-risk components, and standardizing certain part designs across different models to enable production flexibility in case of supply chain disruptions.

Toyota has also invested heavily in infrastructure improvements, ensuring that its warehouses and production plants are built to withstand extreme weather events and seismic activities. The company has worked with engineering firms to develop earthquake-resistant structures and has introduced automated systems that can quickly detect and respond to potential threats. Additionally, Toyota has developed emergency preparedness training programs for its workforce and suppliers, ensuring

that all stakeholders are equipped to handle unexpected disruptions effectively. By taking these proactive steps, Toyota has significantly strengthened the resilience of its supply chain and minimized the risk of production halts due to natural disasters.

Both Coca-Cola and Toyota exemplify the use of prevention strategies in supply chain risk management. Coca-Cola's approach focuses on ensuring the long-term availability of water, a key resource in its operations, while Toyota has taken extensive steps to fortify its supply chain against the risks posed by natural disasters. These strategies highlight how leading global corporations are not only addressing existing vulnerabilities but also taking proactive steps to prevent disruptions before they occur, ultimately securing their supply chains against future uncertainties. By prioritizing risk prevention, both companies set an industry standard for resilience, demonstrating that long-term strategic planning is essential in managing supply chain risks effectively.

### 2.4.3. Mitigation

Apple's supply chain risk management strategy has prominently featured mitigation efforts, particularly in response to the disruptions caused by COVID-19 lockdowns in China. Mitigation, as a risk management strategy, involves taking steps to reduce the impact of a risk once it has occurred rather than preventing it outright. Apple's response to pandemic-related factory shutdowns exemplifies this approach, demonstrating how rapid adjustments and contingency planning can help sustain operations during crises.

When China, a key hub for Apple's manufacturing, imposed strict lockdowns during the COVID-19 pandemic, the company faced significant disruptions to its production lines. In response, Apple swiftly activated its contingency plans by shifting part of its manufacturing to alternative locations, such as Vietnam and India. This move was not a long-term relocation strategy but rather a short-term, drastic mitigation effort to ensure continued production and minimize disruptions in product availability. By leveraging its diversified supply chain and relationships with multiple manufacturers, Apple was able to maintain the momentum of its product launches and sales despite regional shutdowns.

Apple's ability to implement rapid mitigation measures highlights the importance of a well-structured supply chain strategy that prioritizes flexibility and adaptability. The company's investments in diversifying its manufacturing base before the pandemic played a crucial role in its ability to execute these adjustments effectively. While China remains a critical player in Apple's supply chain, the ability to shift production to facilities in other countries provided a crucial buffer against localized disruptions.

This example underscores the significance of mitigation as a key strategy in supply chain risk management. Unlike prevention strategies that focus on avoiding risks

altogether, mitigation ensures that businesses can continue operations even when disruptions occur. Apple's quick response to supply chain disruptions during the pandemic illustrates how mitigation efforts, including contingency planning and diversified manufacturing, can safeguard a company's operational continuity and market presence in times of crisis.

#### 2.4.4. Transfer and sharing

The transfer or sharing strategy in supply chain risk management involves distributing risks to third parties through outsourcing, partnerships, or joint ventures. This approach allows companies to reduce their direct exposure to operational, regulatory, and financial risks while focusing on their core competencies. Two prominent examples of this strategy can be seen in the pharmaceutical and energy industries.

Pharmaceutical giants like Pfizer and Novartis utilize Contract Manufacturing Organizations (CMOs) to handle certain aspects of drug production. By outsourcing manufacturing to specialized firms, these companies effectively transfer the risks associated with production, including quality control, regulatory compliance, and supply chain disruptions. This approach enables them to concentrate on core activities such as research and development, innovation, and marketing. CMOs, with their expertise in large-scale pharmaceutical manufacturing, are better equipped to navigate the complexities of production and regulatory requirements, reducing the burden on pharmaceutical companies. By leveraging CMOs, Pfizer and Novartis not only mitigate production risks but also increase flexibility in responding to fluctuating demand and global market shifts.

Beyond risk reduction, outsourcing to CMOs allows pharmaceutical companies to achieve cost efficiencies and scalability. Instead of investing in expensive manufacturing facilities, these firms can allocate more resources toward drug discovery and expanding their product pipelines. However, the reliance on CMOs does present challenges, including potential quality control issues and supply chain vulnerabilities. To address these concerns, companies establish stringent oversight mechanisms, including regular audits, quality assurance programs, and long-term contracts with trusted partners. This careful balance of risk-sharing ensures that pharmaceutical companies maintain a high standard of product safety and compliance while benefiting from the advantages of outsourced manufacturing.

Similarly, BP employs risk-sharing mechanisms through joint ventures when operating in high-risk environments such as deepwater drilling. By forming partnerships with local firms or governments, BP transfers portions of environmental, operational, and financial risks to its partners. These joint ventures are particularly important in projects requiring significant capital investment and exposure to regulatory and environmental scrutiny. In projects like those in the Gulf of Mexico, BP

structures joint ventures to distribute costs and liabilities across multiple stakeholders, ensuring that risks are not borne solely by the company.

A notable instance of this strategy was seen during the Deepwater Horizon disaster, where BP's joint venture structure played a role in distributing financial and legal responsibilities across various entities involved in the project. While BP faced significant legal and reputational consequences, the shared investment structure meant that the burden of damages and response efforts was not entirely shouldered by the company alone. Through these joint ventures, BP minimizes its exposure to unpredictable geopolitical, environmental, and economic risks, allowing it to operate in regions with high resource potential despite inherent challenges.

Joint ventures also provide BP with strategic advantages, such as gaining local market expertise, securing regulatory approvals more easily, and accessing infrastructure that might otherwise be unavailable. However, just like in the pharmaceutical industry, risk-sharing through joint ventures requires careful structuring. Contracts must clearly define responsibilities, profit-sharing mechanisms, and crisis response protocols to ensure smooth collaboration between partners. By leveraging joint ventures, BP maximizes its ability to undertake large-scale, high-risk projects while mitigating financial and operational uncertainties.

Both Pfizer's reliance on CMOs and BP's joint ventures exemplify how the transfer/share strategy helps organizations manage complex risks in highly regulated and volatile industries. By distributing risk through outsourcing and partnerships, these companies enhance their operational flexibility and resilience while reducing the direct impact of disruptions and liabilities on their core business activities. While this strategy reduces a company's immediate exposure, it necessitates rigorous oversight, strong contractual agreements, and strategic partner selection to ensure continued operational success and risk mitigation. As industries evolve and global supply chains grow more intricate, the ability to effectively transfer and share risk will remain a crucial component of long-term business sustainability.

#### 2.4.5. Acceptance

The acceptance strategy in supply chain risk management involves acknowledging certain risks and continuing operations despite their presence. Companies that adopt this approach typically determine that the benefits of maintaining operations in a risk-prone environment outweigh the potential downsides. This strategy is particularly evident in industries where relocation or immediate risk mitigation measures would be either impractical or cost-prohibitive. Two key examples of this approach can be seen in the semiconductor and automotive industries.

Intel has long maintained a significant presence in earthquake-prone regions such as California and Taiwan, where it operates several semiconductor manufacturing

facilities. The company is fully aware of the seismic risks associated with these locations but accepts them due to the strategic advantages they offer. These areas provide proximity to highly skilled labor, cutting-edge research institutions, and well-established technology supply chains, which are critical for semiconductor innovation and production. Instead of relocating its facilities, Intel has incorporated advanced engineering solutions to strengthen its factories against potential earthquakes. These measures include designing buildings with seismic-resistant structures, implementing rigorous disaster preparedness protocols, and ensuring backup systems for critical operations. Despite these efforts, earthquakes remain an inherent risk, but Intel deems them an acceptable trade-off in exchange for the technological and logistical advantages these locations provide. Additionally, Intel continuously invests in research to improve the resilience of its infrastructure, working alongside government agencies and industry experts to develop state-of-the-art safety measures. This long-term commitment to mitigating earthquake risks while maintaining strategic positioning underscores the company's reliance on the acceptance strategy in risk management.

Tesla's approach during the global semiconductor shortage in 2021 exemplifies another case of acceptance in supply chain risk management. As chip supply dwindled due to pandemic-related disruptions, many automakers scrambled to find alternative sources or adjust their production strategies. Tesla, however, chose to accept the short-term consequences of the shortage, temporarily halting production at certain plants rather than making drastic operational changes. The company openly communicated these delays to stakeholders and used the downtime to refine its production processes and secure future chip supplies. Unlike other automakers that shifted to using alternative chips or scaled back production permanently, Tesla made a strategic decision to maintain its product standards and prioritize long-term stability over immediate fixes.

During this period, Tesla also reinforced its supplier relationships, working closely with chip manufacturers to ensure a more stable supply for future production cycles. The company explored in-house semiconductor development as a long-term solution to future shortages, recognizing that reliance on external suppliers posed continued risks. By investing in new technology and broadening its supplier base, Tesla demonstrated a nuanced acceptance strategy—acknowledging short-term disruptions while actively seeking ways to reduce their impact in the long run. This approach allowed Tesla to emerge from the crisis with a more resilient supply chain and a clearer strategy for handling similar disruptions in the future.

Both Intel and Tesla demonstrate how acceptance can be a viable strategy in supply chain risk management when companies evaluate risks alongside their strategic advantages. Intel continues operations in earthquake-prone areas due to the unique benefits they provide, while Tesla accepted temporary disruptions as part of a larger strategy to enhance future resilience. By understanding and managing these risks

rather than attempting to eliminate them entirely, both companies exemplify how acceptance can play a crucial role in navigating complex supply chain challenges. Furthermore, these cases highlight that acceptance does not equate to inaction but rather a calculated decision to endure specific risks while implementing measures to mitigate their long-term effects. Companies employing this strategy must balance resilience with efficiency, ensuring that their operational goals align with the risks they are willing to tolerate. As global supply chains become increasingly complex and susceptible to disruptions, businesses that master the acceptance strategy will be better positioned to adapt and thrive in an unpredictable landscape.

## 2.5. Decisions factors

While the literature extensively discusses various risk management strategies, it provides limited insight into the factors that influence the selection of one strategy over another. Most existing studies focus on the effectiveness of different approaches but do not sufficiently address the decision-making criteria that guide companies in choosing the most appropriate response to a given risk. This gap highlights the need for a deeper understanding of the key variables that shape strategic risk management choices.

This section explores the primary factors that influence decision-making in risk management, including geographical location, regulatory frameworks, technological capabilities, financial considerations, corporate risk tolerance, and reputational concerns. By identifying and analyzing these determinants, this research provides a more structured framework for understanding how businesses navigate uncertainty and tailor their risk mitigation strategies to their specific operational and market conditions.

### 2.5.1. Geographical area

Geographic location plays a crucial role in determining the most effective risk management strategies for companies operating in different regions. The inherent risks associated with specific geographical areas influence whether a company adopts prevention, mitigation, transfer, or acceptance strategies. The cases of Toyota in Japan and General Motors (GM) in the United States illustrate how geography shapes corporate decisions on risk management.

Japan is particularly prone to natural disasters such as earthquakes and tsunamis, which have historically caused significant disruptions to production and supply chains. The devastating 2011 earthquake and tsunami severely impacted Japanese manufacturers, including Toyota, which faced production halts and supplier failures.

As a response, Toyota adopted a prevention strategy to safeguard its operations against future disruptions. The company diversified its supplier base, ensuring that critical components were sourced from multiple regions to avoid single points of failure. Additionally, Toyota increased its inventories of essential parts, allowing for greater flexibility in the event of supply chain disturbances. These measures aimed to enhance resilience by reducing dependency on specific suppliers and mitigating the potential impact of natural disasters. Toyota also collaborated closely with local suppliers to implement disaster preparedness measures, further strengthening the overall stability of its supply network.

In contrast, General Motors, with a significant presence in the United States, has taken a different approach to risk management. While the U.S. does experience natural disasters, such as hurricanes and tornadoes, they are generally less frequent and severe than Japan's earthquakes and tsunamis. As a result, GM has opted for an acceptance strategy, acknowledging the risks posed by natural disasters but not undertaking large-scale preventative measures like Toyota. Instead of extensively diversifying its supplier network, GM has focused on forming strategic partnerships with key suppliers. This approach allows the company to maintain lower inventory levels and reduce holding costs while ensuring a steady supply of critical components. By accepting the inherent risks in its geographical region and balancing them against cost considerations, GM has prioritized operational efficiency over extensive disaster preparedness.

The differing approaches of Toyota and GM show how geographic factors can significantly influence risk management decisions. Companies operating in regions with a high frequency of natural disasters, like Japan, must proactively implement prevention strategies to ensure business continuity. Meanwhile, companies in regions with lower risk levels, such as the United States, may find acceptance strategies more viable, optimizing costs while maintaining manageable levels of risk exposure. Understanding the geographical landscape is therefore essential for companies to tailor their risk management strategies effectively, ensuring resilience while balancing financial and operational considerations.

### 2.5.2. Legislations

The regulatory landscape of different countries needs to be considered in shaping corporate risk management strategies. Companies operating in regions with strict environmental regulations must take proactive steps to align with legal requirements, while those in more lenient regulatory environments may opt for risk acceptance. The cases of Shell in Europe and Petrobras in Brazil highlight how regulatory differences influence corporate decision-making.

In Europe, where environmental regulations are increasingly stringent and governments are pushing for a green transition, Shell has adopted a prevention strategy to mitigate regulatory risks. The company has made significant investments in renewable energy sources such as wind and solar power to ensure compliance with evolving regulations and avoid potential sanctions or restrictions in the fossil fuel industry. By proactively embracing sustainability, Shell has not only reduced its exposure to regulatory risks but also positioned itself as a leader in the transition to cleaner energy. This forward-thinking approach allows the company to maintain a competitive advantage in a market that is rapidly moving toward decarbonization.

Conversely, in Brazil, where environmental regulations are comparatively less stringent, Petrobras has taken an acceptance approach to risk management. The company continues to invest heavily in oil and gas resources, acknowledging the potential regulatory and environmental risks but prioritizing short-term economic gains. Given Brazil's reliance on fossil fuel revenues and the government's more lenient stance on environmental enforcement, Petrobras has determined that the immediate regulatory impact is less critical than in Europe. Instead of shifting towards renewable energy, the company remains focused on maximizing its traditional energy resources to support national economic growth.

The contrast between Shell's prevention strategy in Europe and Petrobras' acceptance strategy in Brazil underscores how companies tailor their risk management approaches based on regional legislative environments. Stricter regulations push firms toward sustainability initiatives to mitigate legal and financial risks, while more permissive regulatory frameworks allow companies to prioritize existing business models over immediate compliance concerns. Understanding and adapting to these legal differences is crucial for multinational corporations aiming to navigate the complexities of global risk management effectively.

### 2.5.3. Technological resources and skills

Technological resources and workforce skills play a fundamental role in choosing corporate risk management strategies. Companies operating in industries reliant on digital security and complex supply chains must carefully evaluate how their technological capabilities and expertise influence their approach to mitigating risks. The cases of Sony and Microsoft in cybersecurity, as well as Apple and Samsung in component shortages, illustrate how different strategies are influenced by available technology and skills.

With the rise of cyber threats, companies in the video game industry have faced increasing risks associated with data breaches and system vulnerabilities. Sony experienced a major cyberattack in 2011 when the PlayStation Network was compromised, exposing millions of users' personal data and resulting in significant

financial and reputational damage. Before this incident, Sony had adopted an acceptance strategy, assuming that standard security measures were sufficient to manage cyber risks. However, after suffering the consequences of the breach, Sony shifted to a mitigation strategy, investing heavily in improved security infrastructure, developing rapid response protocols, and implementing stronger encryption measures to prevent future attacks. The company's change in approach demonstrates how technological risks, when underestimated, can force businesses to alter their risk management strategies post-crisis.

Microsoft, on the other hand, had already recognized the growing threat of cyberattacks and had proactively chosen a prevention strategy. By investing in a highly secure infrastructure for Xbox Live, Microsoft built robust cybersecurity protocols designed to protect user data and prevent major breaches before they could occur. This approach required substantial upfront investments but allowed Microsoft to maintain trust among consumers while avoiding the disruptions that plagued its competitor. Microsoft's advanced cybersecurity expertise played a crucial role in enabling this preventative strategy, showing how companies with strong technological capabilities are more likely to preemptively address risks rather than reactively mitigating damage.

A similar divergence in risk management strategies can be observed in how Apple and Samsung navigated the global shortage of electronic components. Samsung's strategy was influenced by its vertical integration, which allowed the company to produce key components such as semiconductor chips in-house. Given this advantage, Samsung was able to adopt an acceptance strategy, recognizing that while supply chain risks existed, its internal production capabilities provided a level of insulation from severe shortages. The company accepted the risk of occasional supply constraints but relied on its manufacturing capacity to mitigate major disruptions.

Apple, by contrast, does not manufacture its own chips and is heavily dependent on third-party suppliers. To mitigate the risks associated with component shortages, Apple pursued a long-term prevention strategy, securing strong partnerships with key suppliers to ensure a steady flow of critical materials. By locking in contracts and fostering close relationships with semiconductor manufacturers, Apple reduced its exposure to supply chain fluctuations and ensured greater stability in production. This strategy required foresight and investment but allowed Apple to maintain continuity in its operations even during industry-wide shortages.

These cases demonstrate how a company's technological resources and internal expertise significantly influence its risk management decisions. Businesses with advanced technological capabilities, such as Microsoft's cybersecurity expertise or Samsung's vertical integration, may find acceptance strategies more feasible due to their ability to internally mitigate risks. Conversely, companies that rely on external resources, like Sony before its security breach or Apple with its supply chain, must

adopt more proactive strategies to ensure stability and continuity. Understanding and leveraging technological capabilities is therefore a critical factor in crafting effective risk management strategies that align with a company's operational strengths and vulnerabilities.

#### 2.5.4. Reputation and cost

Also reputation and the cost of mitigation are key factors in corporate risk management, particularly in industries where consumer trust is critical. Companies must balance the financial burden of preventive measures with the potential long-term consequences of reputational damage. The case of Johnson & Johnson's Tylenol contamination crisis in the 1980s serves as a prime example of how businesses navigate this delicate balance.

After a series of poisonings linked to Tylenol, Johnson & Johnson took decisive action to protect its brand reputation and consumer safety. The company immediately recalled all Tylenol products from the market, despite the significant financial loss this entailed. Rather than opting for a reactive or acceptance strategy, Johnson & Johnson implemented a long-term prevention strategy by introducing tamper-proof packaging and investing in advanced security measures to prevent future contamination incidents. While this proactive approach involved substantial upfront costs, it ultimately allowed the company to rebuild consumer trust and reinforce its brand reputation as one committed to safety and reliability. By addressing reputational risks head-on and taking clear preventive measures, Johnson & Johnson was able to maintain its position as a leader in the pharmaceutical industry.

In contrast, several generic pharmaceutical brands, facing similar contamination risks, opted for an acceptance strategy. Instead of investing in costly preventive packaging solutions, these companies chose to maintain their standard packaging, accepting the statistically low probability of contamination. This approach allowed them to minimize costs and sustain their low-margin business model. While this decision reduced immediate financial strain, it left these companies more vulnerable to potential reputational damage if contamination incidents occurred. Unlike Johnson & Johnson, which leveraged its proactive measures to strengthen consumer confidence, generic brands prioritized cost efficiency, assuming that the likelihood of major reputational fallout was low.

These contrasting strategies highlight how reputation and mitigation costs influence corporate decision-making. Companies with strong brand recognition and long-term market presence, like Johnson & Johnson, may find it worthwhile to invest in costly preventive measures to protect their reputation and consumer trust. In contrast, businesses operating on thin profit margins may weigh the cost of mitigation against the probability of risk occurrence, sometimes opting to accept certain risks to maintain

financial stability. Ultimately, the choice between prevention and acceptance strategies is shaped by a company's resources, market position, and tolerance for reputational exposure.

### 2.5.5. Risk tolerance

Last factor considered is risk tolerance. Different companies adopt varying levels of risk tolerance based on their strategic vision, financial stability, and market positioning. The contrasting approaches of Apple and Nokia in the mobile phone industry, as well as Apple and Microsoft in the tablet market, illustrate how companies navigate risk exposure in different ways.

In the 2000s, the rise of touchscreen smartphones introduced a significant risk of technological obsolescence for traditional mobile phone manufacturers. Apple embraced a high-risk tolerance approach by accepting the radical industry shift and focusing all its resources on the development of the iPhone. Rather than diversifying its investments across multiple models or technologies, Apple bet entirely on the success of touchscreen innovation. The company accepted the risks of market uncertainty, heavy financial investment, and reputational exposure, calculating that pioneering the new technology would provide long-term advantages. This bold acceptance strategy ultimately proved highly successful, positioning Apple as a market leader.

Nokia, on the other hand, took a more risk-averse approach by adopting a mitigation strategy. While the company explored the smartphone market, it continued to focus on its traditional mobile phone business, avoiding heavy investments in touchscreen innovation. By mitigating the risks of failure, Nokia aimed to maintain stability and avoid the potential pitfalls of an untested market. However, this cautious approach proved less effective in the long run, as competitors like Apple and Samsung overtook Nokia with more aggressive innovation strategies. Nokia's lower risk tolerance resulted in a slower adaptation to industry shifts, ultimately contributing to its decline in the smartphone market.

A similar contrast in risk tolerance can be observed in Apple and Microsoft's approaches to the tablet market. Apple once again demonstrated high risk tolerance by accepting the uncertainties associated with launching new products like the iPod and iPhone, focusing on continuous innovation despite the potential for market rejection. The company introduced these devices without guarantees of success, relying on its ability to set industry trends and maintain consumer interest.

Microsoft, by contrast, employed an avoidance strategy when entering the tablet market. Rather than competing directly with Apple's consumer-focused iPad,

Microsoft delayed its entry until it could develop a differentiated product. The company launched the Surface tablet with a strong emphasis on enterprise features, deliberately avoiding direct competition in the consumer space. By taking a cautious approach, Microsoft minimized exposure to potential failure, ensuring that its product had a clear value proposition before entering the market.

These cases show how different levels of risk tolerance shape corporate decision-making. Apple's willingness to accept high-risk ventures has fueled its success in pioneering new technologies, while Nokia's and Microsoft's more cautious approaches illustrate the trade-offs between mitigating risks and seizing market opportunities. Companies must carefully assess their risk tolerance to align their strategies with long-term goals and industry dynamics.

## 2.6. Risk and solutions in the planning process

Effective risk management is not a one-time action but a continuous process that must be integrated into every phase of business planning. Each stage—ranging from strategic planning to operational execution—presents unique risks that can impact a company's performance, resilience, and long-term sustainability. Identifying these risks early and implementing appropriate mitigation strategies is crucial for ensuring stability and minimizing disruptions.

This section examines the specific risks associated with different planning phases and explores targeted solutions that organizations can adopt to mitigate potential threats. By understanding the vulnerabilities present in each stage, businesses can develop proactive risk management approaches, enhancing their ability to adapt to uncertainties and maintain efficient, resilient, and competitive operations.

### 2.6.1. Supply planning

The planning phase in supply chain management is a critical stage where companies design strategies to ensure the efficient and uninterrupted flow of goods and services. This phase involves forecasting demand, coordinating procurement, managing inventory, and identifying potential risks that could disrupt the supply chain. Effective planning enables businesses to build resilience and adaptability, ensuring operational continuity even in uncertain environments.

One of the primary risks in supply chain planning is supply disruption, which can arise from various factors such as natural disasters, political instability, wars, labor strikes, or cybersecurity attacks. Low visibility into supplier operations further exacerbates this risk, making it difficult for companies to anticipate and respond to sudden disruptions. A lack of real-time data and poor communication across supply

networks can lead to delays or missed deliveries, severely impacting production schedules and customer satisfaction.

Another significant challenge is price volatility, which can result from fluctuations in raw material costs, changes in exchange rates, or broader financial issues. Businesses that rely on imported goods or commodities are particularly vulnerable to price swings, which can increase procurement costs and reduce profit margins. Without effective planning and hedging strategies, companies may struggle to maintain stable pricing and competitive advantage.

Quality issues also pose a major risk during the planning phase. Defective or substandard materials can lead to production delays, increased waste, and higher costs associated with rework or replacements. Poor quality control within the supplier network can damage a company's reputation and lead to regulatory or legal complications. Establishing strict quality assurance measures and supplier evaluation processes is essential to mitigating this risk.

Reputational risks further add complexity to supply chain planning, as companies must ensure that their suppliers adhere to environmental, ethical, and safety regulations. Instances where suppliers fail to meet these standards can lead to public backlash, legal penalties, and loss of consumer trust. Companies must conduct due diligence and enforce compliance protocols to safeguard their brand image and uphold corporate responsibility.

Addressing these risks during the planning phase is crucial for maintaining a resilient supply chain. By implementing advanced analytics, diversifying supplier networks, and investing in risk management strategies, businesses can enhance their ability to anticipate disruptions and maintain stability in an increasingly volatile global market.

To effectively mitigate supply chain risks, companies must adopt proactive strategies that enhance resilience and ensure operational stability. One key approach is supplier diversification, which involves sourcing materials and components from multiple suppliers or regions. This reduces dependency on a single provider and minimizes the impact of potential disruptions, such as geopolitical conflicts, natural disasters, or production failures. By maintaining a diverse supplier base, companies can quickly adapt to unforeseen challenges and secure alternative sources when needed.

Establishing long-term contracts with key suppliers is another essential measure. These agreements help businesses secure stable pricing, ensuring predictability in procurement costs even in volatile market conditions. Long-term partnerships also foster collaboration and reliability, as suppliers are more likely to prioritize clients with ongoing commitments. By negotiating favorable terms, companies can reduce exposure to price fluctuations and supply shortages.

Improving supplier monitoring and training plays a crucial role in maintaining quality and regulatory compliance. Regular assessments of suppliers' financial health,

adherence to quality standards, and compliance with environmental, social, and governance (ESG) regulations help mitigate risks related to poor performance or unethical practices. Providing training programs and incentives can further enhance supplier capabilities and ensure alignment with corporate objectives.

Enhancing supply chain visibility is another effective risk management strategy. By sharing demand forecasts, production schedules, and potential risk factors, companies and suppliers can collaborate on joint mitigation plans. Implementing digital tools such as real-time tracking, predictive analytics, and blockchain technology improves transparency and enables faster responses to disruptions. Increased visibility allows businesses to anticipate issues and make informed decisions to maintain supply chain continuity.

Building safety stock of critical materials is also a fundamental precaution against supply chain disruptions. By maintaining buffer inventories, companies can absorb short-term supply shocks and continue operations without significant delays. However, balancing inventory levels is essential to avoid excess storage costs while ensuring adequate reserves for unexpected events. A well-planned inventory strategy optimizes resource allocation and provides a safeguard against uncertain market conditions.

By implementing these strategies, businesses can strengthen their supply chains against various risks and ensure sustained operational efficiency. A combination of diversification, contractual stability, supplier oversight, enhanced transparency, and strategic inventory management creates a robust framework for mitigating supply chain disruptions and maintaining competitiveness in a dynamic global market.

### 2.6.2. Production planning

Effective production planning is essential for maintaining efficiency, optimizing resources, and minimizing operational risks. Companies must anticipate and address potential disruptions to ensure smooth manufacturing processes and maintain a competitive edge. A key challenge in production planning is operational disruptions, which may arise from a lack of skilled labor, equipment breakdowns, or inadequate maintenance. Investing in workforce training programs and preventive maintenance schedules helps mitigate these risks, ensuring production lines remain functional and efficient.

Capacity management is another critical factor in production planning. Overburdened facilities can lead to inefficiencies, bottlenecks, and quality control issues, while underutilized assets result in wasted resources and increased costs. To address this, companies can implement capacity forecasting models and flexible production systems that adjust to demand fluctuations. Strategic resource allocation and

investment in automation further enhance efficiency and reduce reliance on manual processes.

A lack of flexibility in production planning can hinder a company's ability to adapt to shifts in consumer demand or customization requirements. Implementing agile manufacturing techniques, such as modular production lines and just-in-time (JIT) strategies, enables businesses to quickly respond to market changes. Advanced analytics and digital twin technology provide real-time insights into production performance, allowing for proactive adjustments and improved adaptability.

Workplace safety is another crucial consideration, as accidents can halt operations, lower productivity, and increase compliance risks. Establishing strict safety protocols, conducting regular training, and leveraging IoT-enabled monitoring systems help prevent workplace hazards and ensure compliance with occupational health standards. A strong safety culture not only protects employees but also enhances overall operational efficiency.

Reputational risks associated with production quality or ESG (Environmental, Social, and Governance) concerns must also be carefully managed. Poor product quality can lead to recalls, customer dissatisfaction, and financial losses. Similarly, failing to meet ESG standards can result in regulatory penalties and damage to brand image. Companies can implement robust quality control measures, conduct supplier audits, and invest in sustainable manufacturing practices to uphold high production standards and maintain a strong market reputation.

By adopting proactive strategies in production planning, businesses can mitigate operational risks and ensure sustainable growth. A combination of skilled labor investment, capacity optimization, flexible production techniques, safety initiatives, and stringent quality control measures strengthens production resilience and supports long-term success in a competitive industry.

To effectively manage risks in production planning, companies must implement strategies that enhance flexibility, efficiency, and resilience. One key approach is increasing capacity flexibility by utilizing modular production lines or outsourcing certain processes. This allows businesses to scale operations up or down based on market demand, ensuring optimal resource utilization without overburdening facilities or underutilizing assets. A dynamic production system enables companies to remain competitive and responsive to shifting consumer preferences.

Predictive maintenance is another critical strategy for preventing unexpected downtime and maintaining operational continuity. By leveraging real-time data and advanced monitoring systems, businesses can assess equipment health and schedule maintenance proactively. This approach reduces the risk of sudden breakdowns, extends equipment lifespan, and minimizes production interruptions, leading to cost savings and improved efficiency.

Developing a cross-trained workforce is essential to addressing labor shortages and ensuring operational resilience. By training employees in multiple roles, companies can create a more adaptable workforce capable of filling critical gaps when needed. This strategy not only enhances workforce versatility but also increases overall productivity and reduces the impact of absenteeism or turnover.

Adopting lean manufacturing principles helps businesses minimize waste, optimize resource utilization, and improve efficiency. Streamlining production processes, eliminating non-value-adding activities, and enhancing workflow coordination contribute to cost reduction and higher productivity. Lean manufacturing also supports sustainable production practices by reducing material and energy waste.

Strengthening quality assurance measures is vital to mitigating reputational and compliance risks. Implementing stringent quality control checks throughout the production process helps detect defects early and ensures products meet industry standards. Conducting regular audits, utilizing automated inspection technologies, and fostering a quality-focused organizational culture further enhance production reliability and customer trust.

By integrating these solutions into production planning, companies can enhance their operational resilience, maintain efficiency, and mitigate risks associated with disruptions, capacity constraints, labor shortages, and quality concerns. A proactive and strategic approach to production management ensures long-term stability and competitiveness in an evolving marketplace.

### 2.6.3. Inventory planning

Effective inventory planning is crucial to balancing supply and demand while mitigating risks associated with stock management. Overstocking poses a significant challenge, leading to higher storage costs and the risk of obsolescence or spoilage. Excess inventory ties up capital and can result in financial losses, especially for perishable or technology-driven products with short life cycles. Companies must implement demand forecasting techniques and real-time inventory tracking to maintain optimal stock levels and minimize waste.

Understocking, on the other hand, creates the risk of insufficient inventory, which can result in lost sales and decreased customer satisfaction. When businesses fail to meet demand due to low stock levels, they risk damaging their reputation and losing market share. To prevent this, companies can adopt data-driven inventory replenishment models and automated supply chain systems that ensure timely restocking and prevent stockouts.

Safety concerns are another major risk in inventory planning, as goods are vulnerable to theft, fires, earthquakes, and other unforeseen events. Proper warehouse security

measures, such as surveillance systems, restricted access controls, and fire prevention protocols, help safeguard inventory. Additionally, storing goods in structurally secure and geographically diverse locations can mitigate risks associated with natural disasters.

Emergency costs can arise when companies need to procure inventory at the last minute to fill unexpected gaps. Rush orders often come with higher prices and expedited shipping fees, significantly increasing overall costs. Businesses can reduce emergency procurement risks by maintaining a well-planned safety stock of critical items and collaborating with reliable suppliers who can offer flexible replenishment options.

By addressing these risks through strategic inventory planning, companies can optimize storage, improve supply chain efficiency, and ensure business continuity. Leveraging advanced forecasting tools, automated inventory management systems, and risk mitigation strategies allows organizations to maintain the right balance between supply and demand while minimizing financial and operational disruptions.

To effectively mitigate risks in inventory planning, businesses must implement strategic solutions that balance supply chain efficiency and cost management. One approach is adopting just-in-time (JIT) systems, which align inventory replenishment with real-time demand. This minimizes excess stock while ensuring that goods are available when needed. By reducing overstocking, JIT helps lower storage costs and the risk of obsolescence, particularly for perishable and fast-moving products.

Investing in advanced storage solutions enhances inventory security and preservation. Warehousing systems equipped with climate control, automated retrieval systems, and enhanced security measures help protect goods from spoilage, damage, and theft. Additionally, companies can implement real-time tracking technologies such as RFID and IoT sensors to improve inventory visibility and security.

Predictive analytics plays a crucial role in optimizing inventory management. By leveraging historical data and AI-driven forecasting models, companies can accurately predict demand fluctuations and adjust stock levels accordingly. This approach helps prevent understocking and overstocking, improving customer satisfaction while maintaining cost efficiency.

Establishing contingency plans is essential for handling supply chain disruptions. Businesses can mitigate emergency procurement costs by securing alternative suppliers or developing flexible sourcing strategies. Diversifying supplier networks ensures that inventory shortages can be quickly addressed, reducing the risks associated with last-minute purchasing at inflated prices.

By integrating these solutions into their inventory planning processes, companies can enhance operational resilience, minimize financial losses, and maintain a steady supply of goods to meet customer demands. A proactive and data-driven approach

ensures inventory remains optimized, safeguarding business continuity in an ever-changing market landscape.

#### 2.6.4. Transportation planning

Effective transportation planning is essential for maintaining a reliable and efficient supply chain. One of the primary risks associated with transportation is logistical delays, which can result from infrastructure congestion, labor strikes, accidents, or adverse weather conditions. These disruptions can significantly impact delivery schedules, leading to production halts and customer dissatisfaction. Companies must develop contingency strategies to ensure flexibility in their transportation networks and mitigate potential delays.

Product safety is another critical concern, as goods may deteriorate or be lost during transit. Perishable products, fragile items, and high-value shipments require specialized handling and tracking mechanisms to minimize damage or theft. Implementing real-time monitoring systems, secure packaging, and appropriate transportation conditions helps protect shipments and maintain product integrity.

Regulatory changes also pose a challenge in transportation planning. New emissions regulations, for example, may require companies to invest in cleaner transportation methods, potentially increasing costs and causing delays in compliance transitions. Additionally, customs regulations vary between countries, complicating cross-border logistics and increasing the risk of delays due to documentation errors or policy shifts.

Geopolitical disruptions further threaten transportation stability. Trade restrictions, sanctions, or the blocking of transit routes due to conflicts or diplomatic tensions can force companies to find alternative shipping methods or reroute logistics entirely. Businesses operating on a global scale must stay informed of political developments and maintain flexible transportation strategies to adapt to changing trade environments.

By understanding these risks, companies can better prepare for disruptions in transportation planning, ensuring supply chain resilience and reliability. A strategic approach to logistics, incorporating flexibility, compliance readiness, and robust safety measures, is crucial in mitigating transportation-related challenges.

Effective transportation planning is essential for maintaining a reliable and efficient supply chain. One of the primary risks associated with transportation is logistical delays, which can result from infrastructure congestion, labor strikes, accidents, or adverse weather conditions. These disruptions can significantly impact delivery schedules, leading to production halts and customer dissatisfaction. Companies must develop contingency strategies to ensure flexibility in their transportation networks and mitigate potential delays.

To address these challenges, businesses can diversify transportation modes by combining road, rail, sea, and air transport. This approach helps mitigate delays and cost spikes by offering alternative routes and flexibility in case of disruptions. Partnering with reliable logistics providers is another key solution, as collaborating with carriers known for on-time deliveries and safety ensures consistency and reduces the risk of product loss or damage.

Product safety is another critical concern, as goods may deteriorate or be lost during transit. Perishable products, fragile items, and high-value shipments require specialized handling and tracking mechanisms to minimize damage or theft. Implementing real-time monitoring systems, secure packaging, and appropriate transportation conditions helps protect shipments and maintain product integrity.

Regulatory changes also pose a challenge in transportation planning. New emissions regulations, for example, may require companies to invest in cleaner transportation methods, potentially increasing costs and causing delays in compliance transitions. Additionally, customs regulations vary between countries, complicating cross-border logistics and increasing the risk of delays due to documentation errors or policy shifts. Utilizing route optimization and tracking tools powered by AI can help businesses find the most efficient routes, avoid regulatory-related delays, and monitor shipments in real time.

Geopolitical disruptions further threaten transportation stability. Trade restrictions, sanctions, or the blocking of transit routes due to conflicts or diplomatic tensions can force companies to find alternative shipping methods or reroute logistics entirely. Businesses operating on a global scale must stay informed of political developments and maintain flexible transportation strategies to adapt to changing trade environments. Establishing regional distribution centers can help mitigate transit delays by positioning warehouses closer to key markets, reducing dependency on long-haul shipments.

By implementing these solutions, companies can enhance transportation resilience, reduce risks, and improve overall supply chain efficiency. A strategic approach to logistics, incorporating flexibility, compliance readiness, and robust safety measures, is crucial in mitigating transportation-related challenges.

#### 2.6.5. Demand planning

Effective demand planning is crucial for maintaining a balanced supply chain and meeting customer needs efficiently. However, several risks can impact this process, leading to operational inefficiencies and financial losses. One of the primary risks is inaccurate forecasting, where errors in demand prediction can result in either overproduction or shortages. Overproduction leads to excess inventory and increased holding costs, while shortages can cause missed sales opportunities and customer

dissatisfaction. Companies must refine their forecasting models using advanced analytics and historical data to improve accuracy.

Demand volatility presents another significant challenge, as sudden shifts in customer preferences or market conditions can disrupt supply chain planning. Economic fluctuations, seasonal trends, and unexpected global events can all influence consumer demand, making it difficult to maintain a stable supply strategy. Businesses must remain agile, employing flexible production schedules and responsive inventory management systems to adjust to rapid changes in demand.

Competition is another factor that can impact demand planning. Companies that fail to differentiate their products or align with evolving market trends risk losing market share to competitors with better offerings. Continuous market research and innovation are essential for maintaining a competitive edge. Businesses must track competitor strategies, customer feedback, and industry trends to refine their product offerings and marketing approaches.

Failed product launches pose an additional risk to demand planning. New products that do not meet sales expectations can lead to financial losses, excess inventory, and reputational damage. To mitigate this risk, companies should conduct thorough market testing, engage in customer feedback loops, and use pilot programs before full-scale production. Leveraging data-driven insights and predictive modeling can enhance the chances of a successful launch.

By addressing these risks proactively, businesses can optimize their demand planning strategies, ensuring better alignment with market needs and improving overall supply chain performance. A well-executed demand planning approach enables companies to minimize inefficiencies, enhance customer satisfaction, and maintain a competitive advantage in an unpredictable market landscape.

Effective demand planning is crucial for maintaining a balanced supply chain and meeting customer needs efficiently. However, several risks can impact this process, leading to operational inefficiencies and financial losses. One of the primary risks is inaccurate forecasting, where errors in demand prediction can result in either overproduction or shortages. Overproduction leads to excess inventory and increased holding costs, while shortages can cause missed sales opportunities and customer dissatisfaction. Companies must refine their forecasting models using advanced analytics and historical data to improve accuracy. Implementing AI-driven demand planning tools (demand sensing) can enhance forecasting precision, allowing businesses to predict customer needs more effectively.

Demand volatility presents another significant challenge, as sudden shifts in customer preferences or market conditions can disrupt supply chain planning. Economic fluctuations, seasonal trends, and unexpected global events can all influence consumer demand, making it difficult to maintain a stable supply strategy. To address this issue,

businesses can develop agile sales strategies that allow them to quickly shift focus to different products or markets in response to changing conditions.

Competition is another factor that can impact demand planning. Companies that fail to differentiate their products or align with evolving market trends risk losing market share to competitors with better offerings. To counteract this, businesses should continuously monitor competitor moves and market conditions, adjusting their pricing and strategies accordingly. Additionally, launching promotions strategically can help balance demand peaks and troughs, ensuring a steady flow of sales.

Failed product launches pose an additional risk to demand planning. New products that do not meet sales expectations can lead to financial losses, excess inventory, and reputational damage. To mitigate this risk, companies should conduct thorough market testing, engage in customer feedback loops, and use pilot programs before full-scale production. Enhancing customer communication through CRM systems can provide valuable insights into changing preferences, helping businesses reduce demand uncertainty.

By addressing these risks proactively and implementing solutions such as AI-driven forecasting, strategic promotions, agile sales strategies, enhanced customer communication, and competitor monitoring, businesses can optimize their demand planning strategies. A well-executed demand planning approach enables companies to minimize inefficiencies, enhance customer satisfaction, and maintain a competitive advantage in an unpredictable market landscape.

## 3 Methodology

The initial phase of this research was conducted through a comprehensive literature review, aimed at analyzing various academic papers to identify similarities and differences in risk management processes. This review also sought to highlight existing research gaps that could be addressed through a more in-depth investigation of the topic.

A total of 13 academic papers were analyzed, published between 2004 and 2020. The selection process was based on relevance to the research topic and methodological rigor. The sources were drawn from esteemed academic journals, including *Journal of Industrial Engineering and Management (JIEM)*, *International Journal of Physical*

*Distribution & Logistics Management, International Journal of Retail & Distribution Management, International Journal of Logistics Research and Applications, Journal of the Operational Research Society, and Supply Chain Management: An International Journal.*

The identification of relevant literature was carried out using academic databases such as Scopus, Web of Science, and Google Scholar. The search process involved the use of carefully selected keywords related to the study's core themes, ensuring the inclusion of high-quality and impactful contributions to the field. Additionally, a snowballing technique was employed to further refine the selection by examining the references cited in the initially identified papers.

The research was further expanded by identifying and analyzing various real-world applications of risk management. To complement the theoretical insights gained from the literature review, several well-documented case studies were examined, focusing on how major corporations—such as Nike, Apple, and Coca-Cola—have implemented risk management strategies discussed in academic literature.

Following the case study analysis, a deeper investigation was conducted to understand the rationale behind the selection of specific risk management strategies over others. This phase of the research aimed to uncover the key factors influencing risk management decision-making, an aspect that remains insufficiently addressed in existing literature. By comparing theoretical models with real-world practices, this study seeks to bridge the gap between academic research and practical applications, providing a more comprehensive understanding of the dynamics that shape risk management strategies in complex business environments.

Finally, to gain an even more practical perspective on risk management, three interviews were conducted with managers from Casappa, Tecniplast, and Iltom—three manufacturing companies with varying degrees of structured risk management processes. The primary objective of these interviews was to assess how risk management is perceived within organizations, the level of importance assigned to it, and the way it is structured and implemented in business operations.

Furthermore, the interviews aimed to explore how emerging technologies can be leveraged to enhance corporate risk management processes and the extent to which companies recognize the importance of integrating such technologies at an early stage. Understanding these aspects is crucial for evaluating the role of digital transformation in improving risk management efficiency and decision-making.

Additionally, valuable insights were gained from participation in a risk management workshop held at Politecnico di Milano (Polimi). This event featured presentations from corporate representatives—including executives from Bauli and Zalando—as well as university professors specializing in risk management. The workshop provided an opportunity to examine real-world experiences, challenges, and best

practices shared by industry leaders and academics, further enriching the study with practical and contemporary perspectives on risk management strategies.



## 4 Findings

### 4.1. Analysis of the possible impact on the supply chain of the chosen strategy

The implementation of risk management strategies has far-reaching consequences not only for individual companies but also for the entire supply chain ecosystem. When businesses adopt specific risk mitigation measures, they influence suppliers, logistics partners, distributors, and customers, creating both intended and unintended effects across the network. These impacts can manifest in various ways, such as increased operational stability, shifts in sourcing strategies, changes in inventory management, or disruptions in established trade routes.

This section explores the practical implications of risk management strategies on supply chains, providing concrete examples of how different industries have adapted to evolving risks. By analyzing these real-world cases, this research highlights the potential challenges and opportunities that arise when companies implement risk mitigation frameworks, offering insights into how businesses can navigate these changes while maintaining resilience and efficiency.

#### 4.1.1. Product redesign

Risk management plays a crucial role in shaping supply chain strategies, often leading to significant modifications in operations and product design. One of the key implications of implementing risk management measures is product redesign, which allows companies to adapt to disruptions and maintain business continuity. By reassessing product components and sourcing strategies, businesses can mitigate risks associated with supply shortages and ensure continued production.

A prominent example of product redesign driven by risk management is Ford's response to the global semiconductor shortage. As the supply of advanced microchips became constrained, Ford took proactive measures to redesign certain vehicles to use alternative, less sophisticated chips that were more readily available. This approach allowed the company to navigate the crisis without halting production entirely. For instance, Ford temporarily removed advanced features such as automatic climate control from its trucks, reducing reliance on high-end semiconductor components. By

making these strategic adjustments, Ford successfully mitigated the impact of supply chain disruptions while maintaining production flow and meeting consumer demand.

Another example of product redesign as a risk management strategy comes from Apple during supply chain crises. In response to the semiconductor shortage, Apple strategically reduced the features and components of lower-cost models like the iPhone SE to minimize the use of scarce chips. This allowed the company to allocate more resources toward producing its more popular, advanced models, such as the iPhone 13 and Pro versions. By prioritizing high-margin products and adjusting component allocation, Apple managed to sustain production despite supply chain constraints, ensuring profitability and market presence.



Figure 2: iPhone 13 and its cheaper version with less components, iPhone SE.

One significant trend in 2022 was the increased substitution of oils in food processing recipes. While vegetable oils differ in flavor and functionality, they can often be replaced with one another. This interchangeability leads to price fluctuations that tend to follow similar patterns across different types of oils. However, substitution presents challenges due to differences in processing characteristics and taste profiles, making it a complex decision for food processing companies. As a result, such changes are typically implemented only when absolutely necessary.

The war in Ukraine was a major driver behind the widespread substitution of sunflower oil in food products throughout 2022. Sunflower oil, a key ingredient in many processed foods, became scarce due to supply chain disruptions, forcing manufacturers to seek alternatives. Products such as mayonnaise and pre-fried frozen vegetables were particularly affected. In response, rapeseed oil emerged as the most commonly used substitute, followed by linseed, groundnut, and palm oil. However,

the adoption of palm oil was often limited due to sustainability concerns, as its production is associated with deforestation and environmental degradation.

This shift in oil usage underscores the broader impact of geopolitical events on global supply chains. The necessity of adapting to shortages highlights the importance of flexibility and contingency planning in food manufacturing. Companies had to quickly evaluate viable alternatives to maintain production while considering factors such as cost, taste, and consumer perception. The events of 2022 demonstrated the delicate balance required in ingredient sourcing and the importance of resilience in the face of supply disruptions.

These cases highlights how companies can leverage risk management to implement flexible and adaptive supply chain strategies. Product redesign not only helps in overcoming immediate challenges but also fosters resilience in the long term. By building alternative sourcing strategies and ensuring that critical components have substitutes, businesses can enhance their ability to withstand future disruptions. This approach exemplifies how risk management extends beyond short-term solutions and contributes to the overall sustainability of supply chain operations. In a dynamic global market, companies that incorporate risk management into their decision-making processes are better positioned to navigate uncertainties and maintain a competitive edge.

#### 4.1.2. Logistical and production network redesign

Another critical implication of risk management in supply chains is the redesign of logistical and production networks. Companies facing major disruptions have had to reevaluate their supplier and manufacturing strategies to ensure greater resilience and stability.

Toyota provides a key example of this shift. Following the devastating 2011 earthquake and tsunami in Japan, Toyota restructured its supply chain to reduce dependence on suppliers concentrated in a single geographic area. The company introduced the "Resilient Supply Chain" system, which involved diversifying its supplier base and spreading the production of critical components across multiple regions. This redesign reduced Toyota's vulnerability to localized disasters and ensured greater operational continuity.

Similarly, Intel has taken significant steps to redesign its production network in response to the global semiconductor shortage and geopolitical tensions in China. To mitigate risks associated with over-reliance on Asian manufacturing facilities, Intel has committed to building new semiconductor factories in the U.S. and Europe. By expanding its production footprint into these regulated and strategically important markets, Intel aims to enhance supply chain stability and reduce exposure to disruptions in Asia.

Eni and TotalEnergies have also adapted their supply strategies in response to geopolitical risks. Following the reduction of Russian gas supplies due to geopolitical tensions, these energy giants have accelerated their search for alternative sources. They have entered into agreements with African countries such as Algeria, Egypt, and Mozambique to secure stable energy supplies. This shift illustrates how companies in critical industries must continuously reassess and restructure their supply chains to mitigate risks and ensure long-term sustainability.

Additionally the outbreak of the Russia-Ukraine war has significantly disrupted global trade routes, forcing companies and logistics providers to reassess and restructure their transportation networks. Traditionally, the Northern Route, which passes through Russia and the Arctic region, was considered a viable option for transporting goods between Asia and Europe. However, due to geopolitical tensions, economic sanctions, and security risks, many businesses have shifted their focus to alternative routes that minimize exposure to Russian-controlled corridors.

Two major alternatives have emerged as the preferred options for global supply chains: the Middle Corridor and the Ocean Route.

- The Middle Corridor, also known as the Trans-Caspian International Transport Route (TITR), connects China to Europe via Kazakhstan, Azerbaijan, Georgia, and Turkey, bypassing Russia. This route has gained strategic importance due to its shorter transit time compared to ocean freight and its ability to avoid politically sensitive regions. However, logistical challenges remain, including infrastructure limitations, border-crossing inefficiencies, and higher costs compared to traditional land routes.
- The Ocean Route, which primarily relies on maritime transport via the Suez Canal, has also seen increased usage. While this route remains cost-effective and reliable, it poses challenges such as longer transit times, congestion at major ports, and rising fuel costs. Additionally, geopolitical tensions in regions such as the Red Sea and the Strait of Hormuz add another layer of uncertainty for shipping companies.

The shift away from the Northern Route reflects broader trends in global trade, where businesses must balance cost, speed, and geopolitical stability in their transportation decisions.

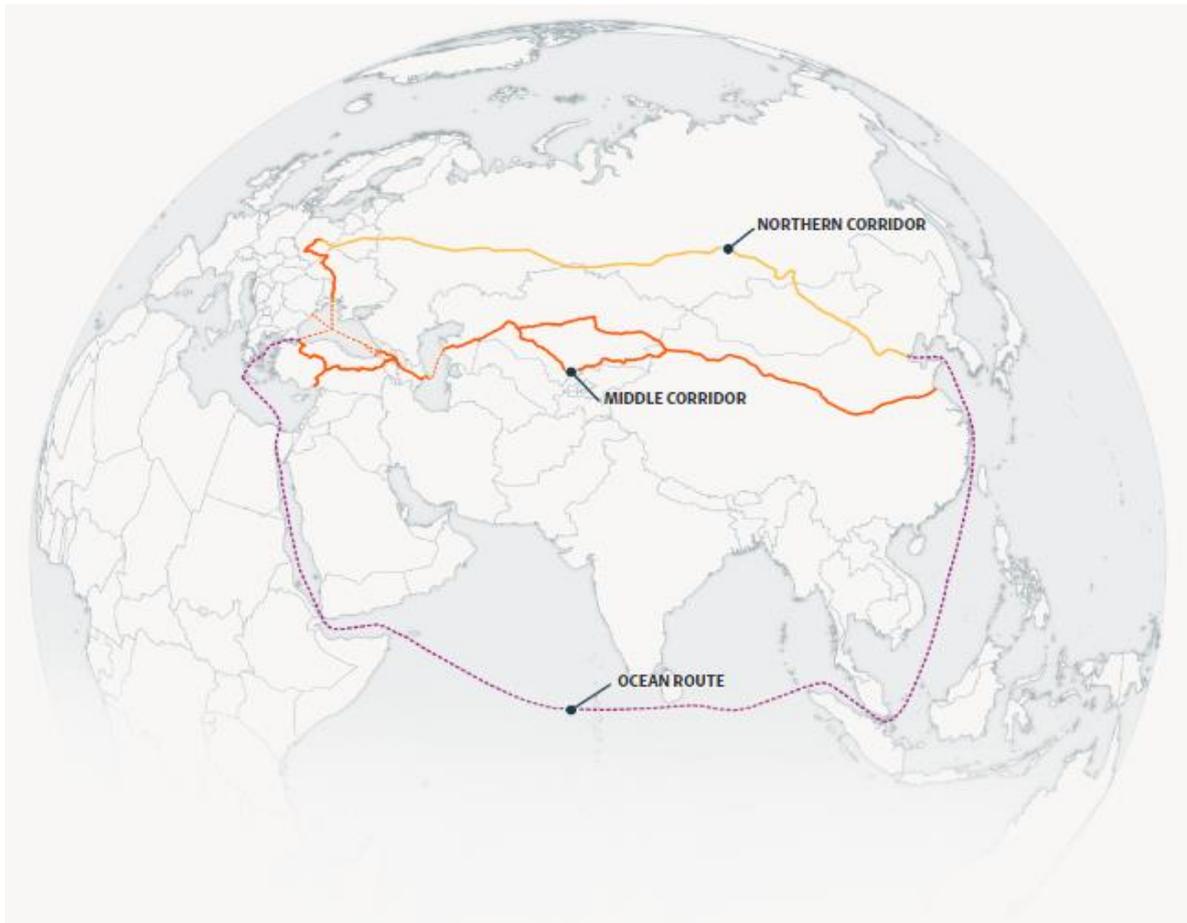


Figure 3: The new routes after the outbreak of the conflict between Russia and Ukraine

This is how companies facing substantial supply chain risks must rethink their logistical and production networks. Whether driven by natural disasters or geopolitical uncertainties, a more diversified and regionally balanced supply chain can help businesses maintain stability and competitive advantage in an increasingly uncertain world.

#### 4.1.3. Strategic partnership

Strategic partnerships play a crucial role in supply chain risk management, allowing companies to share resources, expertise, and operational capabilities to mitigate risks and enhance resilience. These collaborations help firms secure critical supplies, manage geopolitical uncertainties, and accelerate innovation.

One notable example is the partnership between Pfizer and BioNTech during the COVID-19 pandemic. Faced with the urgent need to develop and distribute vaccines on a global scale, Pfizer and BioNTech combined their strengths to overcome production and distribution challenges. BioNTech, with its cutting-edge mRNA

technology, focused on vaccine development, while Pfizer utilized its extensive manufacturing and logistics infrastructure to ensure rapid production and worldwide distribution. This strategic alliance allowed both companies to scale up vaccine output efficiently, meeting global demand in record time while minimizing supply chain disruptions.

Another significant example is the collaboration between Volkswagen and Northvolt. As the automotive industry transitions toward electric vehicles, battery supply has become a critical factor in ensuring production continuity. To reduce reliance on Asian battery manufacturers and strengthen local production capabilities, Volkswagen partnered with Northvolt to establish a battery factory in Germany. This strategic move not only secures a stable battery supply for Volkswagen's electric vehicle production but also mitigates geopolitical and international transportation risks, reinforcing the resilience of its supply chain.

Strategic partnerships like these demonstrate how companies can navigate complex supply chain challenges by leveraging shared expertise and infrastructure. By forming strong alliances, businesses can enhance operational stability, reduce vulnerabilities, and ensure long-term sustainability in an increasingly uncertain global environment.

#### 4.1.4. Nearshoring

Nearshoring has emerged as an other consequence in supply chain management, allowing companies to reduce logistical complexities, enhance resilience, and respond more effectively to market demands. By shifting production closer to their primary markets, businesses can mitigate risks associated with global disruptions and reduce transportation costs.

General Motors provides a compelling example of nearshoring in action. In response to supply chain vulnerabilities exacerbated by the COVID-19 pandemic, GM relocated portions of its vehicle and component production to Mexico. This decision was driven by the need to reduce dependence on Asian suppliers and to create a more agile supply chain that could better serve the U.S. market. By manufacturing closer to its primary consumer base, GM minimized logistical delays, optimized inventory management, and ensured a more stable production flow.

The move to Mexico also allowed General Motors to benefit from lower production costs while maintaining proximity to its key sales regions. Additionally, it provided greater flexibility in navigating trade regulations and tariffs, as well as reducing exposure to geopolitical tensions that could disrupt supply chains reliant on distant markets. Through nearshoring, GM strengthened its ability to adapt to unforeseen challenges and reinforced the resilience of its supply network.

As supply chain uncertainties persist, nearshoring continues to be an attractive strategy for companies seeking stability and efficiency. General Motors' approach highlights the advantages of relocating production to nearby regions, ensuring a more secure and responsive supply chain in an increasingly volatile global environment.

#### 4.1.5. Supply chain digitalization

Supply chain digitalization has become a critical strategy for companies aiming to improve efficiency, resilience, and responsiveness in an increasingly complex global market. By leveraging advanced technologies, businesses can gain real-time insights, optimize operations, and mitigate risks associated with supply chain disruptions.

Walmart serves as a prime example of how digital transformation can enhance supply chain management. The retail giant has invested heavily in an AI-driven platform designed to monitor its global supply chains and anticipate potential supply issues. This advanced system allows Walmart to analyze vast amounts of data, identifying patterns and predicting disruptions before they impact operations. By integrating AI into its logistics network, Walmart can respond in real-time to potential delays, rerouting orders across different suppliers or warehouses to maintain the stability of its distribution chain.

This digital approach enables Walmart to maintain high levels of inventory accuracy, reduce lead times, and improve overall supply chain efficiency. Additionally, it enhances Walmart's ability to navigate global uncertainties such as economic fluctuations, geopolitical tensions, and natural disasters. Through supply chain digitalization, Walmart strengthens its competitive advantage, ensuring that products remain available to consumers while minimizing costs and inefficiencies.

As digitalization continues to shape the future of supply chains, companies that invest in AI and data analytics will be better positioned to adapt to disruptions and meet evolving consumer demands. Walmart's approach underscores the transformative power of technology in building a resilient and agile supply chain.

## 4.2. New technologies and software for supply chain risk management

As previously discussed, emerging technologies are expected to have a transformative impact on risk management processes within companies. The challenge, therefore, lies in integrating these innovations into business operations as swiftly and effectively as

possible, in order to gain a significant competitive advantage over industry rivals. Throughout my academic journey, supported by case study analyses and extensive research, I have identified the key technologies and software solutions currently under development that have the potential to enhance risk management strategies within organizations.

One of the most groundbreaking advancements in this field is Artificial Intelligence (AI) and Machine Learning (ML). These technologies, with their ability to process vast amounts of data in real time, allow businesses to detect recurring patterns and anticipate potential risks before they materialize. For instance, many companies are already leveraging AI to monitor financial markets, identify fraudulent activities, and assess credit risk with greater accuracy. Additionally, AI-driven automation reduces human intervention in decision-making processes, thereby minimizing the risk of errors and increasing overall operational efficiency.

In parallel, Big Data and advanced analytics techniques are revolutionizing risk management by enabling organizations to aggregate and analyze data from multiple sources and build highly reliable predictive models. This approach is particularly valuable in supply chain management, where data analytics can help identify vulnerabilities, optimize logistics, and prevent operational disruptions. Furthermore, by utilizing sophisticated data-driven decision-making tools, companies can shift from relying on intuition or past experiences to making well-informed, evidence-based strategic choices.

Another technology gaining significant attention in the risk management landscape is Blockchain. With its decentralized and immutable structure, blockchain provides greater transparency, security, and traceability in business transactions and operational processes. It is already being widely adopted in sectors such as finance and logistics, where it helps reduce fraud, data manipulation, and counterfeiting risks while ensuring data integrity and regulatory compliance.

Similarly, the Internet of Things (IoT) is playing an increasingly critical role in risk management. The integration of smart sensors and connected devices enables continuous monitoring of production plants, industrial machinery, and workplace environments, allowing for early detection of anomalies or malfunctions. In manufacturing industries, for example, IoT devices are used to prevent workplace accidents, improve equipment maintenance, and minimize operational risks by providing real-time data on system performance.

In recent years, the risk management sector has also seen significant advancements due to the development of specialized software solutions provided by leading technology companies. These platforms assist businesses in monitoring potential risks, analyzing real-time data, and making proactive decisions to mitigate financial, operational, and cybersecurity threats. Many of these solutions integrate AI, predictive

analytics, and automation, allowing organizations to streamline risk management processes and reduce the impact of unforeseen events.

Among the most prominent software providers in this field is SAP, which offers the SAP GRC (Governance, Risk & Compliance) platform. This software equips companies with comprehensive tools to monitor and manage operational, financial, and regulatory risks. By automating internal controls and ensuring compliance with legal requirements, SAP GRC minimizes the likelihood of errors and violations. Its widespread adoption in finance, manufacturing, and logistics underscores its importance in maintaining business stability and mitigating corporate risks.

Another innovative solution is IBM's OpenPages with Watson, which utilizes artificial intelligence to analyze vast data sets and proactively identify potential threats. By integrating Watson's AI capabilities, this platform enables organizations to forecast risks, enhance compliance management, and continuously monitor operational vulnerabilities. Through AI-powered insights, businesses can receive intelligent recommendations on how to mitigate risks before they escalate into major challenges.

In the financial sector, one of the most recognized names is SAS, which provides SAS Risk Management and SAS Fraud Management. These software solutions are widely used by banks and insurance companies to evaluate credit risk, detect fraudulent activities, and simulate future risk scenarios. By leveraging predictive modeling, financial institutions can anticipate emerging risks and respond swiftly, reducing economic losses and reputational damage.

Another key player in the industry is MetricStream, which specializes in Enterprise Risk Management (ERM) software. This platform allows businesses to adopt a structured and integrated risk management approach, making it particularly valuable in energy, finance, and manufacturing sectors. Given the increasing need for organizations to monitor operational and regulatory risks, MetricStream provides a strategic framework to ensure business continuity and resilience.

For companies seeking a more technology-driven and automated approach, ServiceNow offers a cloud-based risk management and cybersecurity solution. This software incorporates real-time risk assessment tools, enabling businesses to detect cybersecurity threats, manage corporate crises, and safeguard sensitive data. With the rising concerns surrounding cyber risks, organizations in industries such as IT, telecommunications, and healthcare are increasingly adopting ServiceNow's solutions to prevent data breaches and mitigate security vulnerabilities.

Another widely used platform is LogicManager, which helps organizations map, assess, and monitor enterprise risks in a structured manner. By automating reporting and compliance processes, LogicManager allows businesses to identify weaknesses in their internal procedures and ensure better risk oversight.

In the industrial sector, DNV has developed Synergi Life, a software solution designed for risk management in workplace safety and environmental protection. This tool is extensively used in oil and gas, energy, and manufacturing industries to monitor workplace incidents, evaluate environmental risks, and ensure compliance with safety regulations.

Lastly, another noteworthy provider is Resolver, which specializes in Risk Intelligence solutions based on data analytics and AI. This software is particularly effective in real-time risk monitoring and automated incident management, making it a preferred choice in finance, retail, and healthcare industries.

The adoption of advanced risk management technologies is reshaping how organizations approach risk mitigation. By integrating AI-driven analytics, automation, and predictive modeling, businesses can detect and address risks more efficiently, improving operational resilience and long-term stability. As industries continue to evolve in an increasingly complex and digitalized landscape, selecting the right risk management software will become a strategic imperative for ensuring sustained growth and competitiveness.

# 5 Conclusions and recommendations

## 5.1. Summary of the main results emerging from the research

This section provides a comprehensive summary of the key findings obtained throughout this research, highlighting the most relevant insights emerging from the analysis. The aim is to offer a structured and holistic overview of the collected evidence, underlining the study's contribution to both the academic discourse and practical applications in the field. Specifically, this section will outline the implications of emerging technologies in risk management, the strategies adopted by companies to enhance risk mitigation, and the role of advanced software solutions in supporting these processes.

One of the most significant observations derived from this study is the lack of uniformity in the existing literature regarding the conceptualization and classification of risk management processes. The divergence appears across multiple dimensions, including the classification of risk types, the various stages involved in risk management, and the strategies employed to address different risk scenarios. Given this inconsistency, the present research proposes a structured classification system that categorizes risks based on their impact on the supply chain, distinguishing them into three primary categories:

- Supply-related risks, associated with disruptions in sourcing, procurement, and supplier reliability.
- Operational risks, linked to internal processes, production failures, and logistical inefficiencies.
- Demand-related risks, referring to fluctuations in customer demand, market volatility, and forecasting inaccuracies.

From these broad categories, further subclassifications can be established, incorporating specific risk factors such as environmental risks, cybersecurity threats, geopolitical uncertainties, and other external or internal vulnerabilities that may impact business operations.

While the classification of risk types varies significantly across the literature, there is greater consensus on the fundamental stages of the risk management process. The research confirms that most frameworks converge on a five-phase model, which consists of the following steps:

- **Internal Environment and Objective Setting**  
This phase defines the organizational approach to risk management, shaping how risks are perceived and addressed within the company. It includes the establishment of risk management philosophy, risk appetite, corporate integrity, and ethical values. Effective enterprise risk management (ERM) ensures that management has a structured process to define objectives aligned with the company's mission and risk tolerance.
- **Risk Identification**  
This step involves a comprehensive and systematic identification of potential risks, whether internal or external, that may impact business objectives. It requires distinguishing between risks and opportunities, employing methodologies such as supply chain mapping, checklists, event tree analysis, Failure Mode and Effects Analysis (FMEA), and Cause-and-Effect Analysis (CEA).
- **Risk Measurement and Assessment**  
At this stage, organizations determine the consequences and potential impact of each identified risk on business performance. This involves evaluating the likelihood of occurrence, assessing risk exposure values, and establishing acceptable risk levels to inform decision-making.
- **Risk Mitigation and Response**  
This phase focuses on developing and implementing risk response strategies aimed at reducing the likelihood of risks occurring and/or minimizing their negative impact. Companies must consider multiple mitigation strategies, balancing costs, feasibility, and effectiveness to ensure optimal risk management.
- **Control and Monitoring**  
Given the dynamic nature of risks, an ongoing monitoring system is essential to ensure that implemented risk response strategies remain effective. This phase includes continuous assessment, performance evaluation, and real-time adjustments to risk management processes as new challenges arise.

Another critical aspect examined in this research is the classification of risk mitigation strategies, which can be categorized based on how an organization chooses to approach and manage risk exposure. The main approaches identified in the literature and case studies are:

- **Avoidance** – When a company chooses to completely eliminate exposure to a specific risk by ceasing certain activities or modifying operations.
- **Prevention** – When a risk is inevitable but can be controlled to prevent potential damage. This involves proactive measures to minimize vulnerabilities.

- **Mitigation** – When a company accepts the occurrence of a risk but implements strategies to reduce its impact and limit negative consequences.
- **Acceptance** – When a risk is deemed manageable, and the company decides to tolerate its potential impact without taking further preventive action.
- **Transfer/Sharing** – When a company seeks to distribute risk by outsourcing, partnering with third parties, or utilizing insurance mechanisms to mitigate financial losses.

This study also explores how, through the analysis of real-world cases in which companies have implemented risk management strategies, organizations decide which strategies to adopt and how these choices can contribute to a significant competitive advantage over industry rivals. While existing literature extensively discusses different risk management approaches, it has yet to fully explain why companies choose certain strategies over others. This research aims to address this gap by identifying the key decision-making factors influencing strategy selection. These factors include:

- **Geographical location**, which determines exposure to region-specific risks such as political instability, natural disasters, or market fluctuations.
- **Regulatory frameworks**, as companies must comply with varying national and international legal requirements that shape their risk management policies.
- **Technological resources and expertise**, influencing a company's ability to implement advanced risk mitigation tools effectively.
- **Corporate reputation**, as certain strategies may be favored to maintain stakeholder trust and brand integrity.
- **Cost of mitigation vs. potential impact**, as businesses must weigh the financial feasibility of risk reduction measures against the possible consequences of inaction.
- **Risk tolerance**, reflecting an organization's overall approach to risk-taking, whether conservative or aggressive in its strategic choices.

Furthermore, the research highlights that risk mitigation actions not only impact individual companies but can also influence the entire supply chain to which they belong. The implementation of specific risk management strategies may create secondary risks or new opportunities for other stakeholders within the network. This interconnectivity suggests that businesses must be highly agile and adaptable, leveraging these evolving circumstances to their advantage in order to foster continued growth and resilience.

Finally, this thesis examines how the development and adoption of emerging technologies such as Artificial Intelligence (AI), Digital Twins, and Machine Learning could become crucial to the risk management process in the near future. Organizations

capable of integrating these innovations into their internal operations swiftly and efficiently will likely gain a substantial competitive edge within their respective markets. These technologies enable real-time risk assessment, predictive modeling, and automated decision-making, allowing businesses to anticipate challenges, optimize resource allocation, and enhance overall risk resilience. Given the accelerating pace of technological advancement, companies that proactively embrace digital transformation will not only mitigate risks more effectively but also unlock new strategic opportunities for long-term success.

## 5.2. Contribution of the thesis

This thesis aims to provide a comprehensive and structured understanding of the risk management process, offering a clearer framework for both academics and practitioners. By examining the various types of risks that organizations may encounter and detailing the key phases of an effective risk management system, this research seeks to enhance awareness of the fundamental principles and best practices that businesses should adopt. A well-structured risk management framework is essential for companies to anticipate potential threats, mitigate their impact, and ensure business continuity, particularly in an increasingly volatile and complex global environment.

A key contribution of this thesis lies in its effort to bridge an existing gap in the literature. While numerous studies have explored different risk management strategies, few have focused on the factors that influence the selection of one approach over another. The ability to choose the most suitable risk mitigation strategy is crucial, as companies operate in diverse geographical, regulatory, and technological contexts, each of which presents unique challenges and constraints. This research identifies several critical decision-making factors that organizations should consider when designing their risk management approach, including:

- Geographical location – The region in which a company operates significantly affects its exposure to political, economic, and environmental risks.
- Regulatory frameworks – Compliance with national and international regulations is a determining factor in shaping risk management policies.
- Technological resources and expertise – The availability of digital tools, automation, and skilled personnel influences the ability to implement risk mitigation strategies effectively.
- Corporate reputation and stakeholder expectations – Companies must balance risk management efforts with their commitment to social responsibility, sustainability, and long-term brand integrity.

- Cost-benefit analysis of mitigation measures – Organizations must evaluate whether the cost of preventive actions justifies the reduction in potential damage.
- Risk tolerance and strategic orientation – Some firms may adopt a risk-averse approach, while others may embrace calculated risks as part of their growth strategy.

By integrating these elements into the decision-making process, companies can develop more informed and context-specific risk management strategies, ensuring that their approach aligns with their business objectives and operational environment.

Furthermore, this thesis highlights the increasingly critical role of emerging technologies in modern risk management. In an era where data-driven decision-making and automation are becoming key drivers of business success, leveraging technological advancements can significantly enhance a company's ability to detect, assess, and respond to risks in real time. This research emphasizes the potential of Artificial Intelligence (AI), Digital Twins, and Machine Learning to revolutionize risk management processes by enabling:

- Real-time risk monitoring and predictive analytics, allowing businesses to anticipate threats before they escalate.
- Enhanced automation and efficiency, reducing reliance on manual risk assessment methods and minimizing human error.
- Data-driven decision-making, integrating big data analytics to improve the accuracy of risk forecasting.
- Adaptive and responsive mitigation strategies, enabling businesses to react swiftly to emerging risks and capitalize on new opportunities.

Given the rapid evolution of digital solutions, this thesis encourages companies to proactively integrate technological tools into their risk management frameworks. Those that can adopt and implement these technologies efficiently will gain a substantial competitive advantage, ensuring greater operational resilience and adaptability in the face of uncertainty.

In conclusion, this research contributes to both the theoretical understanding and practical application of risk management. By clarifying key concepts, addressing existing gaps in the literature, and advocating for the strategic adoption of new technologies, this thesis provides valuable insights that can help businesses navigate an increasingly complex risk landscape. The findings presented here not only support more robust and informed decision-making but also offer a foundation for future research on the intersection between technological innovation and risk management strategies.

### 5.3. Future researches

The future of risk management will be closely intertwined with the continuous advancement of technology. As businesses operate in an increasingly dynamic and unpredictable environment, the integration of emerging digital solutions into risk management frameworks will become a critical area of study. Future research should focus on how companies can effectively adopt and optimize the use of technologies such as Artificial Intelligence (AI), Digital Twins, Machine Learning (ML), Blockchain, and the Internet of Things (IoT) to enhance risk identification, assessment, and mitigation processes.

One of the key challenges will understand how to seamlessly integrate these technologies into existing corporate structures, ensuring that risk management strategies evolve in parallel with technological advancements. Future studies should explore best practices for aligning digital transformation with corporate risk culture, investigating how companies can develop adaptive, technology-driven risk management models that leverage real-time data, automation, and predictive analytics.

Moreover, research should address the barriers to technology adoption in risk management, including financial constraints, lack of expertise, cybersecurity risks, and regulatory compliance issues. The successful implementation of advanced digital solutions requires not only technological investments but also significant organizational change, including workforce training and the development of new risk governance models.

Another crucial area for future research is the interconnectivity of risk management across supply chains and industries. As companies become more digitally interconnected, risk mitigation strategies must be designed to consider external dependencies, potential vulnerabilities in global supply networks, and cross-industry risk implications. The role of collaborative risk management platforms that leverage shared data and AI-driven insights could be a key area of study in the coming years.

Finally, with the rise of AI-driven decision-making in risk management, ethical considerations must also be examined. Future research should explore how to balance automation with human oversight, ensuring that AI-driven risk assessment tools remain transparent, accountable, and free from bias while maintaining corporate resilience.

In conclusion, as technological advancements continue to reshape risk management, future studies should focus on bridging the gap between innovation and corporate risk strategy. The ability to effectively integrate new technologies into risk management

processes will define the success and competitiveness of organizations in the digital era.

## 6 References

- M. S. Shahbaz (2019), "A novel classification of supply chain risks: Scale development and validation", *Journal of Industrial Engineering and Management (JIEM)*
- G. L. Schlegel & R. J. Trent (2015), "Supply Chain Risk Management An Emerging Discipline"
- D. Bandalay et al. (2012), "Supply chain risk management – I: Conceptualization, framework and planning process"
- M. Christopher & H. Peck (2004), "Creating agile supply chains in the fashion industry", *International Journal of Retail & Distribution Management*
- I. Manuj & J. T. Mentzer (2008), "Global supply chain risk management strategies", *International Journal of Physical Distribution & Logistics Management*
- P. G. P. Gaspar (2020), "Phases and tools for supply chain risk management: a systematic literature review"
- Y. Fan & M. Stevenson (2018), "A review of supply chain risk management: definition, theory, and research agenda", *International Journal of Physical Distribution & Logistics Management*
- I. Kilubi (2016), "The strategies of supply chain risk management – a synthesis and classification", *International Journal of Logistics Research and Applications*
- B. Ritchie & C. Brindley (2007), "An emergent framework for supply chain risk management and performance measurement", *Journal of the Operational Research Society*
- D. Bandalay et al. (2013), "Supply chain risk management – II: A review of individual and integrated operational and financial approaches"
- D. Waters (2007), "SUPPLY CHAIN RISK MANAGEMENT, Vulnerability and Resilience in Logistics"
- R. Tummala & T. Schoenherr (2011), "Assessing and managing risks using the Supply Chain Risk Management Process (SCRMP)", *Supply Chain Management: An International Journal*
- "<https://www.taiwannews.com.tw/news/4399466>," [Online].

"[https://www.controlrisks.com/our-thinking/insights/big-picture-series-the-great-supply-chain-relocation?utm\\_referrer=https://](https://www.controlrisks.com/our-thinking/insights/big-picture-series-the-great-supply-chain-relocation?utm_referrer=https://) ," [Online].

"<https://www.scmp.com/comment/opinion/article/3016550/moving-factories-china-southeast-asia-watch-out-rising-costs-and>," [Online].

"<https://www.nationthailand.com/business/trading-investment/40029075>," [Online].

"<https://arc-group.com/move-manufacturing-china-to-southeast-asia/> ," [Online].

"<https://www.controlrisks.com/our-thinking/insights/big-picture-series-the-great-supply-chain-relocation>," [Online].

"<https://eustochos.com/nike-and-the-2024-supply-chain-disruption-a-case-study-in-crisis-management/>" [Online].

"<https://www.globalsources.com/knowledge/manufacturing-in-vietnam-4-key-factors-for-moving-from-china/>" [Online].

"<https://www.nationthailand.com/business/trading-investment/40029075>," [Online].

"<https://www.scmp.com/news/asia/south-asia/article/3218025/chinese-companies-are-moving-supply-chains-out-china-manage-risks-india-malaysia-and-indonesia>," [Online].

"<https://www.yicaiglobal.com/news/chinese-industrial-chains-new-home-is-southeast-asia>," [Online].

"<https://assomac.it/en/news/news-from-world/relocation-from-china-to-vietnam-confirmed/>" [Online].

"<https://arc-group.com/move-manufacturing-china-to-southeast-asia/>" [Online].

"<https://www.slideshare.net/slideshow/supply-chain-managementnike-50874312/50874312>," [Online].

"<https://www.coca-colacompany.com/content/dam/company/us/en/reports/coca-cola-business-sustainability-report-2022.pdf#page%253D24>," [Online].

"<https://esgnews.com/coca-cola-releases-key-goals-detailing-2030-water-security-strategy/> ," [Online].

"<https://www.coca-cola.com/eu/en/media-center/our-water-security-strategy>," [Online].

"<https://nepsoort.com/coca-cola-aims-for-100-water-replenishment-and-recycling/>" [Online].

"<https://www.ineak.com/toyotas-strategy-for-supply-chain-resilience/>" [Online].

"<https://abiedu.com/case-study-supply-chain-management-at-toyota/>," [Online].

"<https://www.ineak.com/case-study-toyotas-response-to-the-2011-earthquake-and-tsunami/>" [Online].

"[https://www.toyota-global.com/pages/contents/investors/ir\\_library/annual/pdf/2012/p30\\_31.pdf](https://www.toyota-global.com/pages/contents/investors/ir_library/annual/pdf/2012/p30_31.pdf)," [Online].

"<https://asia.nikkei.com/Spotlight/Supply-Chain/Apple-to-shift-iPad-capacity-to-Vietnam-amid-China-supply-chain-woes>," [Online].

"<https://www.washingtonpost.com/technology/2024/04/02/tesla-deliveries-sales-elon-musk/>," [Online].

"<https://www.ft.com/content/f414ef82-2298-4611-a202-9af42fbf644f>," [Online].

"<https://www.ineak.com/case-study-toyotas-response-to-the-2011-earthquake-and-tsunami/>," [Online].

"<https://www.reuters.com/business/energy/petrobras-new-investment-plan-have-greater-focus-oil-gas-cfo-says-2024-09-16/>" [Online].

"<https://nltimes.nl/2024/03/14/shell-invest-15-billion-renewables-2026>," [Online].

"<https://cybersoochna.com/sony-playstation-network-data-breach-2011-lessons-in-data-security-and-user-protection/>," [Online].

"<https://www.linkedin.com/pulse/samsung-electronics-innovation-challenges-global-chip-race-3z7of/>," [Online].

"<https://www.ou.edu/deptcomm/dodjcc/groups/02C2/Johnson%20&%20Johnson.htm>," [Online].

"<https://www.enterprisegarage.io/2015/12/case-study-how-nokia-lost-the-smartphone-battle/>," [Online].

"<https://media.ford.com/content/fordmedia/fna/us/en/news/2021/03/18/ford-global-semiconductor-update.html>," [Online].

"<https://www.ft.com/content/f414ef82-2298-4611-a202-9af>," [Online].

<https://www.ineak.com/case-study-toyotas-response-to-the-2011-earthquake-and-tsunami/42fbf644f>," [Online].

<https://www.volkswagen-group.com/en/press-releases/volkswagen-and-northvolt-form-joint-venture-for-battery-production-16646>, [Online].

<https://www.pfizer.com/news/press-release/press-release-detail/pfizer-and-biontech-announce-further-details-collaboration#:~:text=The%20collaboration%20aims%20to%20rapidly,to%20the%20vaccine%2C%20if%20approved>, [Online].

<https://seekingalpha.com/news/4169189-general-motors-in-talks-to-move-asian-manufacturing-to-mexico>, [Online].

<https://www.investopedia.com/how-walmart-can-benefit-from-ai-and-automation-8675785>, [Online].

<https://www.cbi.eu/market-information/grains-pulses-oilseeds/what-impact-war-ukraine-exports-vegetable-oils>, [Online].

<https://www.lumsanews.it/eni-i-contratti-stretti-dopo-la-guerra-in-ucraina>, [Online].

<https://www.rferl.org/a/middle-corridor-china-ukraine-war/33041577.html>, [Online].

<https://www.gartner.com/reviews/market/integrated-risk-management>, [Online].



## Appendix A – Iltom interview

### AZIENDA

Il Gruppo Iltom è un'azienda internazionale specializzata nella carpenteria industriale leggera, con sede principale in Italia e siti produttivi distribuiti in Francia, Bulgaria e Romania. Oltre alla produzione conto terzi basata su disegni forniti dai clienti, l'azienda si distingue per un processo produttivo integrato, che spazia dalla lavorazione delle materie prime fino all'assemblaggio finale. Tra le principali lavorazioni figurano il taglio, la piegatura, l'assemblaggio e la saldatura, supportate da diversi gradi di automazione, nonché la verniciatura, effettuata in Italia anche con tecniche a polvere elettrostatica.

Con circa 700 dipendenti e un fatturato annuo di 100 milioni di euro, Iltom opera in un contesto competitivo, grazie a una rete produttiva flessibile e alla capacità di rispondere con tempestività alle esigenze dei clienti in diversi mercati.

### ESIGENZA

Nel contesto di un mercato sempre più competitivo e globalizzato, Iltom dedica particolare attenzione alla gestione del rischio, integrando strategie preventive e correttive per garantire la continuità operativa e la soddisfazione del cliente. Questo approccio consente di affrontare sia rischi strategici, come la perdita di competitività o clienti, sia rischi operativi legati alla produzione e alla supply chain.

### ORGANIZZAZIONE E PROCESSO DI RISK MANAGEMENT

Il processo di gestione del rischio in Iltom si articola su due livelli. Da un lato, vi è un'analisi strategica annuale, in cui le principali aree di rischio vengono identificate e valutate da un team dedicato, che propone le azioni da intraprendere ai livelli decisionali superiori. Dall'altro, vi è una gestione più operativa e quotidiana, che si concentra sugli impatti immediati per garantire la continuità del business e rispondere tempestivamente alle criticità.

Uno degli aspetti più critici è la valutazione dei fornitori. Ogni anno viene effettuata un'analisi per individuare i fornitori strategici, difficilmente sostituibili, come ad esempio quelli che forniscono polveri per la verniciatura. Questi fornitori vengono classificati come critici e ne viene verificata la solidità attraverso analisi finanziarie e

audit periodici. In caso di rischio associato a un fornitore critico, le azioni intraprese includono la ricerca di fornitori alternativi e l'avvio di test sui loro prodotti o l'adozione di strategie per facilitare una risposta immediata, come il testing di prodotti alternativi.

In ambito produttivo, il rischio può derivare da guasti ai macchinari o dalla mancanza di personale qualificato. Per affrontare queste situazioni, Iltom ha implementato una pianificazione delle competenze per garantire la polivalenza dei dipendenti, riducendo così le lacune operative. Inoltre, la standardizzazione di programmi tecnici e macchinari in tutti i siti produttivi consente di spostare rapidamente la produzione da una sede all'altra in caso di emergenze o picchi di domanda.

Il gruppo utilizza la metodologia PIFMEA per analizzare i rischi associati ai processi produttivi, identificando e classificando gli errori potenziali in collaborazione con i clienti. Questo approccio valuta tre fattori principali: la probabilità di accadimento, la possibilità di rilevare l'errore e l'impatto sul cliente, producendo una scala di priorità per gestire i rischi in modo efficace.

Sebbene Iltom non utilizzi ancora software avanzati per la gestione del rischio, la digitalizzazione rappresenta una priorità per il futuro. Tecnologie come l'intelligenza artificiale e il machine learning, sebbene ancora immature per alcune applicazioni, potrebbero offrire strumenti utili per prevedere e gestire le criticità in modo più efficiente.

Un altro aspetto rilevante è l'attenzione crescente ai criteri ESG, che i clienti dell'azienda gestiscono attraverso piattaforme come EcoVadis, mentre Iltom si limita all'introduzione di codici etici e audit per i fornitori. Pur essendo ancora in una fase iniziale rispetto ad alcuni clienti, Iltom sta sviluppando un approccio più strutturato alla sostenibilità, riflettendo la crescente importanza di questi temi nel mercato globale.

## Appendix B – Tecniplast interview

### AZIENDA

Tecniplast è un'azienda globale che opera in tre principali ambiti produttivi. Nel settore tessile è gestita dal Gruppo Testori. Nel comparto destinato ai laboratori, l'azienda sviluppa cappe chimiche, frigoriferi tecnici e altri strumenti altamente specializzati. Infine, nel settore del benessere animale, Tecniplast è leader nella progettazione e realizzazione di sistemi per la cura, gestione e manutenzione degli animali da laboratorio.

La struttura produttiva comprende uno stabilimento centrale in Italia e due siti specializzati in Pennsylvania e Cina, focalizzati sull'assemblaggio di gabbie attraverso processi di saldatura avanzati. Con una rete capillare di filiali distribuite a livello mondiale, Tecniplast ha raggiunto un fatturato annuo di 110 milioni di euro, consolidandosi come una realtà di riferimento nel proprio mercato.

### ESIGENZA

Il contesto economico e industriale odierno, caratterizzato da una crescente complessità e da una forte interconnessione globale, ha spinto Tecniplast a sviluppare un approccio integrato al Risk Management. Questo sistema non solo mira a identificare e mitigare i rischi, ma anche a individuare e sfruttare le opportunità, garantendo resilienza e continuità operativa. La gestione del rischio si è dimostrata cruciale in momenti complessi, come la recente crisi globale delle forniture, e continua a evolversi per affrontare le sfide del futuro.

### ORGANIZZAZIONE E PROCESSO DI RISK MANAGEMENT

Il sistema di Risk Management adottato da Tecniplast si fonda su una struttura organizzativa che vede la partecipazione di un team multidisciplinare, coordinato da un accountable, con rappresentanti di tutte le principali business unit. Le riunioni del team si svolgono con cadenza mensile, ma possono essere convocate in via straordinaria in caso di necessità particolari.

Il processo prende avvio dalla segnalazione di un rischio o di un'opportunità, che può essere proposta da qualsiasi collaboratore dell'organizzazione. Le segnalazioni vengono valutate dal team che, una volta validate, le classifica e assegna a un owner specifico. Quest'ultimo è responsabile di condurre un assessment approfondito, stimando l'impatto (che può essere legale, reputazionale o economico) e la probabilità di accadimento, utilizzando scale standardizzate come la matrice di Likert. La matrice a 16 settori consente di classificare i rischi con un livello di severità variabile, che non sempre corrisponde al semplice prodotto tra impatto e probabilità, ma che tiene conto di criteri specifici definiti dall'azienda.

Le strategie di gestione includono l'eliminazione del rischio (avoidance) per casi critici come quelli etici o legati alla salute, il trasferimento (transfer), la mitigazione (mitigation) e, in alcuni casi, l'accettazione consapevole del rischio residuo (acceptance). Tecniplast ha adottato nel corso degli anni un'analisi di doppia materialità per la gestione del rischio. Questo approccio consente di valutare sia i rischi che le opportunità, considerando l'impatto inside-out (cioè dell'azienda sull'ambiente esterno) e outside-in (ovvero delle condizioni esterne sull'azienda stessa). Anche le opportunità saranno trattate con strategie mirate, come l'inazione strategica o lo sfruttamento consapevole, in modo da massimizzare i benefici per l'organizzazione e gli stakeholder.

Un esempio significativo della capacità di gestione dei rischi da parte di Tecniplast è rappresentato dalla crisi delle forniture globali del 2022, quando il lead time per componenti essenziali era di ben 180 settimane. In questa circostanza, l'azienda ha adottato una combinazione di strategie: identificazione di fornitori alternativi, acquisizione di scorte strategiche e redesign dei prodotti per ridurre la dipendenza da fornitori di primo livello. Queste azioni, unite a rapporti di partnership consolidati con i fornitori, hanno consentito di mantenere la continuità operativa e di aumentare la resilienza della supply chain.

Il processo di Risk Management in Tecniplast è sempre stato in continua evoluzione: partendo da un foglio Excel sviluppato internamente dal team di Risk Management, l'azienda ha utilizzato MS Access per analizzare in modo strutturato i dati provenienti da più fonti, e ora l'azienda ha adottato degli applicativi digitali specializzati che considerano diversi fattori di rischio per i processi end-to-end della supply chain, accessibili da qualunque parte del mondo. Guardando al futuro, l'azienda ha intenzione di integrare nuove tecnologie nel processo di Risk Management, come i digital twin, l'intelligenza artificiale generativa e il machine learning che promettono di migliorare le attività di valutazione e monitoraggio dei rischi. Tuttavia, come sottolinea il Supply Chain Director Roberto Crippa, il cuore del sistema rimane umano: "Le nuove tecnologie possono rendere più facile l'interpretazione e la ricerca di

informazioni da parte degli umani, ma non sostituirli. Sono come un esoscheletro: potenziano le nostre capacità, ma non possono completamente sostituirci.”



## List of Figures

Figure 1.....	3
Figure 2.....	56
Figure 3.....	59



## List of Tables

Table 1.....	11
--------------	----







## Acknowledgments

I would like to express my deepest gratitude to all those who have contributed to the completion of this thesis.

First and foremost, I am sincerely grateful to my supervisors, Nataliia Roskladka and Giovanni Miragliotta, for their invaluable guidance, continuous support, and insightful advice throughout this research journey. Without their expertise and dedication, this work would not have been possible.

I would also like to extend my heartfelt thanks to my colleagues and fellow students, for the stimulating discussions, moral support, and exchange of ideas that have enriched my academic experience.

A special thanks goes to Iltom, Casappa, and Tecniplast, whose support and collaboration have been fundamental in the development of this research. Their expertise, resources, and willingness to assist me have significantly contributed to the success of this work.

I am also deeply grateful to my family and friends, whose unwavering support, patience, and encouragement have been essential in overcoming challenges and celebrating achievements along the way. Without them, I would not have reached this milestone.

Finally, I would like to express my appreciation to all those who, in various ways, have contributed to this journey, offering suggestions, motivation, and inspiration.

Thank you all from the bottom of my heart.

