Evaluating and Managing Post-Pandemic Consumer-Packaged Goods Supply Chain Resilience through a Risk Analysis and Mitigation Lens

by Diane Alsing

Bachelor of Science in Business Studies, January 2011, Southern New Hampshire University
Master of Science in Engineering Management, May 2021, The George Washington University

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Praxis directed by

Benjamin Stirgwolt
Professorial Lecturer of Engineering Management and Systems Engineering

The School of Engineering and Applied Science of The George Washington University certifies that Diane Alsing has passed the Final Examination for the degree of Doctor of Engineering as of November 30, 2023. This is the final and approved form of the Praxis.

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Diane Alsing

Praxis Research Committee:

Benjamin Stirgwolt, Professorial Lecturer in Engineering and Applied Science, Praxis Director

Daniyal Ali, Professorial Lecturer in Engineering and Applied Science, Committee Member

Amir Etemadi, Assistant Professor of Engineering and Applied Science, Committee Member

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Dedication

I dedicate this praxis to the individuals who have been providing support throughout my academic journey.

To Kevin, my husband: Your encouragement kept me going through this process, providing help and guidance along the way.

To my amazing sisters, Maryanne, Tricia, and Aimee: I am grateful for your constant support, motivation, and belief in my potential. Your confidence in my abilities has inspired me, reminding me of the importance of perseverance, determination, and sleep.

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Abstract of Praxis

Evaluating and Managing Post-Pandemic Consumer-Packaged Goods Supply Chain Resilience through a Risk Analysis and Mitigation Lens

In the years preceding the pandemic, the consumer-packaged goods (CPG) industry faced considerable turbulence, marked by shifting consumer behaviors driven by factors such as pricing pressures due to retail consolidation, commodity price volatility, a growing emphasis on sustainability, and notable generational shifts among consumers. This industry's unique product mix, encompassing essentials like food and beverages along with semi-discretionary items such as personal care and household supplies, intensified supply chain challenges with regulatory and compliance cost considerations. With the onset of the COVID-19 pandemic, vulnerabilities within the global supply chain were exacerbated and exposed, revealing a lack of visibility into shifting consumer demand, disruptions in transportation, and inadequacies in the supply of essential products and raw materials.

As the world progresses beyond the pandemic, businesses must navigate a supply chain landscape fundamentally altered by these events. This new landscape challenges organizations to adapt to a dynamic environment with emergent supply chain disruption risks. This research proposes that CPG companies leverage a decision-support tool to enhance their capacity to identify, assess, and effectively mitigate potential high-probability, high-impact points of failure within their supply chains. This study explores the creation and validation of a decision-support tool specifically designed for the unique challenges within the CPG industry. Employing quantitative methodologies, the research not only formulates this tool but also evaluates its proficiency in identifying and

determining if specific risk mitigation strategies should be considered. The ultimate objective is to equip CPG companies with a robust method to proactively navigate supply chain disruptions, ensuring enhanced resilience and sustainability in the post-pandemic landscape.

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List of Acronyms

AI	Artificial Intelligence
CPG	Consumer-Packaged Goods
CSCO	Chief Supply Chain Officer
ERP	Enterprise Resource Planning
FMEA	Failure Mode and Effects Analysis
IOT	Internet of Things
ISO	International Organization for Standardization
SCRM	Supply Chain Risk Management
SCRQ	Supply Chain Risk Questionnaire
SD	Standard Deviation
U.S.	United States

Chapter 1—Introduction

1.1. Background

The COVID-19 pandemic exposed vulnerabilities within the global supply chain, resulting in unprecedented and substantial financial losses. To gauge the extent of these impacts, a research study conducted by Dimensional Research in collaboration with Jabil, a prominent manufacturing solutions provider, engaged supply chain leaders in an assessment. The study's findings were striking, with a 92% of the participating companies acknowledging they had directly suffered significant financial setbacks attributable to supply chain challenges brought on by the COVID-19 pandemic (Jabil, 2020).

Figure 1-1, derived from the results of Jabil's survey, depicts the extensive financial implications that the pandemic wrought on businesses. The survey's participants were presented with a question, asking them to assess the negative financial impact on their company's business outcomes arising from the supply chain disruptions directly linked to COVID-19. The responses painted a clear picture of the widespread financial distress experienced across industries and sectors, accentuating the significance of the challenges encountered during this period.

Figure 1-1. Losses from Supply Chain Disruption (Jabil, 2020)

The study's output furnishes the following pertinent statistical insights:

- “6 in 10 supply chain leaders say their supply chain strategies are focused on responding to disruption and reducing risk in the next two years.”
- “82% say their supply chain footprint has shifted notably due to COVID-19.”

The CPG industry was particularly hard hit by the pandemic and was center stage at its onset. Consumers faced empty store shelves and extraordinary uncertainty (Consumer Brands Association, 2021). While the pandemic exacerbated supply chain vulnerability, the industry was already undergoing a revolution. In the years preceding the pandemic, the CPG industry encountered considerable turbulence, marked by shifting consumer behaviors. These behaviors were driven by factors such as pricing pressures due to retail consolidation, commodity price volatility, a growing emphasis on sustainability, and notable generational shifts among consumers. The unique product mix of this industry, which includes essentials, such as food and beverages, along with semi-discretionary items, such as personal care and household supplies, amplified supply chain challenges by introducing additional regulatory and compliance cost considerations (Bustamante et al., 2022). This research focuses specifically on the CPG industry to assist with understanding the industry’s evolving dynamics and the implications on the global supply chain.

1.2. Research Motivation

In the modern supply chain management landscape, the chief supply chain officer (CSCO) is pivotal in strengthening an organization's global supply chain and enhancing its efficiency and resilience (Global Supply Chain Institute, 2019). However, the CSCO operates within the constraints of both time and budget. To optimize these finite resources effectively, it becomes imperative for the CSCO to prioritize risks that are not only statistically probable but also carry the highest potential impact. This research proposes the utilization of a decision-support tool by the CSCO to help provide a focus on the identification, mitigation, and resolution of supply chain risks that are both statistically probable and consequential, thereby providing a strategic focus on resource allocation.

1.3. Problem Statement

Following the pandemic, the CPG industry faces increased challenges in identifying and addressing supply chain risks (Consumer Brands Association, 2021)*, which can result in disruptions costing an average of 6–10% of annual revenues* (Kingsley, 2021).

In the wake of the global pandemic, the CPG industry confronts a mounting challenge that demands action: identifying and effectively mitigating probable and impactful supply chain risks. As highlighted by the Consumer Brands Association (Consumer Brands Association, 2021), the post-pandemic landscape has ushered in a new era of supply chain complexity and the speed at which change is occurring. This complexity encompasses numerous risk factors, including shifting consumer demands, transportation uncertainties, and volatility in the availability of essential products and raw

materials. The consequences of inadequate risk management are financially substantial (Kingsley, 2021) and need to be addressed.

1.4. Thesis Statement

A decision-support tool is imperative for assisting CPG firms in identifying and addressing the most statistically consequential supply chain issues.

This research furthers the field by introducing a decision-support tool designed to strategically allocate a company's limited supply chain resources toward the most probable and impactful risks, aiming for their mitigation. The CPG industry faces the challenge of managing heightened supply chain complexity, with significant financial repercussions from disruptions, emphasizing the need for innovative solutions. A decision-support tool can enable the industry to proactively address these evolving risks.

1.5. Research Objectives

The primary objective of this research is to develop and propose a decision-support tool specifically tailored to the CPG industry. This tool aspires to empower CSCOs to enhance their capacity to identify, assess, and effectively mitigate the most probable and impactful supply chain risks. This research uses data-driven insights derived from Failure Mode and Effects Analysis (FMEA) and logistic regression models to provide a practical solution enabling CPG companies to strategically allocate limited resources to address the most significant supply chain risks. Ultimately, this research seeks to contribute to the industry's resilience, profitability, and long-term sustainability by aiding the development of proactive risk management strategies. It aims to minimize the adverse financial consequences of disruptions and strengthen the global supply chains of CPG companies. This study represents an expansion of previous research, introducing

a decision-support tool designed to focus a company's limited resources on the most critical risks, thereby facilitating their mitigation.

1.6. Research Questions and Hypotheses

RQ1: What are the common failure modes associated with CPG supply chains?

RQ2: Of the common failure modes associated with CPG supply chains, which are the top failure modes, determined by severity, frequency, and duration?

RQ3: Can a decision-support tool be utilized to advise whether a failure mode should be mitigated for a specific firm?

H1: The common failure modes in the CPG supply chain are demand volatility, lack of raw materials, supplier business failure, transportation logistics, lack of/unpredictable workforce, interruption of the physical flow of goods, and lack of visibility into the supply chain.

H2: The top failure modes in the CPG supply chain are demand volatility, supplier business failure, transportation logistics, and lack of/unpredictable workforce.

H3: A decision-support tool can be developed to advise whether failure modes should be mitigated for a specific firm.

1.7. Scope of Research

The scope of this research is centered on the CPG industry, which encompasses companies that manufacture everyday items, such as food, cleaning products, and personal care items. These products are typically characterized by their affordability and short shelf life. This study proposes that CPG companies leverage a decision-support tool to enhance their capacity to identify, assess, and effectively mitigate potential high-

probability, high-impact points of failure within their supply chains. The research identifies high-risk areas in the CPG industry supply chain and, with the top risks identified, further explores whether CPG companies invest in mitigating these top risks based on their supply chain risk profiles.

1.8. Research Limitations

Acknowledging research limitations is essential, as it provides context for the findings and conclusions drawn. Key aspects to consider include:

- **Manual Data Collection**: One of the primary limitations of this research is the manual data collection process. The necessity for manual mining and case study review introduces the potential for human error and subjectivity. While time, effort, and care were taken, this limitation may impact the comprehensiveness and accuracy of the data analyzed.
- **Timeframe Focus**: This research primarily focuses on late- (September 2022 – May 2023) and post- (May 2023 forward) pandemic timeframes (United Nations, 2023). While this scope is relevant for addressing immediate concerns, it may not encompass all possible scenarios or risks that could emerge in the long term.
- **Resource Intensity**: Manual data collection and review processes are resource-intensive and time-consuming. As such, the scope of the data analysis may be constrained by these resource limitations.

1.9. Organization of Praxis

This research is structured into five main chapters, each contributing to the understanding and exploration of the CPG industry supply chain. Following the Abstract,

Chapter 1 provides a foundational background by discussing the motivation behind this research, presenting the problem statement, articulating the thesis statement, and outlining the research questions and hypotheses that guide this praxis.

Chapter 2 focuses on a literature review that explores historical research performed to date as it relates to the subsequent problem statement: following the pandemic, the CPG industry faces an increased challenge in identifying and addressing supply chain risks, which can result in disruptions costing an average of 6–10% of annual revenues.

Chapter 3 offers a detailed exploration of the methodology employed in this research. It explains how data were collected, analyzed, and synthesized to construct the final model, address the research questions, and evaluate the hypotheses. This section serves as the critical foundation for understanding the basis of the findings.

Chapter 4 describes and analyses the statistical results derived from the research.

The paper concludes with Chapter 5, where a discussion puts this research in context with its contribution to the body of knowledge. This chapter explores the future of this type of research and considers the transformative impact of technological advancements. These advancements may evolve data collection, analysis, and approach; "the art of the possible" is explored.

Chapter 2—Literature Review

2.1. Introduction

2.1.1. A Brief History

Supply chain management is not a new concept. Supply chains, the network of systems that connect the world, have a rich history that reflects the evolving complexities of the modern environment as shown in Figure 2-1 (Ashcroft, 2021).

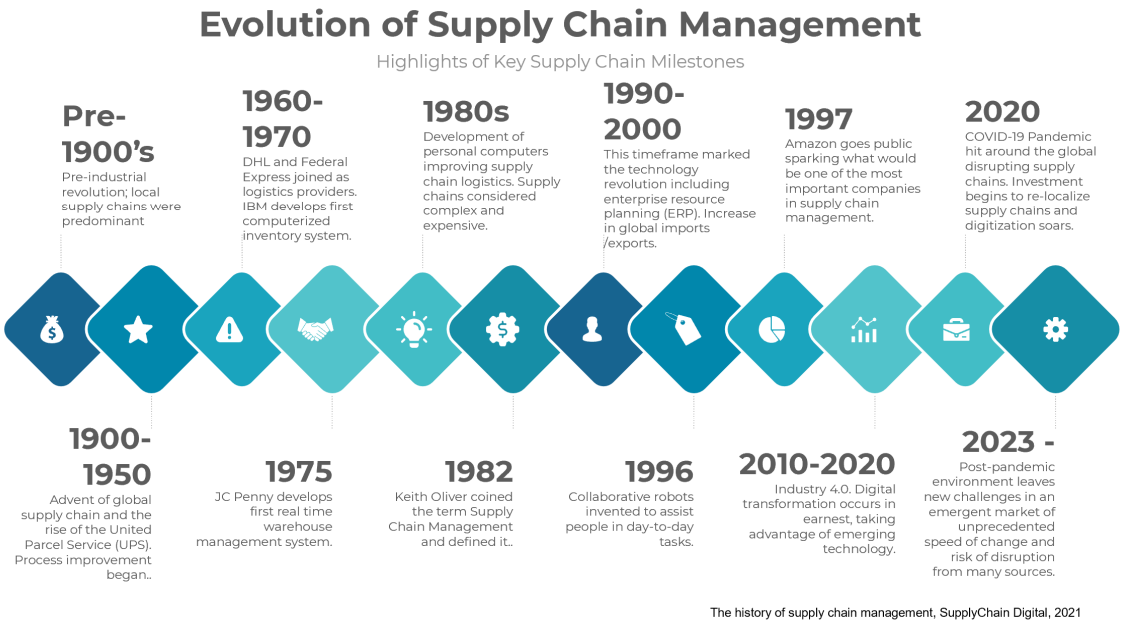


Figure 2-1. Evolution of Supply Chain Management (Ashcroft, 2021)

Prior to the 1900s, supply chains were predominantly local, serving regional needs. The advent of the first Industrial Revolution and the proliferation of railroads expanded the reach of supply chains, ushering in a new era of global distribution. Between the 1900s and 1950s, organizations like UPS emerged, laying the foundation for

global supply chains. Industry leaders explored mechanization and the role of analytics in military logistics after World War II, foreshadowing a future driven by data.

The 1960s and 1970s were marked by the emergence of logistics giants like DHL and Federal Express. A key breakthrough during this time was the development of the first computerized inventory management system by IBM, signifying the shift toward more advanced supply chain management practices. In 1975, JC Penney revolutionized inventory management with the creation of the first real-time warehouse management system, paving the way for streamlined operations. The 1980s saw supply chains gain access to advanced planning capabilities through personal computers, emphasizing the function's growing importance and complexity.

The 1990s and 2000s marked a technology revolution, characterized by the rise of enterprise resource planning, advanced planning and scheduling, and the globalization of imports and exports. In 1996, the invention of collaborative robots marked a significant step toward human–robot collaboration, while Amazon's IPO in 1997 paved the way for the e-commerce giant's global dominance.

The 2010s brought Industry 4.0, characterized by the adoption of technologies like Artificial Intelligence (AI), data analytics, and the Internet of Things (IoT). Organizations around the world embraced these digital transformation strategies. In 2020, the COVID-19 pandemic hit, bringing supply chains to a standstill. This global crisis underscored the critical importance of supply chain management and prompted investment in localization and digitalization to mitigate future risks.

2.1.2. Modern Global Supply Chain and Consumer Product Goods (CPG)

The modern global supply chain landscape is a dynamic and complex ecosystem, susceptible to a multitude of risks and disruptions. The CPG industry, in particular, has been deeply affected by these challenges (Consumer Brands Association, 2021). As an industry responsible for delivering essential and everyday products to consumers, the CPG industry must navigate complex supply chain dynamics that are complicated by factors such as demand volatility, transportation uncertainties, and workforce issues (Bustamante et al., 2022). The onset of the COVID-19 pandemic exacerbated the disruptions in an industry already undergoing transformation. The culmination of these challenges has made it crucial for CPG firms to embrace innovative approaches to supply chain risk management (SCRM). This chapter critically examines the body of knowledge surrounding SCRM, with a specific focus on its application within the CPG industry. It assesses the existing theories, methodologies, and decision-support tools employed in the field, emphasizing their assumptions and limitations. Furthermore, it explores how these approaches have been adapted and applied across various industries and similar situations, aiming to derive insights that can inform the development of a specialized decision-support tool for the CPG sector. This literature review lays the groundwork for the subsequent chapters, which delve into the development and application of a decision-support tool tailored to address the supply chain risks inherent to the CPG industry.

2.2. SCRM in the CPG Industry

The CPG industry plays a pivotal role in the global market by supplying essential and everyday products to consumers. Characterized by products with short shelf lives, affordability, and a diverse range spanning from food and beverages to personal care

items, the CPG industry faces a unique set of challenges that render supply chain management particularly complex. As consumers' preferences and buying behaviors fluctuate, the industry grapples with managing demand volatility. The intricate web of transportation logistics, often involving perishable goods, introduces uncertainties. In addition, maintaining a workforce capable of meeting these demands can prove to be a constant concern (Bustamante et al., 2022). These intrinsic attributes of the CPG industry are underpinned by supply chain risks that manifest in diverse forms, from sudden shifts in consumer demand to disruptions in the flow of essential products and raw materials, each having the potential to impede the efficiency and reliability of supply chains. Therefore, the CPG sector's intricate product mix and its associated regulatory and compliance considerations necessitate a targeted approach to SCRM.

2.3. Supply Chain Literature

2.3.1. Risk-Based Thinking and Decision-Making

Greg Hutchins explores SCRM principles, with a particular focus on risk-based thinking and decision-making. In his work, Hutchins emphasizes the dynamic nature of SCRM, asserting its inherent need for adaptability in the face of constant change (Hutchins, 2018). He observes how this dynamism requires companies to continually adjust their products and processes in response to evolving consumer demands, a necessary adaptation that introduces a heightened level of risk. Hutchins' research posits that such uncertainty has profound implications for problem-solving and decision-making, necessitating a more agile and responsive approach. A key facet of his research is the application of risk-based decision-making, which unites proactive, predictive,

preventive, and preemptive risk management strategies—often referred to as the "4P's" (as depicted in Figure 2-2).

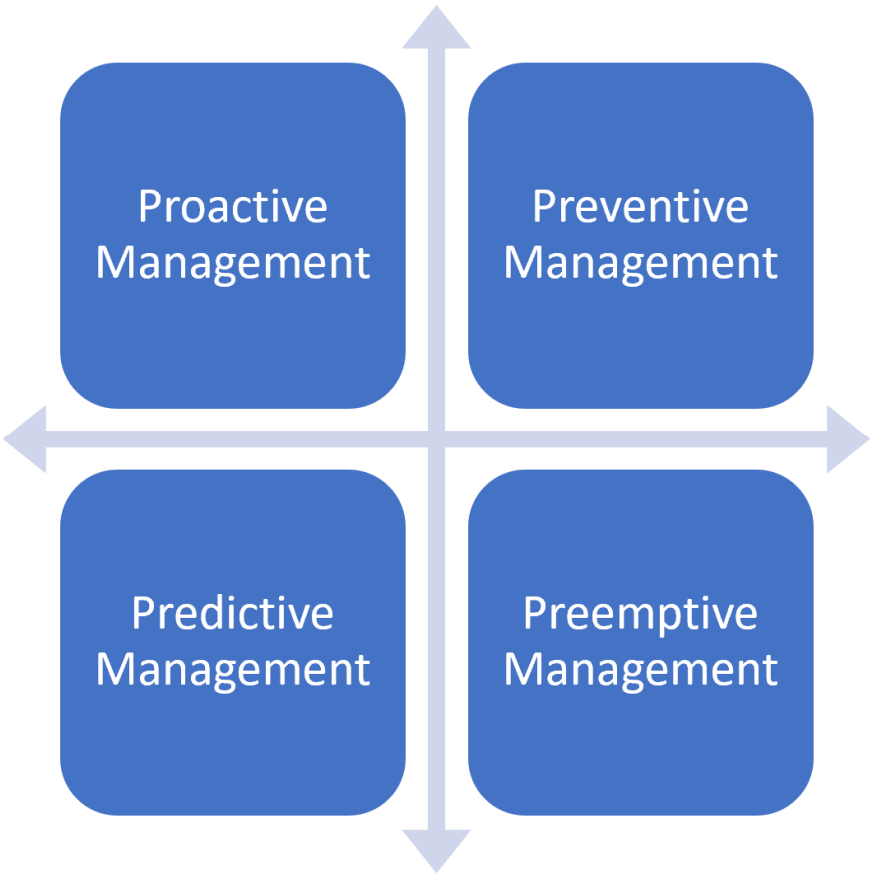


Figure 2-2. Hutchins' 4P's of Risk Management (Hutchins, 2018)

Hutchins' research draws upon the standards established by the International Organization for Standardization (ISO), a recognized leader in the development of global standards. These ISO standards are widely acknowledged for their role in defining common benchmarks for quality and risk management. From a risk perspective, Hutchins' work delves into ISO 9000, a standard emphasizes risk prevention and

mitigation. He underscores the critical nature of proactive, predictive, preventive risk management in the broader context of risk management and decision-making.

Relevant to the goals of this research praxis and the proposed decision-support tool, Hutchins' insights align with the objectives of proactive risk prediction and data-driven decision-making. The decision-support tool under consideration serves as a strategic instrument for identifying and allocating resources toward the prevention and mitigation of risks. It is designed to empower organizations to make informed decisions, guided by proactive risk assessments, thereby optimizing the allocation of limited resources.

2.3.2. Decision Support System in Risk Management Context

Prasanta Kumar Dey's study in 2001 sought to address a pervasive challenge in the construction industry: effective project risk management. Construction projects are inherently complex, influenced by a multitude of variables, including design intricacies, material planning, unpredictable weather conditions and environmental factors, among others. While these projects aim to deliver value, there is an overarching expectation that they must also be completed on time and within budget (Phillipy, 2014). However, the high degree of uncertainty associated with construction projects often led to outcomes characterized by delayed schedules and cost overruns.

Dey's study proposed an innovative approach to mitigate these challenges, examining the feasibility of implementing a decision-support system in construction risk management. The fundamental premise of this investigation was to enable project leaders to make objective, data-driven decisions when assessing and managing project risks. The

study delineated this risk management process into three core phases: risk identification, analysis, and response.

Key factors considered during risk analysis included the likelihood of a particular risk materializing and the severity of the potential consequences (example in Figure 2-2). Dey's research applied decision tree analysis as a decision-support tool, evaluating the necessity of mitigation based on probability, severity, and cost (example in Figure 2-3). In addition, the study introduced the use of an analytical hierarchy process, which provided a balanced approach by incorporating both objective and subjective analysis. This approach recognized that, in risk management, a degree of subjectivity can be justified, as it accounts for the inherent uncertainty and unpredictability of construction projects.

Probability and severity of risk factors

Risk factors	Probability	Severity	
		Time overrun (in months)	Cost overrun (in US$million)
Scope change	0.172	8	90
Engineering and design change	0.112	5	30
Technology selection	0.059	6	20
Land acquisition	0.038	4	0
Contractor's capability	0.041	6	30
Vendor's capability	0.065	8	30
Calamity abnormal	0.036	12	90
Implementation methodology	0.062	3	0
Fund availability	0.087	2	0
Improper estimate	0.058	2	0
Materials risk	0.038	3	0

Figure 2-3. Dey's Probability, Severity, and Cost Factors (Dey, 2001)

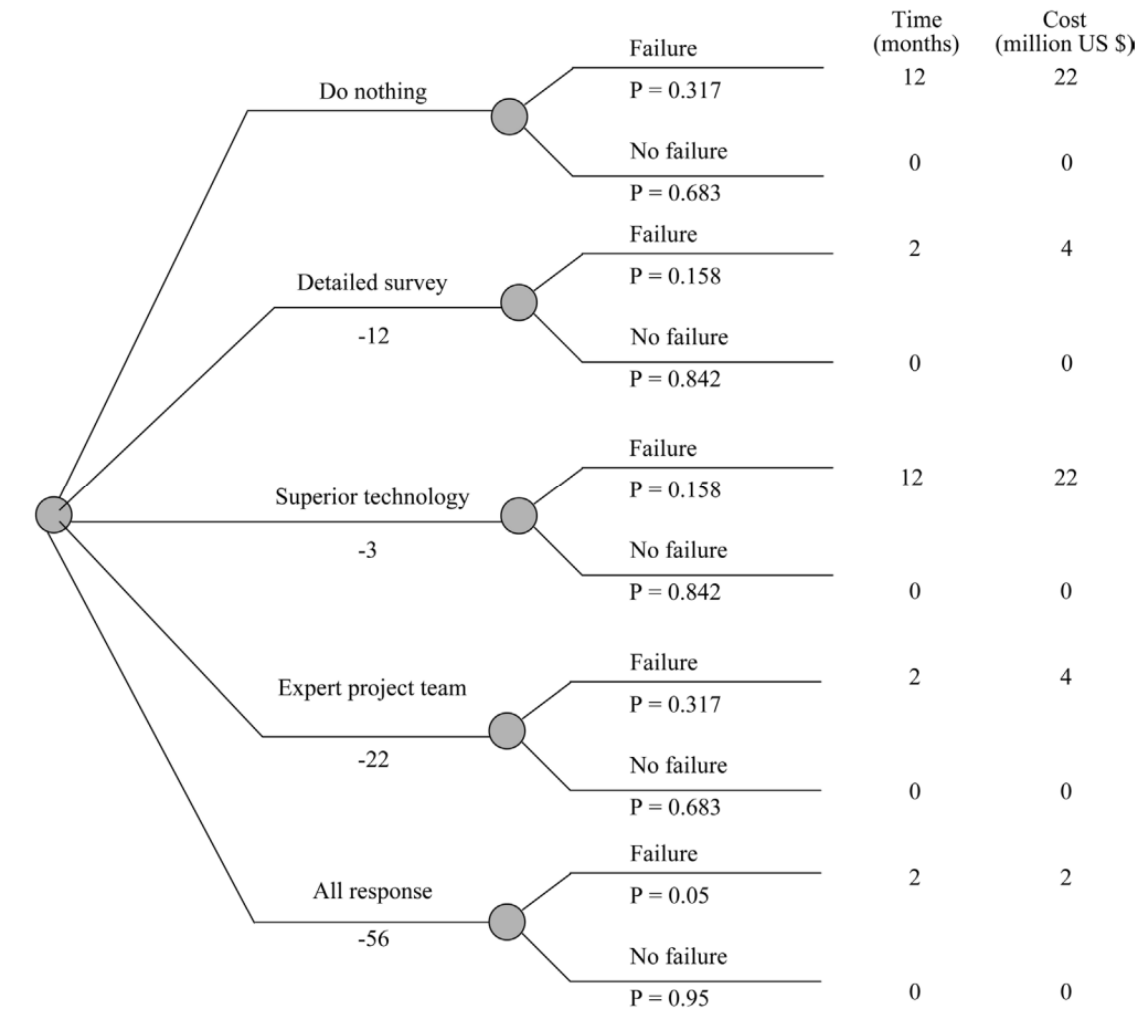


Figure 2-4. Dey's Decision Tree Output (Dey, 2001)

Dey's study is an example of the practical application of a decision support tool in the context of risk management. The core data concepts of risk severity and probability share common ground with the model concepts put forth in this research praxis. Both approaches share the overarching goal of homing in on the most probable and impactful risks.

Nevertheless, a distinct deviation emerges in the choice of analytical methodology. While Dey's study employed decision tree analysis to inform risk mitigation decisions, the proposed praxis model relies on logistic regression, yielding a binary outcome that determines whether mitigation is warranted. This distinction highlights the adaptability and versatility of decision-support tools in risk management, emphasizing the significance of aligning the chosen methodology with the specific requirements and objectives of a given context.

2.3.3. Decision-Support Tool for Binary Decision-Making

In 2006, Jason S. Seibel, et al. undertook a research study aimed at tackling another decision-making challenge. Their study was designed to address the complex challenge that information technology (IT) leaders face when contemplating resource allocation for software upgrades: should a company allocate resources to an upgrade based on a series of attributes. Their research methodology involved distributing surveys to IT leaders, presenting them with a series of scenarios, each requiring a binary decision—whether to invest in software upgrades or not. The scenarios posed in this study encompassed a range of attributes that played a role in shaping the ultimate decision, as illustrated in Table 2-1.

Licensing Structure	Defined as, the "licensing structure change, from the perspective of the business, whether the vendor has changed how it will license the product." (Sledge and Carney, 1998; Taub, 2001) This attribute considers software acquisition options offered by software vendors today (i.e., lease, purchase).	**License Structure Change:** 1. Advantageous 2. No change 3. Disadvantageous
Application's Impact on Productivity	Defined as, "organization can expect a positive impact on the business's bottom line" and is described as percentages of the overall bottom line. (Baum, 1995; Furger, 1988; Sledge and Carney, 1998) This attribute was based on whether the application offers a new capability or feature that would have an impact on the organization's productivity.	**Impact on the Business's Productivity:** 1. No impact, 0% increase 2. Minimal impact, 2-3% increase 3. Significant impact, >3%
Meets Business Goals	Defined as, "the upgrade meets the business's objectives; supports the goals of the business" and is described in decision values using Likert's method as a percentage of meeting the business's goal. (Seddon, Graeser and Willcocks, 2002; Kirk, 1993; Keller, 1994) This attribute considers whether the capabilities offered in the new version meet the overall goals of the business.	**Meets Business Goals as a Percentage:** 1. Meets 100% 2. Meets 75% 3. Meets 50% 4. Meets 25% 5. Meets 0%
New Version Compatibility	Defined as, "the new version is compatible with current system (hardware, applications)" and is described as percentages of compatibility. (Taub, 2001; U.S.Government, 1999; Unknown, 1993) This attribute considers whether the new version will require hardware and/or software upgrades such as operating system or computer hardware.	**New Version Compatibility with Existing Infrastructure as Percentage:** 1. 100% compatible 2. 75 % compatible 3. 50% compatible 4. 25% compatible 5. 0% compatible
Current Product Obsolesced	Defined as, "current version is end-of-life or no longer supported by vendor." (Unknown, 1993; Owens, Eslinger and Chaudhri, 2003; Maybury, 1999) This attribute considers whether the vendor has terminated support for the currently deployed version.	**Vendor's Support for Current Application:** 1. Fully Supported 2. Obsolesced
External Drivers	Defined as, "upgrade is being driven by 'customers' or government regulation" (Nirgudkar, 2000; Stark, 1997) This attribute considers whether external drivers to upgrade to the next release exist and is intended to account for external entities exerting pressure on the organization.	**Existence of External Drivers to Upgrade to the Next Release:** 1. Externally Driven 2. No drivers for upgrade

Table 2-1. Sample Upgrade Scenario Attributes (Seibel et al., 2006)

With this foundational data set in place, Seibel, et al. employed logistic regression models using SPSS. The objective was to determine the relationships between the attributes influencing decision-making and the degree to which these factors impacted the decision outcome. The output of their data analysis shown in Table 2-2 demonstrates the strength of these relationships and the corresponding degree of influence. Attributes that did not contribute to the model were eliminated, as shown in Table 2-3.

The logistic regression model developed in this study was instrumental in determining the probability that an IT leader should opt for a software upgrade within a specific scenario. The model's predictive accuracy was noted, standing at 64% for scenarios where an upgrade was recommended and a remarkable 84.9% for scenarios where an upgrade was not recommended. The overall adjusted model accuracy landed at 76.6%.

Full Variable Set (SPSS)								
Variable	**B**	**S.E.**	**Wald**	**df**	**p-value**	**Odds**	**95.0% C.I. for Odds**	
							Lower	Upper
License_Cost	0.3519	0.0572	37.8471	1	7.65E-10	1.422	1.2710	1.5904
Meets_Business_Goals	0.6525	0.1042	39.2010	1	3.82E-10	1.920	1.5655	2.3554
External_Drivers	-0.9529	0.2364	16.2547	1	0.000055	0.386	0.2426	0.6128
C_Product_Obsol	-1.2449	0.1997	38.8678	1	4.54E-10	0.288	0.1947	0.4259
Tech_Know	0.1356	0.0986	1.8892	1	0.169294	1.145	0.9439	1.3894
Vendor_Stability	0.4230	0.1161	13.2713	1	0.000270	1.527	1.2158	1.9168
License_Struct	-0.0067	0.1087	0.0038	1	0.950739	0.993	0.8027	1.2292
Impact_Productivity	0.4945	0.1909	6.7077	1	0.009600	1.640	1.1278	2.3837
Version_Compat	0.1919	0.0653	8.6401	1	0.003288	1.212	1.0660	1.3770
Constant	-1.9875	0.3334	35.5344	1	2.51E-09	0.137		

Table 2-2. SPSS Model Output First Iteration (Seibel et al., 2006)

Variables in the Equation (SPSS)								
Variable	**B**	**S.E.**	**Wald**	**df**	**p-value**	**Odds**	**95.0% C.I. for Odds**	
							Lower	Upper
License_Cost	0.3573	0.0509	49.3342	1	2.16E-12	1.429	1.2938	1.5793
Meets_Business_Goals	0.9736	0.0645	227.5641	1	2.03E-51	2.647	2.3329	3.0045
External_Drivers	-1.6830	0.1517	123.0221	1	1.38E-28	0.186	0.1380	0.2502
C_Product_Obsol	-1.5125	0.1607	88.5282	1	5.01E-21	0.220	0.1608	0.3020
Constant	-0.6714	0.1909	12.3739	1	0.000435	0.511		

Table 2-3. SPSS Model Output (Seibel et al., 2006)

Building upon the data set developed in this study, the envisioned decision-support tool would be available to IT decision-makers. These professionals would employ the tool to answer a similar questionnaire but answered with their own unique scenarios. Based on the answers and the relative impact of each attribute that remained in the model, the decision-support tool would then recommend whether to upgrade or not.

This study is an example of the application of logistic regression within the domain of decision-support tools. Seibel et al.'s model investigated the relationships between specific company attributes and the binary upgrade decision. The proposed model in this praxis also employs scenario-based inquiries but pivots toward assessing a company's supply chain risk profile. Most importantly, the underlying data for this praxis model is grounded in actual historical data rather than surveys, marking a fundamental distinction. Nonetheless, both models yield analogous outcomes—they extend data-driven recommendations to guide practical yes-or-no decisions. Both the study and this praxis aim to offer support to decision-makers grappling with complex scenarios and resource allocation choices.

2.4. Supply Chain Risks in the CPG Industry

Susan Galer's research (2022) delves into enhancing resiliency within the CPG supply chain by predicting potential disruptions. This study emphasizes the crucial need for resiliency in CPG manufacturing supply chains and highlights the importance of gaining visibility across these supply chains to effectively respond to disruptions. This aspect resonates with the central goal of the praxis, which is to develop a data-driven decision-support tool for bolstering SCRM.

Furthermore, the research emphasizes the significance of comprehending and foreseeing potential supply chain events and taking proactive actions based on this understanding. This parallels the objective of the praxis, which aims to provide a data-driven decision-support tool. In addition, the study recognizes the necessity of incorporating redundancy in supply chains and the capacity to shift production between different facilities to mitigate disruptions. This aligns with the praxis's focus on mitigating risks and employing practical, data-driven decision-making to enhance supply chain resiliency.

However, the research is somewhat limited in scope as it primarily concentrates on predicting individual disruptions within the supply chain. It does not offer a comprehensive view of the entire risk profile or a systematic approach to prioritizing focus. Furthermore, it does not address the magnitude of potential disruptions or provide a practical methodology for assessing their probability.

2.5. Research Methodologies

SCRM research employs a variety of methodologies to assess and address the complex landscape of supply chain vulnerabilities. These methodologies include case

studies, surveys, statistical models, simulations, among others. Each method offers distinct advantages and drawbacks, and the choice of methodology depends on the research objectives and the specific aspects of supply chain risk under investigation.

2.5.1. Case Studies

Case studies have been widely used in SCRM research to provide in-depth insights into real-world supply chain risk scenarios. These studies often involve detailed examinations of specific events, such as natural disasters or disruptions in specific industries. Case studies offer a rich understanding of the complexities of real situations and help uncover unique risk factors. However, they may lack generalizability and can be challenging to apply to broader contexts.

For instance, in a case study conducted by SpendEdge in 2019, a CPG company sought to explore risks associated with product quality from its suppliers and identify opportunities for pricing optimization. SpendEdge undertook this study, assessing risk levels and proposing mitigation strategies tailored to this specific company. While this case study effectively demonstrates how risks can be identified and mitigated within a unique context, it's important to recognize that its applicability is limited to the specifics of that client's situation and cannot be readily extrapolated to the broader industry.

In the context of this praxis, case studies serve a distinct purpose, primarily aimed at constructing a data set specific to the CPG industry. The objective is to discern patterns of risk mitigation based on individual risk profiles within this domain. These individual risk profiles are then synthesized to determine patterns, which subsequently guide the Chief Supply Chain Officer (CSCO) in decision-making.

2.5.2. Surveys

Surveys are valuable tools for collecting data from a large number of supply chain professionals or organizations. They can provide insights into prevailing risk management practices, perceptions, and the impact of risk factors. However, survey-based research may be limited by self-reporting bias and the need for carefully designed questionnaires to ensure data quality.

A 2020 research study by Accenture surveyed experts in the CPG supply chain and operations field to gain insights into their views on sustainability, pricing challenges, and related topics. Their findings underscored the pivotal role of agility in ensuring supply chain resilience. Moreover, the research emphasized the necessity for these firms to prioritize their areas of focus.

In the context of this praxis, surveys do not constitute a part of the methodology employed.

2.5.3. Statistical Models

Statistical models, including regression and predictive analytics, play a significant role in SCRM. These models allow researchers to identify relationships between variables and forecast future risk scenarios. Statistical methods provide quantitative insights and can be applied to large data sets, but their utility depends on the quality and availability of data.

Simulation is another powerful methodology often used to model and test various supply chain risk scenarios (Wolters Kluwer, 2021). Supply chain simulations can provide valuable insights into how different factors interact and impact risk exposure.

However, simulations rely on assumptions that might not always accurately reflect real-world conditions, and their effectiveness is highly dependent on the accuracy of the input data and assumptions.

2.5.4. Methodology Summary

Each of these methodologies comes with assumptions and limitations. Case studies and surveys may be affected by selection bias and self-reporting errors. Statistical models require accurate data and assume that relationships between variables remain stable over time. Simulations depend on the accuracy of assumptions and the complexity of the model.

In the context of this praxis, where the goal is to develop a decision-support tool for SCRM, it is essential to critically evaluate the advantages and disadvantages of these methodologies and carefully choose the most suitable ones to inform the development of the tool. In addition, recognizing the limitations and assumptions inherent in each methodology is crucial for providing meaningful and reliable insights into SCRM.

2.6. Summary and Conclusion

The literature review has uncovered key findings that are directly relevant to the research objectives of this praxis. From a historical standpoint, it elucidated the evolution of supply chain management, charting the progression from localized, regional supply chains to the complex global networks of today. Furthermore, it underscored the role of the CPG industry within the modern global supply chain, shedding light on the industry's distinct challenges and vulnerabilities.

In addition to historical context, the review also explored various decision-support tools and their applications in tackling complex decision-making challenges through the lens of data-driven insights. By showcasing the adaptability of these tools in addressing different problems, the literature review revealed the potential for data-driven solutions in supply chain management.

Furthermore, the literature review delved into the diverse methodologies routinely utilized in SCRM research, encompassing case studies, surveys, statistical models, and simulation. Each of these methods brings its own strengths and limitations, with the choice of methodology contingent upon the specific research objectives and the nature of the supply chain risk in question. The comprehensive review of the existing literature has identified a critical research gap that this praxis aims to address.

Chapter 3—Methodology

3.1. Introduction

This research strives to develop a decision-support tool specifically tailored for CSCOs in the CPG industry. The tool is intended to aid CSCOs in strategically prioritizing supply chain risks by considering both the likelihood of occurrence and the potential impact on their organizations. It relies on historical company risk factors and past mitigation data. Figure 3-1 provides a graphical high-level summary of the research methodology. This chapter will guide the reader through these steps in detail, elaborating on the data collection methods, tools, assumptions, and limitations.

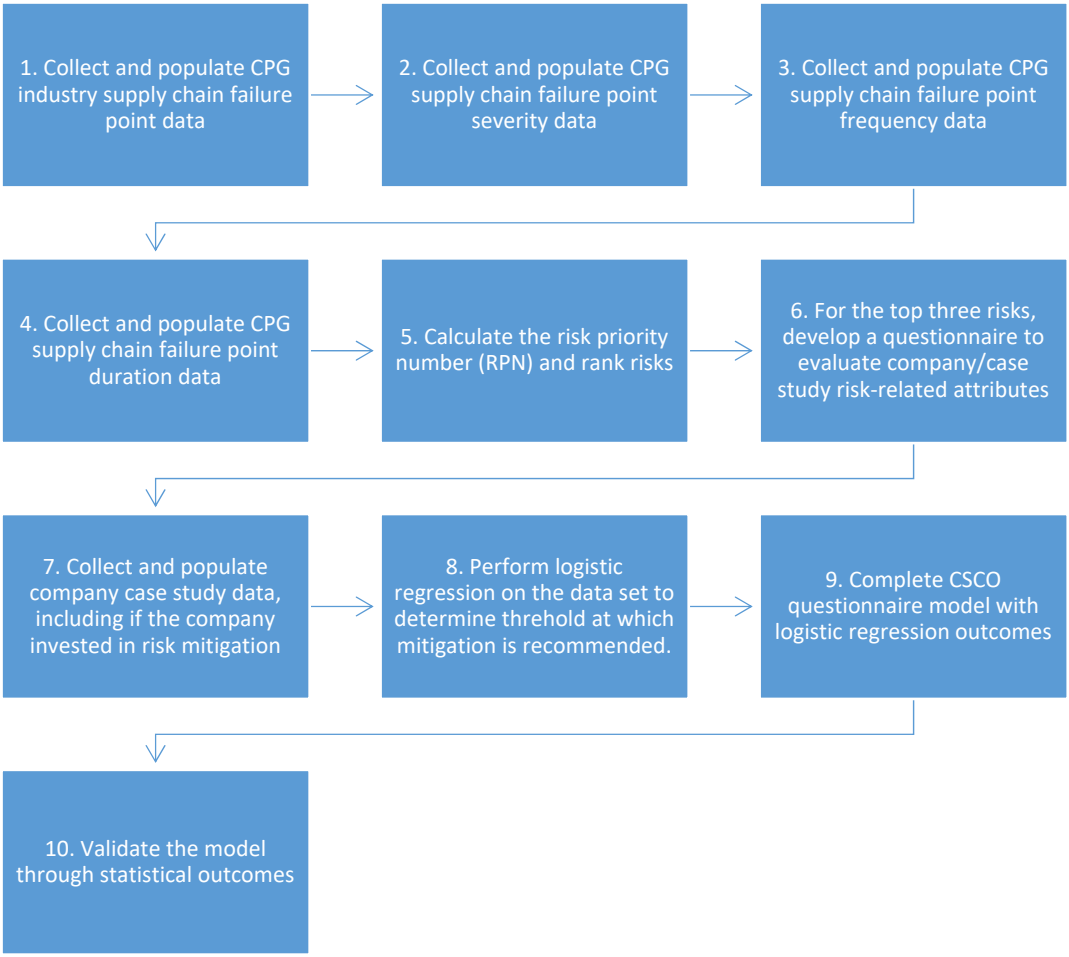


Figure 3-1. Top-Level Graphical Model of Research

- Blocks 1–4 lay the groundwork for the data model, serving as the basis for identifying supply chain risks specific to CPG firms.
- Block 5 articulates the methodology employed to identify and prioritize the most critical risks among those pinpointed in Blocks 1–4.
- Blocks 6–7 oversee the development of a CPG supply chain risk questionnaire customized to address the top-priority risks identified in Block 5. This questionnaire aims to collect risk attribute data by

examining historical case studies and assessing whether companies with similar risk attributes opted to invest in risk mitigation strategies.

- Blocks 8–9 entail the logistic regression analysis of datasets with the goal of extracting statistical attributes for integration into the decision-support tool model.
- Block 10 symbolizes the culmination of the research—a validated tool. CSCOs in the CPG industry can utilize this tool to respond to the same questionnaire formulated in Block 6, thereby identifying their company's specific risk attributes. Subsequently, based on the statistical attributes in Blocks 8–9, the tool calculates whether the CSCO should invest in risk mitigation for each identified top risk.

3.2. Objectives

. The overarching objective of this research is to provide CPG companies with a robust approach to proactively manage supply chain disruptions, ensuring greater resilience and sustainability in the post-pandemic era. The research navigates the newly altered CPG supply chain landscape through the analytical identification of high probability/high impact risks. The research dives deeper into the top three highest probability/highest impact risks to design and create a decision-support tool for this purpose. Using quantitative methodologies, we test the tool's effectiveness in predicting whether companies should address specific risks.

Setting the stage for the discussion on research methods, Figure 3-2 provides a graphical representation of the intended purpose and practical application of the research model.

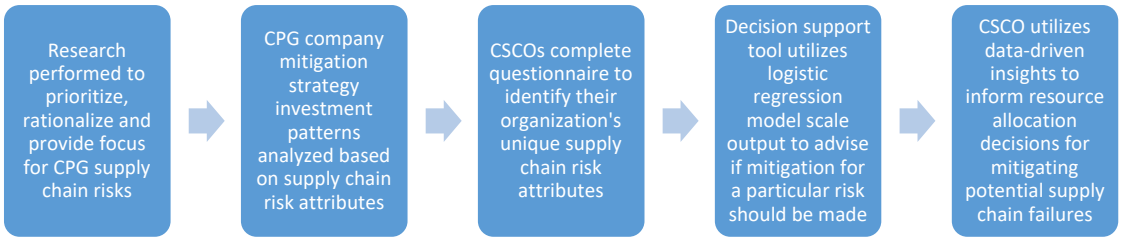


Figure 3-2. Graphical Application of Intended Purpose / Practical Application

3.2.1. Scope and Limitations of Research

The COVID-19 pandemic has precipitated a seismic shift in the operation of global supply chains, revealing their inherent vulnerabilities. These impacts are dynamic and perpetually shaping the strategies businesses must employ to confront emerging challenges and anticipate those on the horizon. In the context of this research, the focus is on the late- and post-pandemic eras, aiming to identify and prioritize the most critical supply chain risks. It is also important to note that the data collection processes used in this research were manual, involving data mining and an in-depth review of case studies.

Chapter 1.8 described the assumptions and limitations of this research. Acknowledging these factors is essential as they provide context for the findings and conclusions drawn. Key aspects to consider include:

- Manual Data Collection
- Timeframe Focus
- Resource Intensity

- Chapter **Expansion of Previous Research:** This study builds upon previous research by introducing a specialized decision-support tool designed to focus resources on critical risks. It extends the body of knowledge in supply chain risk management, particularly in the context of the CPG industry, offering practical solutions for industry professionals and, specifically, CSCOs.

Recommendations for Future Research," explores avenues for future research that can build upon the findings and insights presented in this research. Future research is anticipated to overcome some of the limitations identified in this chapter by incorporating more automated data collection methods, advanced tools, and emerging technologies. While this research was being conducted and completed, there has been a proliferation of new data and artificial intelligence tools. These advancements hold the potential to enhance the accuracy, scope, and efficiency of supply chain risk mitigation analysis.

3.3. Identification of Top Failure Modes (Risks)

3.3.1. Data Collection

A systematic approach was utilized to compile a dataset specific to supply chain risks in the CPG industry. Extensive searches were conducted to locate scholarly journal articles discussing various issues relating to both specific CPG and general supply chain risks. These searches were executed using a specific set of keywords, as detailed in Table 3-1.

Keyword Searches
Supply chain resilience
Consumer packaged goods supply chain
Consumer packaged goods supply chain resilience
Supply chain resilience mitigation strategies

CPG supply chain issues
Supply chain mitigation
CPG supply chain challenges

Table 3-1. Keyword Searches

Each article identified through this method then underwent a review process to determine its relevance to the research objectives. The criteria for relevance were clearly established to ensure the inclusion of only pertinent and insightful information in the analysis. This screening process continued until a dataset comprising 50 unique and relevant articles was obtained. These selected articles form the foundational basis upon which the subsequent research was conducted. A reference table for these articles can be found in Table A-1.

From each of the 50 articles identified, factors were compiled and documented in Table 3-2.

Supply Chain Factors
Risk Name
Severity (Martin, 2021)
Frequency (Martin, 2021)
Duration (Martin, 2021)

Table 3-2. Supply Chain Factors

Some articles discuss multiple risks, but not every article includes every factor. For clarity and uniformity, **Error! Reference source not found.** provides definitions for the various supply chain risks examined.

Potential Failure Mode	Definition

Demand volatility	"Variations in demand for products that include rapidly changing and unpredictable market conditions" (Kluwer, 2021).
Interruption of the physical flow of goods	"The flows of materials, products, inventories, and other goods in logistics networks, are referred to as physical flows, the main direction of which is considered to be from the point of origin to the point of consumption." (Farahani et al., 2011).
Supplier business failure	The condition when a supplier's business ceases to exist (Carter, 2021).
Cyberattacks, ransomware	Cyberattack: "an attempt to gain illegal access to a computer or computer system for the purpose of causing damage or harm." Ransomware: "malware that requires the victim to pay a ransom to access encrypted files." (Merriam-Webster, n.d.).
Warehouse access unavailable	Inability to obtain warehouse space for storage or distribution without disruption (Spivack, 2022).
Lack of/unpredictable workforce	A shortage of supply chain labor, e.g., factory workers and drivers (Conerly, 2021).
Equipment capacity	"Capability to generate output over a predetermined period." (ALG Worldwide, n.d.).
Transportation logistics	The process of moving goods encompasses the various means by which goods are transported (Britannica, n.d.).
Natural disaster/Extreme weather	Weather events and naturally occurring environmental issues disrupt supply chain activities (Leslie, 2022).
Geopolitical issues/instability	Problems created by factors "such as geography, economics, and demography" (Merriam-Webster, n.d.).
Lack of diversification of supplier location	Supply chain disruption due to location-related issues such as lockdowns, high tariffs, and other location-specific problems (Hipplod, 2021).
Too few suppliers	Limited material sourcing options available globally. (Accenture, 2023).
Regulation	"An authoritative rule dealing with details or procedure" that disrupts supply chain logistics" (Merriam-Webster, n.d.).
Fuel production and availability	Impact on the supply chain caused by fluctuations in fuel prices and variations in inventory levels/distribution (Sharafeden et al., 2021).

Economic instability/inflation	Issues arising from price instability/predictability (Vallejo, 2022).
Lack of visibility into the supply chain	The inability to gain insight into supply and demand to make informed decisions (Cecere, 2023).
Lack of raw materials	The absence of critical resources needed for supply chain manufacturing (Girtan et al., 2021).

Table 3-3. Supply Chain Failure Mode Definitions

3.3.2. Data Model

3.3.2.1.Research Score

The research score model quantitatively measures the frequency with which a potential failure mode (risk) is investigated across the entire corpus of articles. To elucidate this scoring process, each article analyzed was reviewed to determine whether it examined a specific risk factor. If it did, a count of one was assigned to the risk count corresponding to that factor. These individual counts were then aggregated to calculate the overall research score. It is crucial to emphasize that this score was primarily utilized as a sanity check to validate the results generated from the dataset.

To maintain data integrity and ensure that the analysis was grounded in adequately explored failure modes (risks), a minimum threshold was established. Failure modes with a research score of less than three were deemed infrequent and thus excluded from further consideration in the study. This threshold helped to concentrate attention on the most extensively studied and substantiated risk factors.

Table 3-4 provides insights into the initial dataset and serves as a foundational basis for the analysis. This analysis was subsequently refined through the application of the research score model. Several potential failure modes (risks), including supplier

business failure, cyber-attacks, ransomware, unavailability of warehouse access, equipment capacity, and lack of diversification of supplier location, were ultimately excluded from further research.

	Reference #																								
Potential Failure Mode	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Demand volatility			1	1	1			1	1	1	1			1							1				1
Lack of/unpredictable workforce	1	1	1					1	1							1	1	1	1				1	1	
Geopolitical issues/instability						1	1				1			1	1	1		1	1	1			1	1	
Economic instability/inflation												1		1		1		1	1				1	1	
Transportation logistics	1	1		1	1	1						1		1										1	
Lack of visibility into supply chain													1	1											
Lack of raw materials														1										1	
Energy production and availability											1			1					1	1			1		
Natural disaster/extreme weather		1					1				1					1	1								
Interruption of physical flow of goods								1	1		1			1				1							
Too few suppliers						1																			
Regulation							1				1				1										
Cyberattacks, ransomware						1	1																		
Equipment capacity					1																				
Lack of diversification of supplier location						1																			
Supplier business failure									1																
Warehouse access unavailable																						1			

Potential Failure Mode	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	TOTAL
Demand volatility	1				1	1	1		1	1	1				1	1	1	1		1				1		23
Lack of/unpredictable workforce			1									1						1	1				1		1	17
Geopolitical issues/instability				1	1				1				1					1								16
Economic instability/inflation			1	1		1						1	1	1				1			1				1	16
Transportation logistics	1			1									1													11
Lack of visibility into supply chain		1					1	1			1				1		1					1				9
Lack of raw materials				1		1	1					1				1							1		1	9
Energy production and availability				1									1												1	8
Natural disaster/extreme weather																		1								6
Interruption of physical flow of goods																										5
Too few suppliers					1				1							1			1							5
Regulation																						1				4
Cyberattacks, ransomware																										2
Equipment capacity															1											2
Lack of diversification of supplier location																1										2
Supplier business failure																										1
Warehouse access unavailable																										1

Table 3-4. Research Score Raw Data

3.3.2.2. Severity Score

In the context of this research, severity plays a pivotal role, as it is integral to assessing the impact of a failure mode (risk) on an organization's overall health. This evaluation primarily focuses on the consequences incurred in terms of costs, revenues, and inventory management. To facilitate an understanding of the severity levels associated with various failure modes (risks), a stratification approach was employed, as shown in Table 3-5 (American Society for Quality, 2023), and the outcomes are detailed in Table 3-5.

While striving for accuracy and precision in assigning severity scores to each failure mode (risk), certain challenges arose concerning data availability. Some data points were more readily accessible than others, introducing a degree of variability in the scoring process. To mitigate this, an average score was computed for each failure mode (risk), ensuring that a minimum score of one (1) was assigned for calculation purposes.

Potential Failure Mode	Reference # 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	Average
Warehouse access unavailable																						10																														10.00
Regulation											4				10																																						7.00
Lack of diversification of supplier location						2																																				10										6.00
Too few suppliers						2																																				10										6.00
Fuel production and availability											10																		1										10												2		5.75
Economic instability/inflation												2								10				1				2	1									10	10	10				2			10			2		5.45
Natural disaster/extreme weather											4					10																													2								5.33
Lack of raw materials														4				10						1				1				4					10					10										5.25
Demand volatility				6				4			4										10				10	2								1						1	10		2									5.00
Geopolitical issues/instability						2					4									10				1					1										10					2									4.29
Transportation logistics	3			5	10	2						2		4			5							1		2			1										10														4.09
Lack of/unpredictable workforce	3		3					4																			2											10						2								4.00
Interruption of physical flow of goods								4		5	4			1																																						3.50
Lack of visibility into supply chain													5														2						5			1					1										2.80
Cyberattacks, ransomware						2																																													2.00
Supplier business failure																																																			1.00
Equipment capacity																																																			1.00

Table 3-5. Severity Score Raw Data

Scoring Model

Score	Revenue lost as a % of overall revenue	Cost increase as a % of overall cost	Inventory Loss as a % of inventory
1	0.1–0.3%	1–5%	1–10%
2	0.3–0.5%	6–10%	11–20%
3	0.5–0.7%	11–15%	21–30%
4	0.7–0.9%	16–20%	31–40%
5	0.9–1.1%	21–25%	41–50%
6	1.1–1.3%	25–30%	51–60%
7	1.3–1.5%	30–35%	61–70%
8	1.5–1.7%	35–40%	71–80%
9	1.7–1.9%	41–45%	81–90%
10	>1.9%	>45%	91–100%

Table 3-6. Severity Scoring

3.3.2.3.Frequency Score

In the context of this research, frequency assumes a pivotal role, as it is integral to assessing the probability of a failure mode (risk) occurring within an organization. This evaluation primarily centers around the consequences of high-probability failures. A stratification approach was employed to facilitate comprehension of the frequency level

associated with various failure modes (risks), as shown in Table 3-8, with the results detailed in Table 3-7.

In the pursuit of accuracy and precision in assigning frequency scores to each failure mode (risk), several challenges were encountered, particularly concerning data availability. Some data points were more readily accessible than others, introducing a degree of variability into the scoring process. To address this, an average score was computed for each failure mode (risk), with care taken to assign a minimum score of one (1) for calculation purposes. This methodology helped standardize the assessment process and ensured that, even in instances where data was scarce, an initial conservative frequency assessment could still be conducted.

	Reference #																																																		
Potential Failure Mode	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	Average
Regulation															8																																10				9.00
Demand volatility			10	10	10			10	10	10	10			10							1													5																	8.60
Cyberattacks, ransomware							6																																												6.00
Energy production and availability																		8		1																															4.50
Natural disaster/Extreme weather							6									1	1																																		2.67
Geopolitical issues/instability							6									1				1																															2.67
Interruption of physical flow of goods																																																			1.00
Supplier business failure																																																			1.00
Warehouse access unavailable																																																			1.00
Lack of/unpredictable workforce																1																																			1.00
Equipment capacity																																																			1.00
Transportation logistics																																																			1.00
Lack of diversification of supplier location																																																			1.00
Too few suppliers																																																			1.00
Economic Instability/inflation																1																																			1.00
Lack of visibility into supply chain																											1																								1.00
Lack of raw materials																																																			1.00

Table 3-7. Frequency Score Raw Data

Scoring Model

Score	Frequency (occurs every)
1	>8 years
2	7–8 years
3	6–7 years
4	5–6 years
5	4–5 years
6	3–4 years
7	2–3 years
8	1–2 years
9	6–12 mos
10	1–6 mos

Table 3-8. Frequency Scoring

3.3.2.4. Duration Score

In the context of this research, duration plays a pivotal role as it pertains to assessing the impact a failure mode (risk) has on the health of an organization. This evaluation assumes that longer-duration failure/risk events have a higher impact on an organization. A stratification approach was employed to understand the impact of duration on various failure modes (risks), as shown inTable 3-8, with the results detailed in Table 3-7.

While striving for accuracy and precision in assigning duration scores to each failure mode (risk), challenges emerged regarding data availability. Some data points were more accessible than others, introducing variability into the scoring process. To address this, an average score was computed for each failure mode (risk), with a minimum score of one (1) assigned for calculation purposes. This approach standardized

the assessment process and ensured that even where data was scarce, an initial conservative duration assessment could be made.

Potential Failure Mode	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	Average
Warehouse access unavailable																						10																													10.00
Geopolitical issues/instability											10									10				10				10									10					10										10.00
Too few suppliers																																												10									10.00
Regulation															10																																						10.00
Fuel production and availability											10																		10									10															10.00
Economic instability/inflation												10								10				10				10	10								3	10								10							9.13
Demand volatility			10							10	10										10				10	10								1	1										10		10					8.20
Interruption of physical flow of goods									6		10																																										8.00
Lack of/unpredictable workforce	6	6																						10				10								3									10	10						7.86
Lack of raw materials																								10					10							3																7.67
Transportation logistics	6	1			6																			10		10			10									10															7.57
Natural disaster/extreme weather		1																																																		5.50
Supplier business failure																																																				1.00
Cyberattacks, ransomware																																																				1.00
Equipment capacity																																																				1.00
Lack of diversification of supplier location																																																				1.00
Lack of visibility into supply chain																																																				1.00

Table 3-9. Duration Score Raw Data

Scoring Model

Score	Duration
1	1–5 Weeks
2	6–10 Weeks
3	11–15 Weeks
4	16–20 Weeks
5	21–25 Weeks
6	26–30 Weeks
7	31–35 Weeks
8	36–40 Weeks
9	41–45 Weeks
10	>45 Weeks

Table 3-10. Duration Scoring

3.3.3. Failure Mode & Effects Analysis Model

FMEA represents a systematic approach employed to proactively identify and mitigate potential issues before they manifest (Chang, 2016). This research uses the FMEA model to pinpoint and prioritize high-probability, high-impact points of failure (risks) within CPG supply chains. This forms a fundamental part of the research that will culminate in constructing and validating a decision-support tool.

Referring to Figure 3-1, Blocks 1–4 of the graphical model of research pertain to the identification of CPG supply chain risks and their quantitative attributes of severity, frequency, and duration, which have been explored and scored.

Block 5 of the graphical model is the stage at which the FMEA risk priority number (RPN) is calculated. The RPN is computed as the product of severity, frequency, and duration, serving as a quantitative representation of the risk magnitude:

$$RPN = Severity \times Frequency \times Duration$$

This calculated RPN guides the prioritization of risks, ultimately shaping their rankings. For this research, the rankings of failure modes (risks) are depicted in the FMEA model in Table 3-11.

Potential Failure Mode	Research Score	Severity	Frequency	Duration	RPN (Severity * Frequency * Duration)	Risk Ranking
Regulation	4	7.00	9.00	10.00	630.00	1
Demand volatility	23	5.00	8.60	8.20	352.60	2
Fuel production and availability	8	5.75	4.50	10.00	258.75	3
Geopolitical issues/instability	16	4.29	2.67	10.00	114.29	4
Natural disaster/extreme weather	6	5.33	2.67	5.50	78.22	5
Too few suppliers	5	6.00	1.00	10.00	60.00	6
Economic instability/inflation	16	5.45	1.00	9.13	49.77	7
Lack of raw materials	9	5.25	1.00	7.67	40.25	8
Lack of/unpredictable workforce	17	4.00	1.00	7.86	31.43	9
Transportation logistics	11	4.09	1.00	7.57	30.97	10
Interruption of physical flow of goods	5	3.50	1.00	8.00	28.00	11
Lack of visibility into supply chain	9	2.80	1.00	1.00	2.80	12

Table 3-11. FMEA Model

3.4. Decision-Support Tool Build

3.4.1. Supply Chain Risk Questionnaire (SCRQ)

Block 6 of Figure 3-1 represents the subsequent step in the research model. This research will place particular emphasis on the top three critical risks: regulation, demand volatility, and fuel production and availability. The questionnaire is designed to assess each risk independently through a series of risk-specific questions. These are aimed at eliciting valuable insights from historical data and participant responses, ultimately guiding the decision-making process regarding risk mitigation investment strategies.

The SCRQ serves a dual purpose:

1. **Data Collection and Analysis:** The SCRQ was developed to gather data from CPG companies regarding their risk profile, determining which, if any, of the top three risks they have invested in mitigating. This data aims to analyze various company risk profiles and assess how they have mitigated risks. The collected data will undergo logistic regression, as described in Section 3.4.3, to develop a scale and threshold—a risk score—that indicates when a company should consider investing in a mitigation strategy.
2. **Decision-Support Tool:** The questionnaire is an integral component of the decision-support tool. CSCOs will interact with the questionnaire by providing their company's specific risk profile. The decision-support tool will then analyze this input, using the analysis from Section 1 above, to determine whether mitigation should be considered based on the individual company's risk profile.

3.4.1.1. Risk 1—Regulation

For this research, regulation is defined as "an authoritative rule dealing with details or procedure" that disrupts supply chain logistics (Merriam-Webster, n.d.). To gain a deeper understanding of this risk category and its implications for supply chain management, a set of thoroughly researched and developed questions has been designed. The primary objective of these questions is to clarify at what risk levels an investment in mitigation strategies becomes necessary. These questions can be found in Table 3-12.

Regulation	Definitions
(R1) To what extent are you subject to regulations related to environmental sustainability in your supply chain? (Gartner, 2023)	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain operations 3: Significant regulations with a heavy influence on supply chain practices
(R2) How much regulatory oversight do you face regarding labor practices in your supply chain? (John, 2023)	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain operations 3: Significant regulations with a heavy influence on supply chain decisions
(R3) What is the extent of regulations governing product safety and quality within your supply chain? (U.S. Consumer Product Safety Commission, 2006)	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain compliance practices 3: Significant regulations with a heavy influence on supply chain compliance activities

(R4) How much do customs and trade regulations impact your cross-border supply chain operations? (KPMG, 2022)	1: Minimal or no regulations 2: Some regulations, but with moderate impact on processes and adaptation to new rules 3: Significant regulations with a heavy influence on supply chain logistics and practices
(R5) To what degree are you impacted by data privacy and cybersecurity regulations within your supply chain? (National Institute of Standards and Technology, 2022)	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain policy compliance 3: Significant regulations with stringent policies throughout the supply chain
(R6) How much are you affected by transportation and logistics regulations in your supply chain? (Federal Register [National Archives and Records Administration], 2021)	1: Minimal or no regulations 2: Some regulations, but with moderate adjustments required for supply chain planning 3: Significant regulations with heavy adjustments required for supply chain planning
(R7) How much regulatory compliance is required regarding ethical sourcing and responsible supply chain practices? (Chorley, 2022)	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain sourcing and responsible practices 3: Significant regulations with a heavy influence on supply chain sourcing and responsible practices
(R8) To what degree do import/export regulations impact your global supply chain network? (KPMG, 2022)	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain compliance 3: Significant regulations with heavy influence on supply chain compliance

Table 3-12. Regulation Risk Questions

3.4.1.2. Risk 2—Demand Volatility

For the purposes of this research, demand volatility is defined as "variations in demand for products that include rapidly changing and unpredictable market" (Kluwer, 2021). A set of researched and developed questions has been designed to gain a deeper understanding of this risk category and its implications for supply chain management. The primary objective of these questions is to bring clarity to determining the risk levels at which investment in mitigation strategies becomes necessary. The questions can be found in Table 3-13.

Demand Volatility	Definitions
(D1) How would you rate the accuracy of your demand forecasting processes? (Hutchins, 2018)	1: Low or no deviations between actual and forecast 2: Moderate deviations between actual and forecast 3: Frequent deviations between actual and forecast
(D2) To what extent does demand volatility impact your inventory levels? (University of Tennessee, 2021)	1: Minimal or no impact on inventory levels 2: Moderate impact on inventory levels 3: Significant impact on inventory levels
(D3) How easily can your production processes adapt to sudden changes in demand? (Hutchins, 2018)	1: Easy production process adaptation with low or no impact 2: Some ability to adapt production processes based on demand fluctuations 3: Low or no ability to easily adapt production processes
(D4) How well do your suppliers respond to shifts in demand? (Bergstrom et al., 2020)	1: Easy production process adaptation with low or no impact 2: Some ability to adapt production processes based on demand fluctuations

	3: Low or no ability to easily adapt production processes
(D5) How adaptable are your supply chain technology systems and data in responding to demand changes? (Hutchins, 2018)	1: Significant adaptability with modern technology platforms leading to the adaptability of demand changes 2: Some adaptability, but we have challenges leveraging our technology to adapt to demand volatility 3: Manual or inflexible systems have a heavy impact on the ability to adapt to changes in demand
(D6) To what extent does demand volatility expose your supply chain to operational and performance risks? (Hutchins, 2018)	1: Minimal risks due to demand volatility 2: Some risk, but manageable with some planning 3: High risk; high exposure
(D7) How does demand volatility influence your customer satisfaction levels? (Cassell, 2022)	1: Demand volatility does not or has little influence on customer satisfaction levels 2: Moderate levels of impact on customer satisfaction due to demand volatility 3: Significant impact on organizational performance due to customer dissatisfaction due to demand volatility
(D8) To what degree does demand volatility affect lead time variability for your supplies? (Ovezmyradov, 2022)	1: Minimal impact; lead times are steady 2: Some impacts on lead times due to demand volatility 3: Significant lead time challenges due to demand volatility; planning is challenging

Table 3-13. Demand Volatility Risk Questions

3.4.1.3. Risk 3—Fuel Production and Availability

For the purposes of this research, fuel production and availability risk is defined as the impact on the supply chain caused by variations in fuel prices and inconsistencies in inventory levels/distribution (Sharafeden et al., 2021). A set of researched and developed questions has been designed to gain a deeper understanding of this risk category and its implications for supply chain management. The primary objective of these questions is to clarify at which risk levels an investment in mitigation strategies becomes necessary. The questions can be found in Table 3-14.

Fuel Production and Availability	Definition
(F1) How would you rate the overall availability of fuel for your supply chain operations? (World Economic Forum, 2022)	1: Reliable fuel supplies 2: Some shortages, but with a moderate impact on the supply chain 3: Frequent shortages leading to supply chain impacts
(F2) How would you assess the volatility of fuel prices and its impact on your supply chain costs? (Larsen, 2022)	1: Stable fuel pricing 2: Moderate price fluctuations affecting costs 3: Significant price fluctuations highly impacting cost controls
(F3) How would you rate your supply chain's adoption of alternative energy sources to reduce reliance on traditional fuels? (World Economic Forum, 2022)	1: Extensive use of alternative fuel sources 2: Some adoption in place or underway 3: Minimal adoption of alternatives
(F4) How well-prepared is your supply chain to handle fuel supply disruptions or sudden price spikes? (Larsen, 2022)	1: Robust contingency plans in place 2: Some plans in place but can be improved 3: No contingency plans in place

(F5) How diversified is your supply chain's portfolio of fuel suppliers to mitigate risks? (World Economic Forum, 2022)	1: Robust diversification of suppliers in place 2: Some diversifications, but improvement needed 3: Dependence on one or few suppliers
(F6) To what extent are sustainable practices integrated into your supply chain to minimize fuel-related environmental impacts? (Pergl, 2021)	1: Robust sustainability practice in place 2: Some sustainability in place, but improvement is needed 3: Limited or no sustainable practices in place
(F7) How accurately can you forecast fuel demand for your supply chain operations? (Pergl, 2021)	1: Accurate forecasting in place 2: Some forecasting, but accuracy needs improvement 3: No or inaccurate forecasts in place
(F8) To what extent do fuel costs significantly impact your profitability? (Larsen, 2022)	1: Minimal or no impact 2: Occasional impact on profitability 3: Significant profitability impact

Table 3-14. Fuel Production and Availability Risk Questions

3.4.2. Data Collection

A systematic approach was employed to ensure the integrity and relevance of the research data. The primary focus was on publicly traded companies, which were chosen for their accessibility, global supply chains and the wealth of publicly available data. While it is assumed that all CPG companies can benefit from a decision-support tool, it was also assumed that organizations with annual revenues exceeding $4 billion would typically possess substantial resources, potentially making this tool less relevant to their

needs. Consequently, the scope was narrowed to include companies with revenues below this threshold.

Data collection efforts concentrated on the most recent available annual reports for each of the selected companies. These reports served as a source of information, offering detailed insights into the operations, financial performance, and risk profiles of the companies in question.

Upon determining the relevance of each annual report, data assessing the specific risk factors for each company were extracted and populated into the questionnaires. A reference table for these company case studies can be found in Table A-2. Due to the manual nature of this process, while all questions were answered for each company, the data is limited to the data available in each current annual report.

3.4.3. Logistic Regression Models

Logistic regression excels in scenarios where the outcome variable falls into discrete categories, such as "Yes" or "No," as opposed to linear regression (Hosmer et al., 2013). Three distinct models were run, aligning with each of the analyzed risks.

In the questionnaires detailed in Tables Table 3-12, Table 3-13, and Table 3-14, a composite scoring system was employed where a score of 1 represents low risk and 3 represents high risk. For each observed company in Table A-2, a risk score was calculated through the summation of the individual question scores, and a “Yes” or “No” was noted to indicate whether mitigation strategies were made based on this score. This data was then analyzed through logistic regression using SPSS, extracting the relevant

statistics described and defined in Table 3 15. Chapter 4—Results provides insights into detailed observations and additional data analysis.

Statistic	Definition
Cronbach's alpha (α)	"Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group. It is considered to be a measure of scale reliability." (University of California, 2023). In the context of this research, Cronbach's alpha will indicate how well the questions within a questionnaire work together to determine whether mitigation should be considered.
B	B, in the context of this research and logistics regression, is the regression coefficient. The regression coefficient represents the estimated strength and direction of independent variables (questionnaire risk scores) on the log-odds of the binary outcome (mitigation yes/no). B will be used to quantify the strength and direction of the relationships between the questionnaire risk scores and the probability of mitigation (Hosmer et al., 2013).
Wald statistic	Calculated as $(B/SE)^2$, the Wald Statistic follows a chi-squared distribution. Researchers compare the Wald statistic to the critical value from the chi-squared distribution to determine whether the coefficient is statistically significant (Hosmer et al., 2013). For this research, this is a test statistic used to test whether the B coefficient differs significantly from zero demonstrating significance – which is does (Field, 2018)
p-value	The p-value is a statistic that will assist in measuring the relationship between the independent variables (in the context of this research, questionnaire responses) and the dependent variable (in the context of this research, mitigation, "Yes" or "No"). A p-value below 0.05 is considered statistically significant and validates the significance of this model. This statistic is related to the confidence level. (Hosmer et al., 2013).

Odds Ratio	Calculated as ε^{β}, the odds ratio will be used to evaluate the likelihood of mitigation versus no mitigation and the magnitude of the effect in my scale (Hosmer et al., 2013).
SE	SE or Standard Error is a measure of variability within a population. For this research a small value indicates a good reflection of the population based on sample (Field, 2018)

Table 3-15. Relevant Logistic Regression Statistics

3.5. Summary

This research centers on the development of a decision-support tool designed to assist CSCOs in the CPG industry in prioritizing supply chain risks. This is achieved by evaluating both the likelihood and potential impact of these risks. The chapter has furnished a comprehensive description of the data collection methods, tools, assumptions, and limitations used in this study. The methodology is comprised of ten high-level steps (blocks), which are depicted in Figure 1-1 and discussed in this chapter. The initial four blocks form the foundation for a data model, facilitating the identification of supply chain risks specific to the CPG industry—block 5 details the methodology for pinpointing and prioritizing the most critical risks from those identified. Blocks 6 and 7 are devoted to developing a CPG SCRQ tailored to each of the top three priority risks, collecting risk factors through historical case studies. Blocks 8 and 9 involve logistic regression analysis of datasets to extract statistical attributes for the decision-support tool model. Finally, Block 10 signifies the culmination of the research, presenting a tool for CSCOs to assess their own company's risk attributes and decide whether to consider investing in risk mitigation strategies for each identified top risk.

Chapter 4—Results

4.1. Introduction

This chapter presents the outcomes of the research activities described in previous chapters including the techniques and processes applied to address the research questions and hypotheses. The decision-support tool will be discussed in more detail, and its practical application will be explored.

4.2.Research Question 1

RQ1: What are the common failure modes associated with CPG supply chains?

H1: The common failure modes in the CPG supply chain are demand volatility, lack of raw materials, supplier business failure, transportation logistics, lack of/unpredictable workforce, interruption of the physical flow of goods, and lack of visibility into the supply chain.

Chapter 3—Methodology provided a comprehensive account of the methodology utilized to initially identify failure modes (risks) within the framework of the CPG supply chain. This process culminated in the identification of a total of 17 distinct failure modes. As shown in Table 4-1, the hypothesis proved to be accurate in recognizing these common failure modes that occur within the CPG industry; the seven hypothesized common failure modes are highlighted in yellow among the universe of common failure modes identified.

Potential Failure Mode
Regulation
Demand volatility
Supplier business failure
Cyber attacks, Ransomware
Warehouse access unavailable
Fuel production and availability
Equipment capacity
Geopolitical issues/instability
Natural disaster/extreme weather
Too few suppliers
Lack of diversification of supplier location
Economic instability/inflation
Lack of raw materials
Lack of/unpredictable workforce
Transportation logistics
Interruption of physical flow of goods
Lack of visibility into supply chain

Table 4-1. Potential Failure Modes (Risks)

4.3.Research Question 2

RQ2: Of the common failure modes associated with CPG supply chains, which are the top failure modes?

H2: The top failure modes in the CPG supply chain are demand volatility, supplier business failure, transportation logistics, and lack of/unpredictable workforce.

As the research progressed, the data models were refined, and the next research question sought to pinpoint the top failure modes. These top failure modes, which form the foundation for the research model's subsequent stages, underwent further scrutiny. Five initially identified failure modes were excluded from further analysis due to their low research scores as discussed in 3.3.2.1, and shown in Table 3-4. This culling was necessary to channel our focus toward thoroughly examined and substantiated risk

factors. Subsequently, we subjected these chosen risks to analysis using the FMEA framework, ultimately culminating in the identification of a top risk ranking. However, as presented in Table 4-2 with rankings highlighted in yellow, our hypothesis proved to be inaccurate in its estimation of the primary failure modes within the CPG industry. It is postulated that this discrepancy stems from a potential lens and bias during the ranking assessment—specifically, a technology consulting perspective without due regard for the broader current economic and geopolitical landscape.

Potential Failure Mode	Research Score	Severity	Frequency	Duration	RPN (Severity * Frequency * Duration)	Risk Ranking
Regulation	4	7.00	9.00	10.00	630.00	1
Demand volatility	23	5.00	8.60	8.20	352.60	2
Fuel production and availability	8	5.75	4.50	10.00	258.75	3
Geopolitical issues/instability	16	4.29	2.67	10.00	114.29	4
Natural disaster/extreme weather	6	5.33	2.67	5.50	78.22	5
Too few suppliers	5	6.00	1.00	10.00	60.00	6
Economic instability/inflation	16	5.45	1.00	9.13	49.77	7
Lack of raw materials	9	5.25	1.00	7.67	40.25	8
Lack of/unpredictable workforce	17	4.00	1.00	7.86	31.43	9
Transportation logistics	11	4.09	1.00	7.57	30.97	10
Interruption of physical flow of goods	5	3.50	1.00	8.00	28.00	11
Lack of visibility into supply chain	9	2.80	1.00	1.00	2.80	12

Table 4-2. FMEA Top Prioritized Risks

4.4.Research Question 3

RQ3: Can a decision-support tool be utilized to advise whether a failure mode should be mitigated for a specific firm?

H3: A decision-support tool can be developed to advise whether failure modes should be mitigated for a specific firm.

The first two research questions served as the foundation for developing a decision-support tool. In this section, we explore the results of the logistic regression analysis, a critical step in building and validating the model described in section 3.4.3. Additional data cleansing and removal that was necessary due to this analysis are explored. To enhance clarity, we will utilize the terminology outlined in Table 4-3 throughout this analysis section.

Risk	Model Reference / Scale
Regulation	R mitigation / R_Scale
Demand volatility	D mitigation / D_Scale
Fuel production and availability	F mitigation / F_Scale

Table 4-3. Mitigation Model Reference

4.4.1. Descriptive Analyses

The initial phase of the results analysis involved an examination of descriptive statistics for each scale item in R (regulation), D (demand volatility), and F (fuel production and availability), as presented in Table 4-4, Table 4-5, and Table 4-6. It was observed that most of the scale items (questionnaire questions) exhibited limited range. Three items displayed zero variance (items: R3, F4, F7). Consequently, these were excluded from subsequent scale development.

As part of the data collection process for the case studies, the annual revenue figures for each company were recorded. In terms of reported revenue, the 20 companies

under study had an average reported revenue of $1,385.7 million (standard deviation [SD] = $975.70), with a range spanning from $141 million to $3,454 million.

Looking at the percentage of companies that reported mitigation:

- 35% of the companies reported mitigation for R-type risks
- 35% of the companies reported mitigation for D-type risks
- 30% of the companies reported mitigation for F-type risks

R variable descriptives.

Item	Mean	SD	Range
(R1) To what extent are you subject to regulations related to environmental sustainability in your supply chain?	2.30	.47	2–3
(R2) How much regulatory oversight do you face regarding labor practices in your supply chain?	2.10	.31	2–3
(R3) What is the extent of regulations governing product safety and quality within your supply chain?	3.00	.00	3
(R4) How much do customs and trade regulations impact your cross-border supply chain operations?	2.50	.52	2–3
(R5) To what degree are you impacted by data privacy and cybersecurity regulations within your supply chain?	1.05	.22	1–2
(R6) How much are you affected by transportation and logistics regulations in your supply chain?	2.30	.47	2–3
(R7) How much regulatory compliance is required regarding ethical sourcing and responsible supply chain practices?	2.40	.50	2–3
(R8) To what degree do import/export regulations impact your global supply chain network?	2.25	.44	2–3

Table 4-4. Regulation Descriptive Statistics

D variable descriptives.

Item	Mean	SD	Range
(D1) How would you rate the accuracy of your demand forecasting processes?	2.00	.32	1– 3
(D2) To what extent does demand volatility impact your inventory levels?	2.35	.49	2–3
(D3) How easily can your production processes adapt to sudden changes in demand?	1.45	.60	1–3
(D4) How well do your suppliers respond to shifts in demand?	1.85	.75	1–3
(D5) How adaptable are your supply chain technology systems and data in responding to demand changes?	1.65	.49	1–2
(D6) To what extent does demand volatility expose your supply chain to operational and performance risks?	2.35	.49	2–3
(D7) How does demand volatility influence your customer satisfaction levels?	2.30	.47	2–3
(D8) To what degree does demand volatility affect lead time variability for your supplies?	2.15	.37	2–3

Table 4-5. Demand Volatility Descriptive Statistics

F variable descriptives.

Item	Mean	SD	Range
(F1) How would you rate the overall availability of fuel for your supply chain operations?	1.05	.22	1–2
(F2) How would you assess the volatility of fuel prices and its impact on your supply chain costs?	2.30	.47	2–3
(F3) How would you rate your supply chain's adoption of alternative energy sources to reduce reliance on traditional fuels?	2.10	.31	2–3
(F4) How well-prepared is your supply chain to handle fuel supply disruptions or sudden price spikes?	2.00	.00	2
(F5) How diversified is your supply chain's portfolio of fuel suppliers to mitigate risks?	2.05	.22	2–3
(F6) To what extent are sustainable practices integrated into your supply chain to minimize fuel-related environmental impacts?	2.10	.45	1–3
(F7) How accurately can you forecast fuel demand for your supply chain operations?	2.00	.00	2
(F8) To what extent do fuel costs significantly impact your profitability?	2.25	.44	2–3

Table 4-6. Fuel Production and Availability Descriptive Statistics

4.4.2. Scale creation

The internal reliability of each scale (R, D, and F) was assessed to determine the consistency of the items within each scale, quantified on a scale from zero (0) to one (1), using Cronbach's alpha. The analysis aimed to assess how well these items hang together and contribute to the determination of mitigation. The results are as follows:

- R scale, 7 items: Cronbach's alpha = .84
- D scale, 8 items: Cronbach's alpha = .92
- F scale, 6 items: Cronbach's alpha = .55

It is worth noting that the F scale, even after excluding the two items with no variability, exhibited lower reliability compared to the R and D scales. On closer examination of the items, it was determined that the removal of additional items would not significantly improve internal reliability. Consequently, results involving the F scale should be interpreted cautiously.

Summary scores were then created for the R, D, and F scales to understand the mean standard deviation and range of scores as shown in Table 4-7. The F scale exhibited a limited range, indicating minimal variability in responses for this risk area. In contrast, the D scale demonstrated a considerably broader range, reflecting a greater variation in company risk profiles within this specific area of risk.

Scale descriptives.

Item	Mean	SD	Range
R scale	14.90	2.15	13–19
D scale	16.10	3.28	12–22
F scale	11.85	1.23	11–14

Table 4-7. Risk Scale Descriptive Statistics

4.4.3. Logistic Regression Analysis

Three distinct logistic regression models were run to forecast the likelihood of mitigation for types R, D, and F. In each of these models, the corresponding scale score (e.g., the R scale for predicting type R mitigation) was incorporated as a predictor variable. Additionally, as part of the initial modeling, company revenue was introduced as a covariate to investigate its potential influence on mitigation behavior. However, after

running initial logistic regression models and analyzing the results, it was determined that company revenue did not exhibit a statistically significant association with any of the three types of mitigation. Given the limited size of the sample used for the analysis, it was deemed prudent to exclude company revenue as a covariate from each of the models; this decision was made to safeguard the statistical power of the models. By removing the non-significant covariate, we aimed to focus the models on the variables that were more likely to have a meaningful impact on the prediction of mitigation behavior, thus optimizing their predictive accuracy. The results of the models are presented in Table 4-8Table 4-8. Logistic Regression Results.

Logistic regression results.

Predicting R Mitigation	(intercept)	B	SE	Wald	P	Odds ratio
R_scale	-22.12	1.41	.56	6.27	.012	4.10
Predicting D Mitigation						
D_scale	-17.32	.94	.41	5.33	.021	2.56
Predicting F Mitigation						
F_scale	-26.39	2.09	.83	6.42	.011	8.08

Table 4-8. Logistic Regression Results

Each of the scale scores was a significant predictor of their respective types of mitigation. An examination of the odds ratios allows us to interpret the increased likelihood of mitigation based on an increase of one scale score point:

- An increase of 1 on the R scale increased the odds of R-type mitigation by 310%
- An increase of 1 on the D scale increased the odds of D-type mitigation by 156%

- An increase of 1 on the F scale increased the odds of F-type mitigation by 708%

4.4.4. Establishing Mitigation Thresholds

To determine the score on the R, D, and F scales at which a company should consider mitigation, the conditional results were examined. The results for the three models are graphed in Figure 4-1, Figure 4-2 and Figure 4-3. The "cut off" or threshold value is the point on the x-axis (score value) where the figure crosses 0.5 on the y-axis (mitigation score). Alternatively, the value can be determined by the following equation −A / B where A = the model intercept, and B = the predictor coefficient:

- R mitigation = − (−22.12 / 1.41) = 15.69: A score of 15.69 (or 16) should lead to mitigation
- D mitigation = − (−17.32 / .94) = 18.43: A score of 18.43 (or 19) should lead to mitigation
- F mitigation = − (−26.39 / 2.09) = 12.63: A score of 12.63 (or 13) should lead to mitigation

4.4.5. Hypothesis Outcome

The p-values in Table 4-8 underscore the significance of the results, confirming the accuracy of the hypothesis: A decision-support tool can be developed to advise whether failure modes should be mitigated for a specific firm.

R scale conditional estimate plot

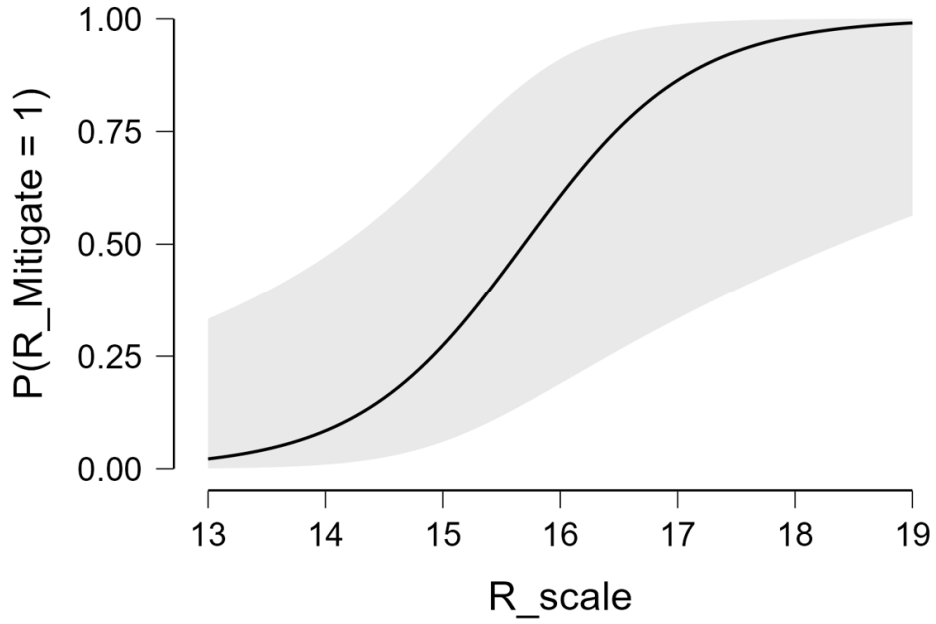


Figure 4-1. R Scale Diagram

D scale conditional estimate plot

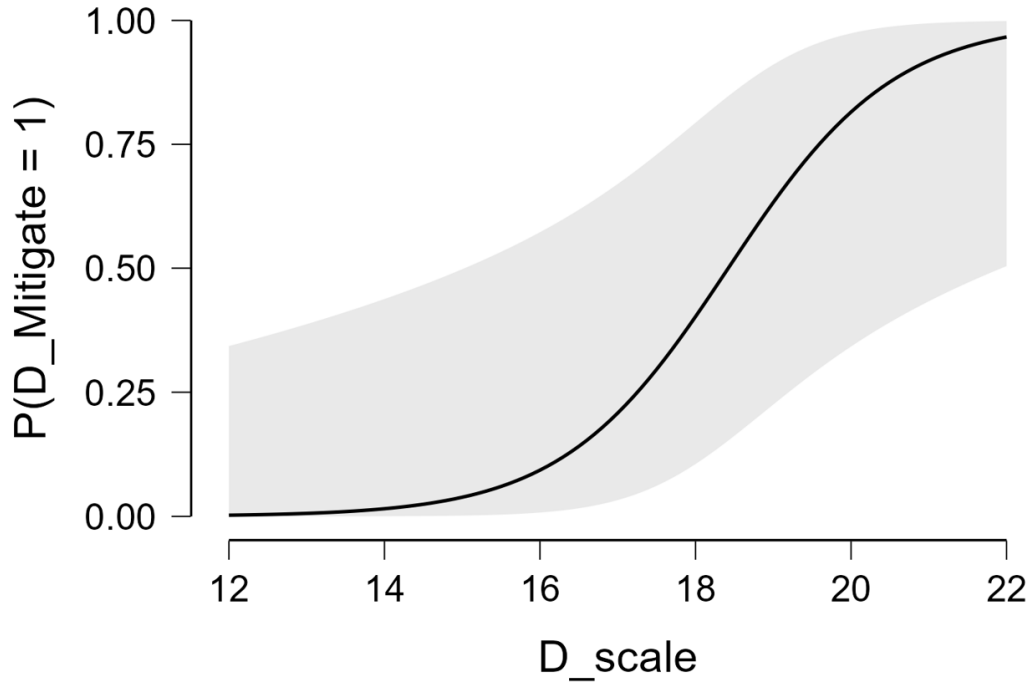


Figure 4-2. D Scale Diagram

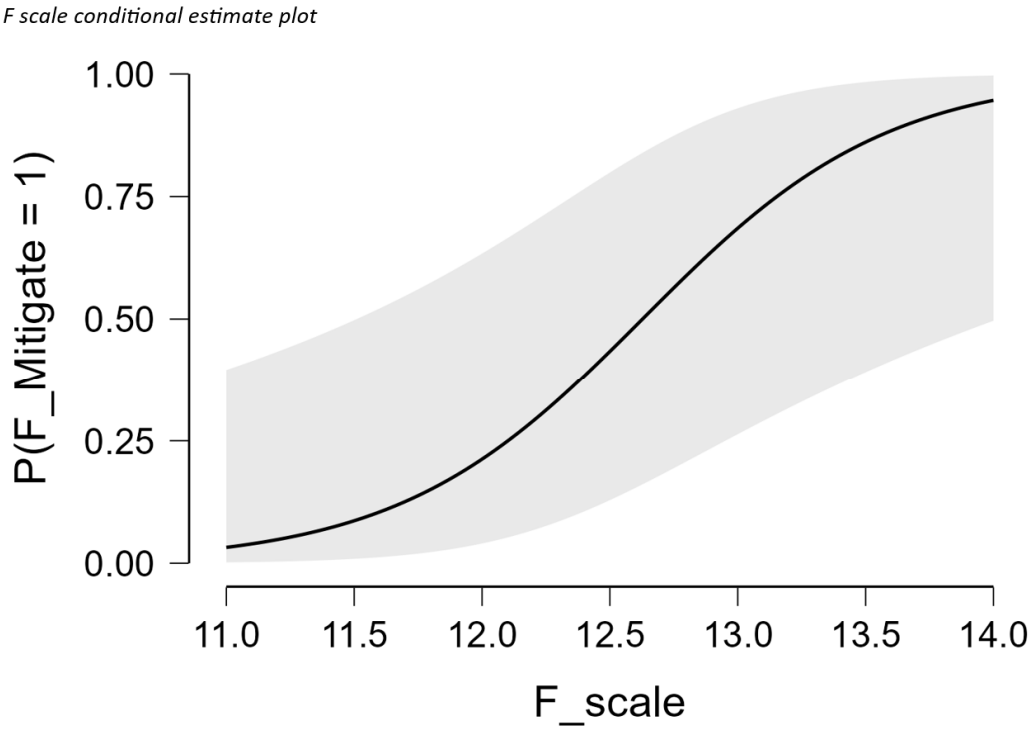
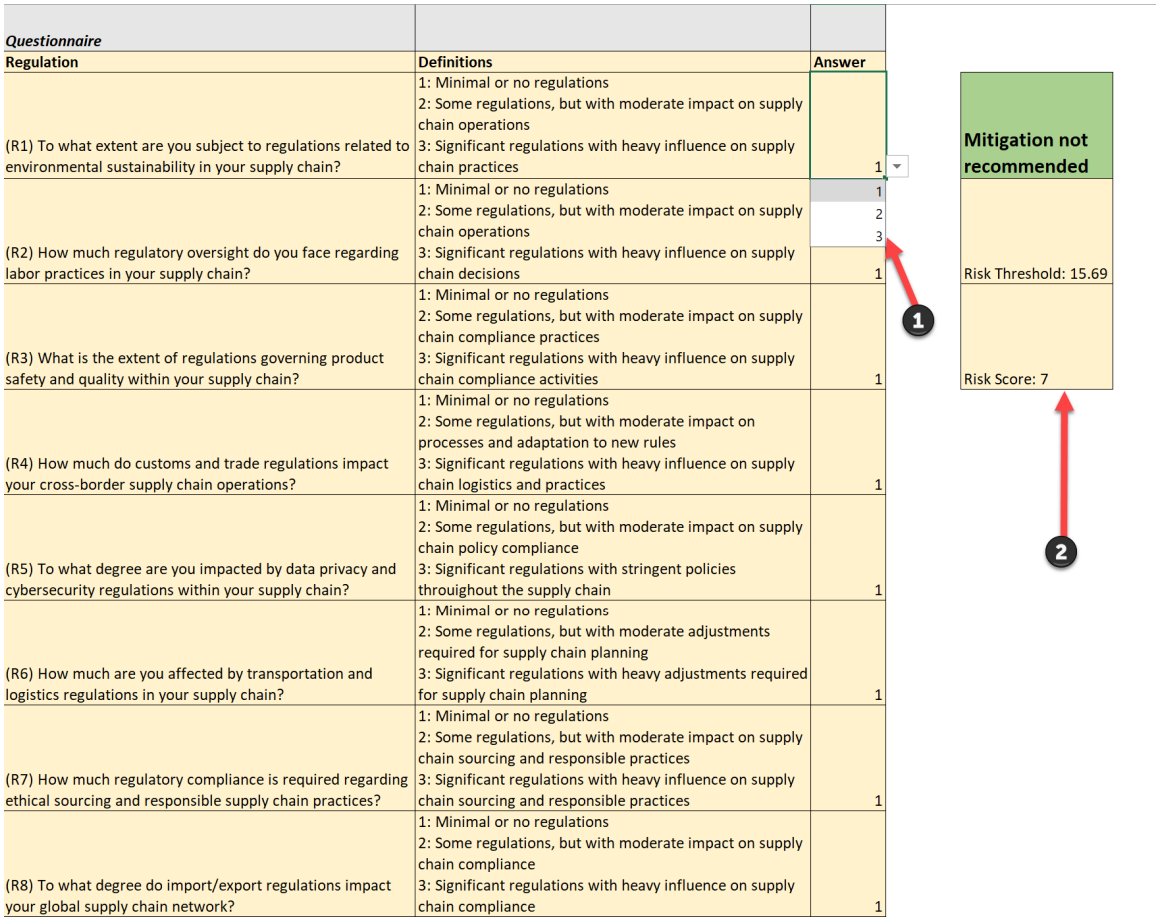


Figure 4-3. F Scale Diagram

4.5. Decision-Support Tool

The decision-support tool was developed in Excel using the underlying statistical results and analysis described in this praxis. It was envisioned that a CSCO would answer the questionnaire, ranking the risk factors for each risk as shown in Figure 4-4. Item 1 in Figure 4-4 shows the drop-down from which the CSCO will rank each risk factor. Item 2 shows the results of these answers by identifying the risk score: the sum of the answers that were not removed due to no variability. The CSCO's company risk score is then assessed in relation to the mitigation threshold and a determination is made if mitigation is recommended.



Questionnaire		
Regulation	**Definitions**	**Answer**
(R1) To what extent are you subject to regulations related to environmental sustainability in your supply chain?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain operations 3: Significant regulations with heavy influence on supply chain practices	1
(R2) How much regulatory oversight do you face regarding labor practices in your supply chain?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain operations 3: Significant regulations with heavy influence on supply chain decisions	1 2 3 1
(R3) What is the extent of regulations governing product safety and quality within your supply chain?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain compliance practices 3: Significant regulations with heavy influence on supply chain compliance activities	1
(R4) How much do customs and trade regulations impact your cross-border supply chain operations?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on processes and adaptation to new rules 3: Significant regulations with heavy influence on supply chain logistics and practices	1
(R5) To what degree are you impacted by data privacy and cybersecurity regulations within your supply chain?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain policy compliance 3: Significant regulations with stringent policies throuighout the supply chain	1
(R6) How much are you affected by transportation and logistics regulations in your supply chain?	1: Minimal or no regulations 2: Some regulations, but with moderate adjustments required for supply chain planning 3: Significant regulations with heavy adjustments required for supply chain planning	1
(R7) How much regulatory compliance is required regarding ethical sourcing and responsible supply chain practices?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain sourcing and responsible practices 3: Significant regulations with heavy influence on supply chain sourcing and responsible practices	1
(R8) To what degree do import/export regulations impact your global supply chain network?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain compliance 3: Significant regulations with heavy influence on supply chain compliance	1

Figure 4-4. Decision-Support Tool: Regulation – Mitigation Not Recommended

The risk threshold of 15.69 in Figure 4-4 was determined in 4.4.4. The risk score of 7 is the sum of the scale items (questions) for the R risk (Regulation). The score was calculated by summing the relevant items for this risk; item (R3) was removed from consideration/calculation in this model because it did not impact results due to no variation as discussed in 4.4.1. Because the score of 7 was below the threshold for mitigation, mitigation was not recommended.

Questionnaire		
Regulation	**Definitions**	**Answer**
(R1) To what extent are you subject to regulations related to environmental sustainability in your supply chain?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain operations 3: Significant regulations with heavy influence on supply chain practices	3
(R2) How much regulatory oversight do you face regarding labor practices in your supply chain?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain operations 3: Significant regulations with heavy influence on supply chain decisions	3
(R3) What is the extent of regulations governing product safety and quality within your supply chain?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain compliance practices 3: Significant regulations with heavy influence on supply chain compliance activities	3
(R4) How much do customs and trade regulations impact your cross-border supply chain operations?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on processes and adaptation to new rules 3: Significant regulations with heavy influence on supply chain logistics and practices	3
(R5) To what degree are you impacted by data privacy and cybersecurity regulations within your supply chain?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain policy compliance 3: Significant regulations with stringent policies throuighout the supply chain	3
(R6) How much are you affected by transportation and logistics regulations in your supply chain?	1: Minimal or no regulations 2: Some regulations, but with moderate adjustments required for supply chain planning 3: Significant regulations with heavy adjustments required for supply chain planning	3
(R7) How much regulatory compliance is required regarding ethical sourcing and responsible supply chain practices?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain sourcing and responsible practices 3: Significant regulations with heavy influence on supply chain sourcing and responsible practices	1
(R8) To what degree do import/export regulations impact your global supply chain network?	1: Minimal or no regulations 2: Some regulations, but with moderate impact on supply chain compliance 3: Significant regulations with heavy influence on supply chain compliance	1

Mitigation recommended
Risk Threshold: 15.69
Risk Score: 17

Figure 4-5. Decision-Support Tool: Regulation – Mitigation Recommended

Figure 4-5 shows the output when mitigation is recommended, highlighting CSCOs should consider action, showing the risk score of 17 above the risk threshold of 15.69.

Demand Volatility		
(D1) How would you rate the accuracy of your demand forecasting processes?	1: Low or no deviations between actual and forecast 2: Moderate deviations between actual and forecast 3: Frequent deviations between actual and forecast	1
(D2) To what extent does demand volatility impact your inventory levels?	1: Minimal or no impact on inventory levels 2: Moderate impact on inventory levels 3: Significant impact on inventory levels	1
(D3) How easily can your production processes adapt to sudden changes in demand?	1: Easy production process adaptation with low or no impact 2: Some ability to adapt production processes based on demand fluctuations 3: Low or no ability to easily adapt production processes	1
(D4) How well do your suppliers respond to shifts in demand?	1: Easy production process adaptation with low or no impact 2: Some ability to adapt production processes based on demand fluctuations 3: Low or no ability to easily adapt production processes	1
(D5) How adaptable are your supply chain technology systems and data in responding to demand changes?	1: Significant adaptability with modern technology platforms leading to the adaptability of demand changes 2: Some adaptability, but we have challenges leveraging our technology to adapt to demand volatility 3: Manual or inflexible systems have heavy impact on the ability to adapt to changes in demand	1
(D6) To what extent does demand volatility expose your supply chain to operational and performance risks?	1: Minimal risks due to demand volatility 2: Some risk, but manageable with some planning 3: High risk; high exposure	1
(D7) How does demand volatility influence your customer satisfaction levels?	1: Demand volatility does not or has little influence on customer satisfaction levels 2: Moderate levels of impact on customer satisfaction due to demand volatility 3: Significant impact on oragnizational performance due to customer disfaction due to demand volatility	1
(D8) To what degree does demand volatility affect lead time variability for your supplies?	1: Minimal impact; lead times are steady 2: Some impacts on lead times due to demand volatility 3: Significant lead time challenges due to demand volatility; planning is challenging	1

Mitigation not recommended
Risk Threshold: 18.43
Risk Score: 8

Figure 4-6. Decision-Support Tool: Demand Volatility

Fuel Production and Availability		
(F1) How would you rate the overall availability of fuel for your supply chain operations?	1: Reliable fuel supplies 2: Some shortages, but with moderate impact on supply chain 3: Frequent shortages leading to supply chain impacts	1
(F2) How would you assess the volatility of fuel prices and its impact on your supply chain costs?	1: Stable fuel pricing 2: Moderate price fluctuations affecting costs 3: Significant price fluctuations highly impacting cost controls	1
(F3) How would you rate your supply chain's adoption of alternative energy sources to reduce reliance on traditional fuels?	1: Extensive use of alternative fuel sources 2: Some adoption in place or underway 3: Minimal adoption of alternatives	1
(F4) How well-prepared is your supply chain to handle fuel supply disruptions or sudden price spikes?	1: Robust contingency plans in place 2: Some plans in place, but can be improved 3: No contingency plans in place	1
(F5) How diversified is your supply chain's portfolio of fuel suppliers to mitigate risks?	1: Robust diversification of suppliers in place 2: Some diversifications, but improvement needed 3: Dependence on one or few suppliers	1
(F6) To what extent are sustainable practices integrated into your supply chain to minimize fuel-related environmental impacts?	1: Robust sustainabilty practice in place 2: Some sustainability in place, but improvement is needed	1
(F7) How accurately can you forecast fuel demand for your supply chain operations?	1: Accurate forecasting in place 2: Some forecasting, but accuracy needs improvement 3: No or inaccurate forecasts in place	1
(F8) To what extent do fuel costs significantly impact your profitability?	1: Minimal or no impact 2: Occasional impact on profitability 3: Significant profitability impact	1

Mitigation not recommended
Risk Threshold: 12.63
Risk Score: 6

Figure 4-7. Decision-Support Tool: Fuel Production and Availability

4.6. Summary

Chapter 4—Results presents the culmination of the research efforts described in previous chapters, with a primary focus on addressing the research questions and hypotheses.

It begins by confirming the presence of common failure modes within CPG supply chains, as initially hypothesized. Seventeen failure modes are identified, validating the hypothesis.

As the research progresses, it refines its focus to pinpoint the top failure modes among the previously identified ones. This culling process narrows the field of consideration to thoroughly examined and substantiated risk factors. However, it is noted that the hypothesis regarding the primary failure modes is found to be inaccurate, possibly due to a lens and bias stemming from a technology consulting perspective.

The chapter then delves into the development of a decision-support tool, which is the goal of the research efforts. Logistic regression analysis is employed to validate the tool's foundation, assessing how well selected variables contribute to the prediction of mitigation. The results highlight the tool's potential, confirming that it can be utilized to advise specific firms on whether to mitigate failure modes (risks). The chapter concludes by detailing the practical application of this tool and its potential impact on decision-making processes.

Chapter 5—Discussion and Conclusions

5.1. Discussion

This research study addresses the critical issue of supply chain vulnerabilities exposed by the COVID-19 pandemic, which resulted in substantial financial losses for businesses worldwide. The study focuses on the CPG industry, which faced unique challenges due to its diverse product mix and evolving consumer behaviors. The primary motivation behind this research is to empower CSCOs with a decision-support tool that can help effectively prioritize and mitigate statistically probable and high-impact supply chain risks. The problem statement underscores the urgent need for CPG firms to identify and address these risks, given the potential disruptions that can cost up to 10% of annual revenues. The thesis statement highlights the significance of a decision-support tool in managing the increasing complexity of supply chain risks in the CPG industry. The research objectives aim to develop a tool tailored for CPG firms that enhances risk identification, assessment, and mitigation decision making, ultimately contributing to industry resilience, profitability, and sustainability.

5.2. Conclusions

Research Question 1 (RQ1) sought to identify common failure modes within the CPG supply chain. The hypothesis accurately pinpointed these common modes, including demand volatility, lack of raw materials, supplier business failure, transportation logistics, lack of/unpredictable workforce, interruption of the physical flow of goods, and lack of visibility into the supply chain.

Research Question 2 (RQ2) aimed to determine the top failure modes among those identified. However, the hypothesis did not align with the actual top failure modes, possibly due to biases during ranking before the research was conducted.

Research Question 3 (RQ3) focused on developing a decision-support tool to advise CSCOs on failure mode mitigation. This section details the logistic regression analysis, scale creation, and mitigation threshold establishment. The results of the logistic regression analysis confirm the hypothesis, providing statistical support for the development of the decision-support tool. This tool, built on rigorous statistical foundations, enables CSCOs to assess risk factors and make informed decisions about mitigation.

5.3. Contributions to Body of Knowledge

- **Supply Chain Risk Prioritization:** The research introduces a novel decision-support tool tailored to the CPG industry, addressing the critical need for helping CSCOs prioritize and mitigate supply chain risks. This tool enhances the ability of CSCOs to allocate limited resources effectively by focusing on statistically probable and impactful risks.
- **Data-Driven Insights:** The research leverages data-driven insights derived from advanced analytical models, including FMEA and logistic regression. These insights provide a practical approach for CPG companies to identify and proactively manage supply chain risks, contributing to improved risk management strategies.
- **Resilience and Profitability:** By aiding in the development of proactive risk management strategies, the research contributes to the resilience, profitability, and

long-term sustainability of the CPG industry. It addresses the financial consequences of disruptions and strengthens global supply chains.

- **Expansion of Previous Research:** This study builds upon previous research by introducing a specialized decision-support tool designed to focus resources on critical risks. It extends the body of knowledge in supply chain risk management, particularly in the context of the CPG industry, offering practical solutions for industry professionals and, specifically, CSCOs.

5.4. Recommendations for Future Research

- **Integration of Emerging Technologies:** The manual approach employed in this study underscores the need to exploit emerging technologies and automation. This necessity extends beyond the scope of this research or similar future studies and encompasses the effective management of the identified risks themselves. The integration of emerging technologies, such as blockchain, the Internet of Things, and artificial intelligence, into supply chain risk management should be investigated, and it should be assessed how these technologies can enhance real-time risk identification, monitoring, early warning systems, and decision support.

- **Cross-Industry Comparison:** While this research focuses on the CPG industry, future studies could easily expand their scope to compare risk management strategies and tools across various industries. This cross-industry analysis could help identify industry-specific best practices and commonalities in risk mitigation.

- **Behavioral Aspects of Risk Management:** This research revealed the potential for experiential biases to influence decision-making processes. The behavioral aspects of risk management within supply chains should be explored, and it

should be examined how human decision-making, biases, and organizational culture impact risk identification, assessment, and mitigation. This research could provide insights into improving risk-awareness and decision-making processes.

- **Resilience and Sustainability:** This research frequently encountered discussions pertaining to emerging sustainability requirements and regulations. Researchers should investigate the intersection of supply chain resilience and sustainability and analyze how companies can align risk management practices with sustainability goals to create more resilient and environmentally responsible supply chains.
- **Global Supply Chain Risks:** Future research should deep dive into these top risks in more detail. Given the increasing globalization of supply chains, research could delve into the unique challenges and risks associated with global supply chain networks. This may include geopolitical risks, trade disruptions, and the impact of regional policies on supply chain operations.
- **Regulatory Compliance**: Further research should investigate this top risk in more detail, analyzing the impact of changing regulations on supply chain risk management and exploring how companies can ensure compliance with evolving regulatory requirements while maintaining supply chain efficiency.
- **Questionnaire Attributes**: This research identified several items within the R-Scale and F-Scale questionnaires that did not enhance the models' reliability, leading to their exclusion. Future research could explore the potential of substituting these non-contributory questions with ones more closely aligned with

the risk framework. This approach may offer a method for enhancing the overall reliability of these models.

- **Retrospective study**: It is recommended to undertake a retrospective analysis in subsequent studies. Although the current research utilized real-world case study data from CPG companies, there is a need for a more comprehensive retrospective evaluation. Such research would validate whether the strategies employed by these firms were indeed successful in mitigating identified risks. This approach would not only confirm the efficacy of the actions taken but also provide deeper insights into the dynamics of risk management in the CPG industry.

These recommendations offer diverse avenues for future research in supply chain risk management, addressing both industry-specific challenges and broader trends in risk mitigation and resilience.

5.5. Summary

The overarching objective of this research is to provide CPG companies with a robust approach to proactively manage supply chain disruptions, ensuring greater resilience and sustainability in the post-pandemic era. The research proposed the development of a decision-support tool that CPG CSCOs could use to assist in prioritizing resources to mitigate the most probable and impactful risks.

Research insights revealed that while common failure modes within the CPG supply chain were correctly identified—including demand volatility and logistical challenges—the hypothesized ranking of these modes did not entirely match their actual criticality. Nonetheless, the successful development of a decision-support tool, grounded in logistic regression analysis, marks a significant advancement in enabling informed, data-driven decision-making for CSCOs, driving enhanced risk management and supply chain resilience.

References

Accenture. (2023). *Supply chain disruption*. Retrieved May 20, 2023. https://www.accenture.com/us-en/insights/consulting/supply-chain-disruption

ALG Worldwide. (n.d.). What is capacity in supply chain management? Retrieved May 14, 2023. https://algworldwide.com/what-is-capacity-in-supply-chain-management/

Alicke, K., Rexhausen, D., & Seyfert, A. (2017, April 17). *Supply Chain 4.0 in consumer goods*. Retrieved April 11, 2023. https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/supply-chain-4-0-in-consumer-goods

Alldredge, K., Henrich, J., Lal, S., & Verna, V. (2021, March 12). *COVID-19's impact on demand and costs in the CPG industry*. Retrieved April 25, 2023. https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/covid-19s-impact-on-demand-and-costs-in-the-cpg-industry

American Society for Quality. (2023, September 24). About stratification. https://asq.org/quality-resources/stratification

B&G Foods, Inc. (2023, February 28). *2022 Annual Report*. Retrieved August 30, 2023. https://bgfoods.gcs-web.com/static-files/3f851b35-7608-4b7c-9b1c-709726947f17

Bain, P. (2023, February 24). *2023 Supply chain outlook: How to navigate through uncertainty*. Retrieved March 23, 2023. https://www.forbes.com/sites/forbestechcouncil/2023/02/24/2023-supply-chain-outlook-how-to-navigate-through-uncertainty/

Bergstrom, J., Gallagher, P., & Steward, I. (2020, December 11). *Preparing today's supply chains to thrive in uncertainty*. Retrieved September 12, 2023. Deloitte website: https://www2.deloitte.com/us/en/insights/focus/industry-4-0/supply-chain-future-post-pandemic.html

Beyond Meat Inc. (2023, March 1). *2022 Annual Report*. Retrieved August 29, 2023. https://investors.beyondmeat.com/static-files/cc32730c-63c3-412e-8912-6c45fe73aa03

Blue Apron Holdings Inc. (2023, March 16). *2022 Annual Report*. Retrieved September 1, 2023. https://otp.tools.investis.com/clients/us/blue_apron/SEC/sec-show.aspx?Type=html&FilingId=16494415&Cik=0001701114

Blue Apron Holdings Inc. (2023, May 16). *Blue Apron announces plans to shift to an asset-light model through the transfer of operational infrastructure to FreshRealm*. Retrieved September 4, 2023. https://investors.blueapron.com/press-releases/2023/05-16-2023-123026343

Blue Apron Holdings Inc. (2023, August 9). *Blue Apron Holdings, Inc. reports second quarter 2023 results*. Retrieved September 4, 2023. https://investors.blueapron.com/press-releases/2023/08-09-2023-113029394

Britannica. (n.d.). *Britannica Definitions*. Retrieved May 6, 2023. https://www.britannica.com/technology/transportation-technology

Bustamante, F., Henstorf, B., Loughlin, R., & Teichner, W. (2022, October 5). *How consumer-packaged-goods companies can drive resilient growth*. Retrieved September 5, 2023. https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/how-consumer-packaged-goods-companies-can-drive-resilient-growth

Cal-Maine Foods. (2023, July 25). Cal-Maine Foods reports results for fourth quarter and fiscal year 2023. Retrieved August 13, 2023. https://calmainefoods.gcs-web.com/node/13316/pdf

Carter, T. (2021, January 3). The true failure rate of small businesses. Retrieved January 15, 2023. https://www.entrepreneur.com/article/361350

Cassell, T. (2022, September 14). Mitigating demand volatility to improve forecasting: An intelligent workflow from IBM and SAP. Retrieved September 21, 2023. https://www.ibm.com/blog/forecasting-intelligent-workflow-ibm-sap/

Cecere, L. (2023, January 23). Supply chain visibility: If it seems simple, look more closely. Retrieved May 20, 2023. https://www.forbes.com/sites/loracecere/2023/01/18/supply-chain-visibility-if-it-seems-simple-look-more-closely/?sh=e902660388f5

Celsius Holdings Inc. (2023). *2022 Annual Report*. Retrieved August 30, 2023. https://dd7pmep5szm19.cloudfront.net/2285/0000950170-23-005612.pdf

Chang, C. M. (2016). *Engineering management: Meeting the global challenges*. CRC Press.

Chorley, J. (2022, August 31). Building ethical supply chains. Retrieved August 30, 2023. https://www.forbes.com/sites/jonchorley/2022/08/31/building-ethical-supply-chains/?sh=469ba44e28b2

Conerly, B. (2021, July 7). The labor shortage is why supply chains are disrupted. Retrieved December 9, 2022. https://www.forbes.com/sites/billconerly/2021/07/07/the-labor-shortage-is-why-supply-chains-are-disrupted/?sh=2b812040301d

Consumer Brands Association. (2021). *Breaking the Chain*. Retrieved September 10, 2023. https://consumerbrandsassociation.org/wp-content/uploads/2021/03/Future_of_Supply_Chain.pdf

Consumer Brands Association. (2021, March). The CPG post-pandemic outlook. Retrieved September 12, 2023. https://consumerbrandsassociation.org/industry-impact/five-trends-emerging-from-covid-shaping-cpg/

Convenience Store News. (2022, August 15). Utz Brands shifts strategies around marketing & supply chain. Retrieved August 15, 2023. https://csnews.com/utz-brands-shifts-strategies-around-marketing-supply-chain

DePuy, M. (2021, June 8). COVID-19's influence on the consumer packaged goods supply chain. Retrieved April 21, 2023. https://www.fmi.org/blog/view/fmi-blog/2021/06/08/covid-19%27s-influence-on-the-consumer-packaged-goods-supply-chain

Devenyns, J. (2021, August 21). CPG manufacturers face 'labor crisis' amid supply chain pressures, report says. Retrieved April 11, 2023. https://www.fooddive.com/news/cpg-manufacturers-face-labor-crisis-amid-supply-chain-pressures-report-s/605745/

Doering, C. (2021). As inflation rages, food and beverage manufacturers pass higher costs on to consumers. *Food Dive*. Retrieved March 23, 2023. https://www.proquest.com/docview/2525234066?accountid=11243

Doering, C. (2022, January 11). CPGs grapple with a murky 2022 outlook as inflation, supply chain weigh on operations. *Food Dive*. Retrieved March 22, 2023. http://proxygw.wrlc.org/login?url=https://www.proquest.com/trade-journals/cpgs-grapple-with-murky-2022-outlook-as-inflation/docview/2620904818/se-2

Edgewell Personal Care. (2022, November 16). *2022 Annual Report*. Retrieved September 1, 2023. https://ir.edgewell.com/~/media/Files/E/EdgeWell-IR/annual-reports/epc-10k-9-30-22-48.pdf

Farahani, R., Rezapour, S., & Kardar, L. (2011). *Logistics Operations and Management: Concepts and Models*. Elsevier.

Federal Register (National Archives and Records Administration). (2021, September 16). America's supply chains and the transportation industrial base. Retrieved September 2, 2023. https://www.federalregister.gov/documents/2021/09/16/2021-19974/americas-supply-chains-and-the-transportation-industrial-base

Felix, I., Mazuera, C., Salguero, J., & Sanger, F. (2022, January 20). Risk and resilience in consumer-goods supply chains. Retrieved April 21, 2023. https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/risk-and-resilience-in-consumer-goods-supply-chains

Freshpet Inc. (2023, February 28). 2022 Annual Report. Retrieved August 30, 2023. https://d18rn0p25nwr6d.cloudfront.net/CIK-0001611647/68fd0483-74ff-46d1-9b74-31de27e8b333.pdf

Galer, S. (2022, October 5). Three principles of resilient supply chains for CPG manufacturing. Retrieved April 11, 2023. https://news.sap.com/2022/10/three-principles-resilient-cpg-supply-chains/

Gartner. (2022). *Transforming Retail Supply Chain*. Retrieved April 23, 2023. https://www.gartner.com/en/supply-chain/insights/retail-supply-chain-management

Gartner. (2023). *Supply Chain Sustainability: Critical Tools and Insights*. Retrieved September 17, 2023. https://www.gartner.com/en/supply-chain/topics/supply-chain-sustainability

Genpact. (2021). *Economic Resilience: The Complete Package*. Retrieved March 23, 2023. https://www.genpact.com/insight/economic-resilience-the-complete-package

GEP. (2022). 2022 CPG Supply Chain & Procurement Outlook. Retrieved April 11, 2023. https://www.gep.com/white-papers/2022-cpg-supply-chain-and-procurement-outlook

Gergele, O. (2020, November 10). How CPG players can thrive now and beyond. Retrieved April 25, 2023. https://www.ey.com/en_id/consumer-products-retail/how-cpg-players-can-thrive-now-and-beyond

Girtan, M., Wittenberg, A., Grilli, M., de Oliveira, D., Giosuè, C., & Ruello, M. (2021). The critical raw materials issue between scarcity, supply risk, and unique properties. *Materials, 14*(8).

Global Supply Chain Institute. (2019, September 16). Guide to Becoming a Chief Supply Chain Officer. Retrieved August 2, 2023. https://supplychainmanagement.utk.edu/blog/chief-supply-chain-officer/

Grindy, B. (2021, October 21). Rising food costs and supply chain issues are creating challenges. Retrieved May 29, 2023. https://restaurant.org/education-and-resources/resource-library/rising-food-costs-and-supply-chain-issues-are-creating-challenges/

Helper, S., & Soltas, E. (2021, June 17). Why the pandemic has disrupted supply chains. Retrieved November 21, 2022. https://www.whitehouse.gov/cea/written-materials/2021/06/17/why-the-pandemic-has-disrupted-supply-chains/

Hendry, L. C., Stevenson, M., MacBryde, J., Ball, P., & Maysara, S. (2019). Local food supply chain resilience to constitutional change: The Brexit effect. *International Journal of Operations & Production Management, 39*(3), 429–453. Retrieved March 23, 2023. https://www.proquest.com/docview/2210975124?accountid=11243&parentSessionId=ln1SYx4paAKBQuLRVKZsKxuI7pG8UrL8NbRxleb81YY%3D&pq-origsite=primo

Hipplod, S. (2021, February 4). Diversifying global supply chains for resilience. Retrieved March 22, 2023. https://www.gartner.com/smarterwithgartner/diversifying-global-supply-chains-for-resilience

Hosmer Jr, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied logistic regression* (Vol. 398). John Wiley & Sons.

Hutchins, G. (2018). *Supply Chain Risk Management: Completing In the Age of Disruption*. Greg Hutchins.

Idserda, R. (2020, December 22). Building a consumer-centric supply chain in CPG. Retrieved April 25, 2023. https://www.accenture.com/us-en/insights/consumer-goods-services/customer-centric-cpg-supply-chain

Idserda, R., McDivitt, C., & Meuwissen, F. J. (2020, December 22). Building a consumer-centric supply chain in CPG. Retrieved April 10, 2023. https://www.accenture.com/us-en/insights/consumer-goods-services/customer-centric-cpg-supply-chain

Industry Week. (n.d.). How the right mix of technology and strategy puts CPG manufacturers on top. Retrieved April 21, 2023. https://go.oracle.com/LP=88895?elqCampaignId=209071

Interos. (2022). *Resilience 2022: The Interos annual supply chain report*. Retrieved March 22, 2023. https://www.interos.com/resilience-2022-report

IRI. (2023, February 16). 2022 CPG growth leaders. Retrieved April 25, 2023. https://www.iriworldwide.com/IRI/media/Library/cpg-growth-leaders-2022-pdf.pdf

Jabil. (2020, September). What has been the negative impact on your company's business outcomes as a result of supply chain issues related to COVID-19? Retrieved September 10, 2023. https://www-statista-com.proxygw.wrlc.org/statistics/1259124/loss-supply-chain-disruption-industry/

Jencks, E. D. (2021). What do supply chain disruptions mean for transportation factors? *Commercial Factor*(November/December).

John, G. (2023, August 2). Forced labor regulations materially impact U.S. and European supply chains. Retrieved September 2, 2023. https://www.interos.ai/blog-forced-labor-regulations-materially-impact-u-s-and-european-supply-chains/

J.P. Morgan. (2022, May 25). What's behind the global supply chain crisis? Retrieved April 10, 2023. https://www.jpmorgan.com/insights/research/global-supply-chain-issues

Kearney. (2022, June 2). More than half of all CPG companies on track to grow below the market by 2027. Retrieved April 21, 2023. https://www.kearney.com/industry/consumer-retail/article/-/insights/more-than-half-of-all-cpg-companies-on-track-to-grow-below-the-market-by-2027

Kenney, E. J. (2021, October 21). How CPG companies can overcome supply shocks with agile procurement. Retrieved April 20, 2023. https://www.forbes.com/sites/sap/2021/10/22/how-cpg-companies-can-overcome-supply-shocks-with-agile-procurement/?sh=6440823cf25d

Kingsley, J. (2021, February 25). The business costs of supply chain disruption. Retrieved September 10, 2023.

https://impact.economist.com/perspectives/sustainability/business-costs-supply-chain-disruption-1

Kopka, U., Little, E., Moulton, J., Schmutzler, R., & Simon, P. (2020, July 30). What got us here won't get us there: A new model for the consumer goods industry. Retrieved September 23, 2023. https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/what-got-us-here-wont-get-us-there-a-new-model-for-the-consumer-goods-industry

KPMG. (2022). *The challenges of cross-border international trade*. Retrieved August 15, 2023. https://home.kpmg/xx/en/home/insights/2022/04/the-challenges-of-cross-border-international-trade.html

Krispy Kreme Inc. (2023, August 15). *2022 Annual Report*. https://s202.q4cdn.com/983903322/files/doc_financials/2022/ar/0001857154-23-000020.pdf

Krispy Kreme Inc. (2023, August 10). Krispy Kreme reports second quarter 2023 results, reiterates full year guidance. Retrieved September 1, 2023. https://investors.krispykreme.com/news/news-releases/news-details/2023/Krispy-Kreme-Reports-Second-Quarter-2023-Results-Reiterates-Full-Year-Guidance/

LaRocco, L. A. (2022, December 23). Most supply chain managers expect problems to continue at least through 2024. Retrieved April 10, 2023. https://www.cnbc.com/2022/12/23/supply-chain-managers-expect-problems-continue-2024.html

LaRocco, L. A. (2022, August 17). The U.S. supply chain is now facing two trade hurdles. Retrieved March 22, 2023. https://www.cnbc.com/2022/08/16/the-us-supply-chain-is-now-facing-two-trade-hurdles.html

Larsen, C. (2022, June 8). How increasing fuel prices are affecting supply chains. Retrieved September 24, 2023. https://www.maersk.com/insights/resilience/fuel-prices-affecting-supply-chains

Leslie, J. (2022, March 10). How climate change is disrupting the global supply chain. Retrieved May 6, 2023. https://e360.yale.edu/features/how-climate-change-is-disrupting-the-global-supply-chain

Lifeway Foods, Inc. (2023, March 27). *Annual Report*. Retrieved August 30, 2023. https://annualreport.stocklight.com/nasdaq/lway/23764700.pdf

Lifeway Foods, Inc. (2023, August 14). Lifeway earnings release. Retrieved September 1, 2023. https://lifewaykefir.com/wp-content/uploads/2Q23-LWAY-Earnings-Release-.pdf

Lin, J. (2022, August 24). Global supply chain resilience issues to watch out for in 2023. Retrieved March 23, 2023. https://criticalmaterials.org/global-supply-chain-resilience-issues-to-watch-out-for-in-2023/

Lobaugh, K., Waelter, A., Locricchio, A., & Oman, C. (2022). *The future of the consumer industry*. Retrieved April 11, 2023. https://www2.deloitte.com/us/en/pages/consumer-business/articles/future-of-consumer-industry.html

Loria, K. (2021, September 9). CPG industry faces labor shortage, supply chain challenges. Retrieved May 29, 2023. https://www.foodqualityandsafety.com/article/report-cpg-industry-faces-labor-shortage-supply-chain-challenges/

Lund, S., Manyika, J., Woetzel, J., & Barriball, E. (2020, August 6). Risk, resilience, and rebalancing in global value chains. Retrieved March 22, 2023. https://www.mckinsey.com/capabilities/operations/our-insights/risk-resilience-and-rebalancing-in-global-value-chains#/

Madrecki, T. (2021, March 19). The future of supply chain. Retrieved April 21, 2023. https://consumerbrandsassociation.org/blog/the-future-of-supply-chain/

Manning, L. (2021). E-commerce, transparency, sustainability key for CPG manufacturers in 2021. *Supply Chain Dive*. Retrieved March 22, 2023. https://www.proquest.com/docview/2503522563?accountid=11243

Martin, B. (2021, November 15). Supply Chain Disruptions: The Risks and Consequences. Retrieved September 2, 2023. https://www.rand.org/blog/2021/11/supply-chain-disruptions-the-risks-and-consequences.html

Mayer, M. (2022, December 27). 2023 will see a continued state of supply chain instability. Retrieved April 21, 2023. https://www.foodlogistics.com/software-technology/supply-chain-visibility/article/22551948/symphony-retailai-cpg-2023-will-see-a-continued-state-of-supply-chain-instability

McGillivray, G. (2021, July 30). An expert explains: How COVID-19 exposed the fragility of global supply chains. Retrieved August 2, 2023. https://www.weforum.org/agenda/2021/07/covid-19-pandemic-global-supply-chains

McKinsey & Company. (2020, October 19). *Rethinking the consumer goods supply chain in response to COVID-19*. Retrieved February 3, 2023. https://www.mckinsey.com/~/media/mckinsey/about%20us/covid%20response%20center/pdfs/rethinkingtheconsumergoodssupplychaininresponsetocovid1911520.pdf

McKinsey & Company. (2022). *CPG operations—How to win in a rapidly changing environment*. Retrieved April 21, 2023. https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/cpg-operations-how-to-win-in-a-rapidly-changing-environment

Merriam-Webster. (n.d.). *Merriam-Webster*. Retrieved May 13, 2023. https://www.merriam-webster.com/dictionary

Morrison, K. (2023, January 23). CPG companies think beyond costs to boost profitability in 2023. Retrieved April 25, 2023. https://foodindustryexecutive.com/2023/01/cpg-companies-think-beyond-costs-to-boost-profitability-in-2023/

NACS. (2023, January 13). 5 industry insights from consumer product executives. Retrieved April 25, 2023. https://www.convenience.org/Media/Daily/2023/Jan/13/1-5-Insights-Consumer-Product-Executives_Consumers

National Beverage. (2022, June 29). *2022 Annual Report*. Retrieved September 4, 2023. https://ir.nationalbeverage.com/static-files/fa9fbfe3-38f6-4811-a6f5-c15ba38ee3ee

National Institute of Standards and Technology. (2022, May 5). NIST updates cybersecurity guidance for supply chain risk management. Retrieved September 1, 2023. https://www.nist.gov/news-events/news/2022/05/nist-updates-cybersecurity-guidance-supply-chain-risk-management

Nobel, P. J. (2022, March 23). When it comes to CPG and food & beverage companies - Investing in purpose-built supply chain intelligence matters. Retrieved June 23, 2023. https://www.forbes.com/sites/paulnoble/2022/06/23/when-it-comes-to-cpg-and-food--beverage-companiesinvesting-in-purpose-built-supply-chain-intelligence-matters/?sh=1d7bf90b3b10

Nomad Foods. (2022). *2022 Annual Report*. Retrieved August 15, 2023. https://www.nomadfoods.com/wp-content/uploads/2023/05/nomad-foods-2022-annual-report-compressed.pdf

Nomad Foods. (2022, May). *Nomad Foods 2021 Impact Report*. Retrieved August 5, 2023. https://www.nomadfoods.com/wp-content/uploads/2022/05/2021-nomadfoodsreport-v14.pdf

Nu Skin Enterprises. (2023, February 15). *2022 Annual Report*. Retrieved August 31, 2023. https://ir.nuskin.com/static-files/af3b280d-150f-4aca-bc26-06c506a88e73

Nuce, M. (2022, January 25). 2022 imperative: Building supply chain resilience. Retrieved April 25, 2023. https://consumergoods.com/2022-imperative-building-supply-chain-resilience

Oller, S. (2022). Big Food's sustainable packaging goals hit supply and demand reality. *Food Dive*. Retrieved March 23, 2023. https://www.proquest.com/docview/2672169257?accountid=11243&parentSessionId=cU%2Fom8aUYwNCvpouftqj6ih2xxQ09cCCNn%2BKn4wzv5M%3D&pq-origsite=primo

Olson, E., Hu, R., & Ngobi, L. (2020). *Securing the supply chain*. Retrieved February 10, 2023. https://www.accenture.com/_acnmedia/PDF-134/Accenture-Securing-The-Supply-Chain.pdf#zoom=40

Ovezmyradov, B. (2022, November 30). Product availability and stockpiling in times of pandemic: Causes of supply chain disruptions and preventive measures in retailing. Retrieved September 22, 2023. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9709757/

Panzino, C. (2021, December 13). US supply chain issues will worsen into 2022 as transportation woes persist. Retrieved March 22, 2023. https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/us-supply-chain-issues-will-worsen-into-2022-as-transportation-woes-persist-67955856

Pergl, N. (2021, August 11). *Why a sustainable supply chain is critical to the future of consumer products*. Forbes. Retrieved September 24, 2023. https://www.forbes.com/sites/sap/2021/08/11/why-a-sustainable-supply-chain-is-critical-to-the-future-of-consumer-products/?sh=410ed38539cd

Pieters, L., Handrinos, N., Cook, J., & Fenech, C. (2022). *2023 Consumer Products Industry Outlook*. Deloitte. Retrieved April 16, 2023. https://www2.deloitte.com/us/en/pages/consumer-business/articles/consumer-products-industry-outlook.html

Poinski, M. (2022). *Supply issues top CPG company leaders' concerns, study finds*. Food Dive. Retrieved March 22, 2023. http://proxygw.wrlc.org/login?url=https://www.proquest.com/trade-

journals/supply-issues-top-cpg-company-leaders-concerns/docview/2694105606/se-2

Pototschnik, L., Kogan, A., Inglesby, J., Austin, M., & Graham, J. (2019, November 15). *Reinventing the CPG supply chain with zero-based budgeting*. Boston Consulting Group. Retrieved April 11, 2023. https://www.bcg.com/publications/2019/reinventing-consumer-packaged-goods-supply-chain-with-zero-based-budgeting

Ramsden-Knowles, B., Houston, J., Stainback, D., & Williams, P. (2023, February 23). *Building resilience in a polycrisis world*. PWC. Retrieved March 23, 2023. https://www.pwc.com/gx/en/issues/risk-regulation/business-resilience-in-a-polycrisis-world.html

Renner, B., Bondar, M., Cook, J., & Fenech, C. (2022). *2022 Consumer Products*. Deloitte. Retrieved March 22, 2023.

Sanger, F. (2022, January 10). *Achieving supply-chain resiliency in consumer goods amid disruption*. McKinsey & Company. Retrieved April 21, 2023.https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/achieving-supply-chain-resiliency-in-consumer-goods-amid-disruption

Schultz, J. D. (2021, June 21). *U.S. logistics business costs rise by 22.4% to $1.85 trillion in 2021*. Logistics Management. Retrieved March 22, 2023. https://www.logisticsmgmt.com/article/u.s._logistics_business_costs_rise_by_22.4_to_1.85_trillion_in_2021_new_rep

Sehgal, P., & Singh, R. (2022, July 29). *Reliable energy requires resilient supply chains*. Accenture. Retrieved March 23, 2023. https://www.accenture.com/us-en/insightsnew/energy/supply-chain-resilience

Seibel, J. S., Mazzuchi, T. A., & Sarkani, S. (2006). A same vendor, version-to-version upgrade decision support model for commercial off-the-shelf productivity applications. *Systems Engineering, 9*(4), 296–312. https://doi.org/10.1002/sys.20058

Sharafelden, B., Twidale, S., & Khasawneh, R. (2021, September 22). Soaring gas prices ripple through heavy industry, supply chains. Retrieved May 7, 2023.https://www.reuters.com/business/energy/soaring-gas-prices-ripple-through-heavy-industry-supply-chains-2021-09-22/

Singh, N., & Singh, S. (2019). Building supply chain risk resilience: Role of big data analytics in supply chain disruption mitigation. *Benchmarking, 26*(7), 2318–2342. https://www.proquest.com/docview/2289359238?accountid=11243&parentSessionId=%2BH7PzUC7KoWfMCBUk8h8tqpV5NvTqRjG3XpSvkWkVng%3D&pq-origsite=primo

Spivack, M. S. (2022, February 1). Warehouse space is the latest thing being hoarded. Retrieved April 16, 2023. https://www.nytimes.com/2022/02/01/business/warehouses-supply-chain.html

Stroh, K. (2023, February 21). TreeHouse Foods to invest $65M on supply chain initiatives in 2023. Retrieved August 1, 2023. https://www.supplychaindive.com/news/treehouse-foods-invests-65m-in-supply-chain-Q4/642970/

Sunopta Inc. (2023, March 1). 2022 Annual Report. Retrieved August 15, 2023. https://s23.q4cdn.com/915258311/files/doc_financials/2022/ar/SUNOPTA-INC-_Annual-Report-April-10-2023.pdf

Tate & Lyle PLC. (2023). *2023 Annual Report*. Retrieved September 2, 2023. https://www.tateandlyle.com/sites/default/files/2023-06/2023-06-06tlar2023-pdf.pdf

The Economist. (2022, January 29). Why supply-chain problems aren't going away. Retrieved April 21, 2023. https://www.economist.com/business/2022/01/29/why-supply-chain-problems-arent-going-away/

The University of Tennessee, Knoxville. (2021, March 19). A guide to forecasting demand in a stretched supply chain. Retrieved September 10, 2023. https://supplychainmanagement.utk.edu/blog/guide-to-forecasting-demand/

The Vita Coco Company. (2023, March 8). *2022 Annual Report*. Retrieved August 30, 2023. https://vitacoco.gcs-web.com/static-files/8aab3e59-e6a7-4406-b664-bc70806d2c1a

The Vita Coco Company Inc. (2023, August 3). The Vita Coco Company reports second quarter 2023 financial results. Retrieved September 1, 2023. https://investors.thevitacococompany.com/node/8206/pdf

Thilmany, D., Canales, E., Bows, S. A., & Boys, K. (2020). Local food supply chain dynamics and resilience during COVID-19. *Applied Economic Perspectives and Policy*. Retrieved April 10, 2023. https://doi.org/[DOI]

Tilray Brands Inc. (2023, July 26). *2022 Annual Report*. Retrieved September 1, 2023. https://ir.tilray.com/static-files/068f0345-3a0b-4218-9cbb-23f5f82ece94

Tootsie Roll Industries, Inc. (2023). *2022 Annual Report*. Retrieved September 2, 2023. https://tootsie.com/financials/

TreeHouse Foods. (2022). *2022 Annual Report*. Retrieved August 28, 2023. https://s23.q4cdn.com/884251494/files/doc_financials/2022/ar/treehouse-foods-2022-annual-report.pdf

U.S. Consumer Product Safety Commission. (2006, July). *Handbook for manufacturing safer consumer products*. Retrieved August 30, 2023. https://www.cpsc.gov/s3fs-public/pdfs/blk_pdf_handbookenglishaug05.pdf

Universal Corporation. (2022). *Universal Corporation Sustainability Report*. Retrieved September 3, 2023. http://universalcorp.com/Resources/Practices/2022%20Universal%20Sustainability%20Report.pdf

Universal Corporation. (2023). *2023 Universal Corporation Annual Report*. Retrieved September 3, 2023. https://s28.q4cdn.com/541138073/files/doc_financials/2023/ar/2023_universal-annual-report-1.pdf

Universal Corporation. (2023, August 2). Universal Corporation reports first quarter results. Retrieved August 3, 2023. https://investor.universalcorp.com/news/news-details/2023/Universal-Corporation-Reports-First-Quarter-Results/default.aspx

University of California, Los Angeles. (2023, September 23). What does Cronbach's alpha mean? https://stats.oarc.ucla.edu/spss/faq/what-does-cronbachs-alpha-mean/

Utz Brands Inc. (2022). *Annual Report*. Retrieved September 2, 2023. https://s25.q4cdn.com/130011723/files/doc_financials/2022/ar/utz-2022-annual-report.pdf

Vallejo, D. (2022, October 28). 3 major impacts of inflation on global supply chains. Retrieved May 20, 2023. https://www.forbes.com/sites/sap/2022/10/28/3-major-impacts-of-inflation-on-global-supply-chains/?sh=34fa19b91614

Westrock Coffee Company. (2023). *2022 Annual Report*. Retrieved August 30, 2023. https://investors.westrockcoffee.com/static-files/c362aaf9-caa2-4800-966e-86f4bf5d907e

Wolters Kluwer. (2021, June 8). How to better manage demand volatility. Retrieved May 6, 2023. https://www.wolterskluwer.com/en/expert-insights/how-to-better-manage-demand-volatility

World Economic Forum. (2022, September 7). 5 challenges facing global supply chains. Retrieved September 24, 2023. https://www.weforum.org/agenda/2022/09/5-challenges-global-supply-chains-trade/

Xu, Z. (2020). Impacts of COVID-19 on global supply chains: Facts and perspectives. *IEEE Engineering Management Review*, *48*(3), 153–166.

Appendix

Article No.	Title
1	U.S. supply chain issues will worsen into 2022 as transportation woes persist (Panzino, 2021)
2	The U.S. supply chain is now facing two trade hurdles (LaRocco, 2022)
3	2022 consumer products industry outlook (Renner et al., 2022)
4	U.S. logistics business costs rise by 22.4% to $1.85 trillion in 2021 (Schultz, 2021)
5	What do supply chain disruptions mean for transportation factors? (Jencks, 2021)
6	Resilience 2022: The Interos annual global supply chain report (Interos, 2022)
7	Risk, resilience, and rebalancing in global value chains (Lund et al., 2020)
8	CPGs grapple with a murky 2022 outlook as inflation and supply chain weigh on operations (Doering, 2022)
9	Supply issues top CPG company leaders' concerns, study finds (Poinski, 2022)
10	E-commerce, transparency, and sustainability are key for CPG manufacturers in 2021 (Manning, 2021)
11	Big Food's sustainable packaging goals hit supply and demand reality (Oller, 2022)
12	As inflation rages, food and beverage manufacturers pass higher costs on to consumers (Doering, 2021)
13	Economic resilience: The complete package (Genpact, 2021)
14	When it comes to CPG and food & beverage companies—Investing in purpose-built supply chain intelligence matters (Nobel, 2022)
15	Global supply chain resilience issues to watch out for in 2023 (Lin, 2022)
16	Building resilience in a polycrisis world (Ramsden-Knowles et al., 2023)
17	Building supply chain risk resilience: Role of big data analytics in supply chain disruption mitigation (Singh & Singh, 2019)
18	Local food supply chain resilience to constitutional change: the Brexit effect (Hendry et al., 2019)
19	2023 Supply chain outlook: How to navigate through uncertainty (Bain, 2023)
20	Reliable energy requires resilient supply chains (Sehgal & Singh, 2022)

21	Local food supply chain dynamics and resilience during COVID-19 (Thilmany et al., 2020)
22	Most supply chain managers expect problems to continue at least through 2024 (LaRocco, 2022)
23	Building a consumer-centric supply chain in CPG (Idserda et al., 2020)
24	What's behind the global supply chain crisis? (JP Morgan, 2022)
25	Supply Chain 4.0 in consumer goods (Alicke et al., 2017)
26	Reinventing the CPG supply chain with zero-based budgeting (Pototschnik et al., 2019)
27	Three principles of resilient supply chains for CPG manufacturing (Galer S. , 2022)
28	CPG manufacturers face 'labor crisis' amid supply chain pressures, report says (Devenyns, 2021)
29	2022 CPG supply chain & procurement outlook (GEP, 2022)
30	The future of the consumer industry (Lobaugh et al., 2022)
31	Rising food costs and supply chain issues are creating challenges (Grindy, 2021)
32	How CPG companies can overcome supply shocks with agile procurement (Kenney, 2021)
33	CPG operations—How to win in a rapidly changing environment (McKinsey & Company, 2022)
34	Risk and resilience in consumer-goods supply chains (Felix et al., 2022)
35	Achieving supply-chain resiliency in consumer goods amid disruption (Sanger, 2022)
36	The future of the supply chain (Madrecki, 2021)
37	Why supply-chain problems aren't going away (The Economist, 2022)
38	2023 will see a continued state of supply chain instability (Mayer, 2022)
39	COVID-19's influence on the consumer packaged goods supply chain (DePuy, 2021)
40	How the right mix of technology and strategy puts CPG manufacturers on top (Industry Week, n.d.)
41	More than half of all CPG companies are on track to grow below the market by 2027 (Kearney, 2022)
42	How CPG players can thrive now and beyond (Gergele, 2020)

43	5 industry insights from consumer product executives (NACS, 2023)
44	CPG companies think beyond costs to boost profitability in 2023 (Morrison, 2023)
45	Transforming retail supply chain (Gartner, 2022)
46	2022 CPG growth leaders (IRI, 2023)
47	COVID-19's impact on demand and costs in the CPG industry (Alldredge et al., 2021)
48	2022 imperative: Building supply chain resilience (Nuce, 2022)
49	Building a consumer-centric supply chain in CPG (Idserda, 2020)
50	The CPG industry faces a labor shortage and supply-chain challenges (Loria, 2021)

Table A-1. FMEA Article Reference Table

Case Study	Company Name	Headquarters	Revenue 2022/2023 (Millions)
1	Lifeway Foods, Inc. (Lifeway Foods, Inc., 2023)	Morton Grove, IL USA	141
2	TreeHouse Foods (TreeHouse Foods, 2022)	Oak Brook, IL USA	3,454
3	Nomad Foods (Nomad Foods, 2022)	Feltham, Middlesex, British Virgin Islands	3,097
4	Universal Corporation (Universal Corporation, 2023)	Richmond, VA USA	2,570
5	The Vita Coco Company (The Vita Coco Company, 2023)	New York, NY USA	427
6	Krispy Kreme Inc. (Krispy Kreme Inc., 2023)	Winston Salem, NC USA	1,530
7	Utz Brands Inc. (Utz Brands Inc., 2022)	Hanover, PA USA	1,408
8	Blue Apron Holdings Inc. (Blue Apron Holdings Inc., 2023)	New York, NY USA	458
9	Nu Skin Enterprises (Nu Skin Enterprises, 2023)	Provo, UT USA	2,226
10	Westrock Coffee Company (Westrock Coffee Company, 2023)	Little Rock, AR USA	868
11	Tootsie Roll Industries, Inc. (Tootsie Roll Industries, Inc., 2023)	Chicago, IL USA	687
12	Celsius Holdings Inc. (Celsius Holdings Inc., 2023)	Boca Raton, FL USA	654

13	Edgewell Personal Care (Edgewell Personal Care, 2022)	Shelton, CT USA	2,172
14	B&G Foods, Inc. (B&G Foods, Inc., 2023)	Parsippany, NJ USA	2,163
15	Tate & Lyle PLC (Tate & Lyle PLC, 2023)	London, England UK	2,110
16	Beyond Meat Inc. (Beyond Meat Inc., 2023)	El Segundo, CA USA	419
17	Freshpet Inc. (Freshpet Inc., 2023)	Secaucus, NJ USA	595
18	Tilray Brands Inc. (Tilray Brands Inc., 2023)	New York, NY USA	627
19	Sunopta Inc. (Sunopta Inc., 2023)	Eden Prairie, MN USA	935
20	National Beverage (National Beverage, 2022)	Fort Lauderdale, FL USA	1,173

Table A-2. Questionnaire Company Reference Table