

Business Continuity Planning in Manufacturing: A Comprehensive Methodology for Operational Resilience

Marcel Nimke

Master's dissertation

Supervisor at FEUP: Prof. Eduardo José Rego Gil da Costa



Master's in Industrial Engineering and Management

2024-06-25

Abstract

In the complex landscape of global manufacturing, ensuring the resilience of operations against potential disruptions is critical. This master's thesis aims to develop a comprehensive Business Continuity Management (BCM) methodology tailored to the multifaceted operational framework of a manufacturing company with critical operations spanning across multiple departments, presenting unique challenges in continuity planning and risk management. The company produces high-quality sanitary components and kitchen fittings, holding a reputable position as a leading innovator in the sanitary industry. The study's primary objective is to create a sustainable methodology that addresses current needs and can be applied across various operational units, ensuring continuity in production, quality assurance, and market competitiveness.

The literature review covers essential concepts and frameworks of BCM, including the application of standards published by the International Organisation for Standardisation ISO 22301:2019 for establishing effective business continuity processes and ISO 9001:2015 for maintaining quality management systems. These standards are employed to ensure that the BCM framework is robust, comprehensive, and aligned with internationally recognized best practices. The review also provides a thorough comparison with other resilience strategies, discussing their strengths and weaknesses, and examines the specific challenges faced by the manufacturing sector. This comprehensive foundation underscores the importance of BCM in ensuring operational continuity and resilience, particularly in the context of complex manufacturing environments.

A mixed-methods approach, integrating both qualitative and quantitative research methodologies, was employed to analyze production processes and assess risks. Comprehensive risk assessments and business impact analyses were conducted to identify key vulnerabilities and develop targeted risk mitigation strategies. These strategies are designed to ensure the continuity of critical operations and uphold the company's brand integrity during potential disruptions.

This research contributes to the theoretical understanding of BCM in manufacturing and provides practical guidelines for its implementation. Despite limitations such as the reliance on qualitative data and stakeholder availability, the findings offer valuable insights into enhancing operational resilience. The developed methodology serves as a benchmark for industry-wide adoption, ensuring sustained operational efficiency and brand integrity amid disruptions.

Acknowledgements

I would like to express my deepest gratitude to everyone who has supported me throughout my master's thesis journey.

Firstly, I am profoundly grateful to my family in Germany. Special thanks go to my mother, Silke Diller, and her husband, Eike Diller, as well as my father, Stefan Nimke. They made it possible for me to study at FEUP and supported me throughout all the semesters. They have always been my greatest supporters, and their unwavering belief in my abilities has been a constant source of motivation. It has not been easy to be at a distance for such a long time (I am in Portugal, and they are in Germany), and that's why I am extraordinarily grateful for their support whenever needed. I also want to extend my heartfelt thanks to my sister, Christina Nimke, and all my close friends for their encouragement, support, and for visiting me in Porto throughout the semesters.

I am deeply appreciative of my dear colleagues from my class at FEUP. They were very welcoming and supportive, especially during stressful and mentally challenging times. A special thanks to my close colleague Pedro Lopes for always supporting me, including me so well in projects and group works, and helping with many organizational topics.

I would also like to extend my sincere thanks to my company supervisor, Liliana Ribeiro, for giving me this opportunity, and Silvia Cunha, for her rigorous support and care during the conduct of my thesis, despite being very busy with concurrent projects and tasks. I truly appreciate it. The entire company team was extraordinarily welcoming and always motivated to support my requests and provide information as quickly as possible.

I wish to thank my supervisor at the University of Porto (Faculty of Engineering), Prof. Eduardo José Rego Gil da Costa, for providing his expertise and help whenever it was needed. His organized and supportive guidance throughout this project was invaluable.

Lastly, I would like to acknowledge all those who, directly or indirectly, have lent their support and contributed to the successful completion of this thesis.

Thank you all.

Contents

1	Introduction	1
1.1	Motivation	1
1.2	Company Overview	2
1.3	Problem Formulation	3
1.4	Research Problem, Objectives, Rationale, and Constraints	5
1.5	Dissertation Structure	6
2	Literature Review	7
2.1	Definition and Introduction to Business Continuity Management	7
2.2	Comparative Analysis of BCM and Other Resilience Strategies	9
2.3	Key Concepts of BCM	10
2.3.1	Business Continuity Management System	13
2.3.2	Establishing BCM: Integration and Organizational Culture	13
2.3.3	Understanding the Organisation and Risk Assessment	15
2.3.4	Business Continuity Planning and Implementation	19
2.3.5	Validation of BCM Programme	22
2.4	The Need for BCM and Challenges in Manufacturing	23
2.5	Gap Analysis	24
2.6	Conclusion of Literature Review	27
3	Methodology	28
3.1	Stages of Methodology Implementation	28
3.2	Detailed Production Process Analysis	30
3.3	Risk Assessment and Business Impact Analysis - Methodology	32
3.3.1	Risk Assessment - Methodology	34
3.3.2	Business Impact Analysis - Methodology	38
4	Results	39
4.1	Risk Assessment - Results	39
4.1.1	Scope, Context and Criteria - Results	39
4.1.2	Bill of Material Analysis	42
4.1.3	Risk Identification, Risk Analysis and Risk Evaluation - Results	44
4.2	Business Impact Analysis - Results	47
5	Discussion	49
5.1	Interpretation and Discussion of Results	49
5.2	Identifying Gaps and Potential Improvements to Business Continuity	50
5.3	Implications for Industrial Engineering	52
5.4	Limitations of the Study	53

6 Conclusion	54
References	55
Contribution to Sustainable Development Goals	57
A Exemplary SKU-Machine Matrix	59
B Exhaustive Risk Register with Categorization of Risks and Incidents	60
C Application of Risk Analysis in Assembly and Warehouse	63
D Visualizing Risk Priority Levels with Threshold Criteria	65
E ABC Analysis for SKUs	67
F SKU-Sub-department Matrix	72
G SKU-Machine Matrix Analysis	74
H Visualizing Risk Priority Levels with Threshold Criteria	79

Acronyms and Symbols

AL	Albergaria-a-Velha
BCI	Business Continuity Institute
BCM	Business Continuity Management
BCP	Business Continuity Plan
BIA	Business Impact Analysis
BOM	Bill of Material
CI	Continuous Improvement
CM	Crisis Management
DR	Disaster Recovery
DRP	Disaster Recovery Plan
EU	European Union
FMEA	Failure Mode and Effects Analysis
FY	Fiscal Year
HAZOP	Hazard and Operability Study
HR	Historical Record
ISO	International Organisation for Standardisation
JIT	Just-In-Time
MAO	Maximum Acceptable Outage
MTPD	Maximum Tolerable Period of Disruption
PDCA	Plan-Do-Check-Act
PS	Priority Score
PVD	Physical Vapor Deposition
P2P	Plant-to-Plant
QM	Quality Management
RA	Risk Assessment
RI	Risk Identification
RM	Risk Management
SC	Supply Chain
SCM	Supply Chain Management
SDG	Sustainable Development Goal
SKU	Stock Keeping Unit
UAE	United Arab Emirates
UK	United Kingdom
USA	United States of America
WH	Warehouse

List of Figures

2.1	Risk Management Process. Source: (ISO 31000, 2018, Section 6.1)	9
2.2	The BCM life-cycle. Source: The Business Continuity Institute (2013)	11
2.3	BCP Development. Source: Adapted from Swartz and Elliott (2010)	20
3.1	Stages of Methodology Implementation	28
3.2	Manufacturing Process Flow for Top 50 Products	31
3.3	Flowchart summarizing the methodology steps for developing the BCP, including SKU identification, machine/equipment identification, RI, evaluation, and integration into the BCP.	33
4.1	Supplier distribution for Top50 SKU by country, highlighting the number of suppliers in each country with a color-coded map and a table providing the supplier count per country.	42
4.2	Stacked bar chart showing the count and percentage of components by country and the percentage of EU and Non-EU suppliers for each SKU.	43
4.3	Stacked bar chart showing the count of components for each SKU by country, including first source and alternative suppliers.	44
A.1	SKU-Machine Matrix illustrating production paths through Grinding, Polishing, and Plating sub-departments.	59
C.1	Risk analysis for Assembly and Warehouse departments, assessing pre-determined risks by Likelihood, Impact, Historical Record, and Priority Score.	64
D.1	Three dimensional representation of risk priority levels, illustrating Likelihood (X-axis), Impact (Y-axis), and Historical Record (Z-axis) of various risks.	66
E.1	ABC Analysis, sorted by Output € (X-axis: % of total SKUs, Y-axis: % of total output).	68
E.2	Calculation table for ABC Analysis, sorted by Output €.	69
E.3	ABC Analysis, sorted by Output pieces (X-axis: % of total SKUs, Y-axis: % of total output).	70
E.4	Calculation table for ABC Analysis, sorted by Output pieces.	71
F.1	SKU-Sub-Department Matrix: Shaded cells indicate SKU presence in sub-departments.	73
G.1	SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 34558000, 34562000, and 34814003.	75
G.2	SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 34790000, 34594000, and 35788000.	75

G.3	SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 34598000, 26538000, and 26677000.	76
G.4	SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 26677001, 26075001, and 26403002.	76
G.5	SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 27296003, 27615002, and 266772430.	77
G.6	SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 33281003, 31374001, 33202003, and 32221003.	77
G.7	SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 31369001, 30307001, 32441002, and 34798000.	78
H.1	Priority scores for various external risks across different departments.	80
H.2	Priority scores for various internal risks across different departments.	80
H.3	Priority scores for various departments across different external risks.	81
H.4	Priority scores for various departments across different internal risks.	81

List of Tables

2.1	Number of ISO 22301 certificates. Source: (ISO/CASCO, 2020, 2021, 2022) . . .	25
2.2	Top ten countries for ISO 22301 certificates, including Germany and Portugal for company relevance. Source: (ISO/CASCO, 2020, 2021, 2022)	25
2.3	Top five industrial sectors for ISO 22301 certificates, including Basic metal & fabricated metal products for company relevance. Source: (ISO/CASCO, 2020, 2021, 2022)	26
3.1	Evaluation criteria for supporting/peripheral equipment.	34
3.2	Evaluation criteria for likelihood with categorization and descriptions.	35
3.3	Evaluation criteria for impact with categorization and descriptions.	36
3.4	Evaluation criteria for HR of the past 5 years with categorization and descriptions.	36
3.5	Evaluation Score Weights and Maximum Possible Scores	37
3.6	Thresholds for BIA Inclusion Based on Priority Scores	37
6.1	Contribution to Sustainable Development Goals and Performance Indicators . . .	58
B.1	Categorization of external risks and incidents with descriptions impacting manufacturing operations.	61
B.2	Categorization of internal risks and incidents with descriptions impacting manufacturing operations.	62

Chapter 1

Introduction

This chapter introduces the foundation of the thesis. Section 1.1 discusses the importance of operational resilience in today's interconnected global supply chain (SC), with a specific focus on the impact of disruptions in the manufacturing sector. Section 1.2 provides an overview of Grohe, detailing its strategic significance and operational processes. Section 1.3 formulates the problem by analyzing the status of business continuity (BC) at the Grohe Portugal plant and critically evaluating existing documents. Section 1.4 outlines the research problem, main objective, specific objectives, rationale, significance, and limitations of the study. Finally, Section 1.5 describes the structure of the dissertation, summarizing the content of each chapter.

1.1 Motivation

In today's interconnected global SC, manufacturers form an important node that is dependent on both upstream suppliers and downstream customers. Any disruption in manufacturing processes can cascade into significant global SC losses, making operational resilience paramount (Munro, 2022).

The COVID-19 pandemic demonstrated the vulnerabilities within global SCs, emphasizing the necessity of robust Business Continuity Management (BCM). Industries like automotive, where precision and timing are crucial, showcased the criticality of contingency planning in maintaining operational resilience (Munro, 2022). According to ISO 22301:2018, BC is defined as the capability of an organization to continue delivering products and services within acceptable time frames during disruptions (ISO22301, 2019).

Manufacturing companies, such as Grohe, are susceptible to a wide range of disruptions, from global pandemics to environmental catastrophes. Effective BCM plans are indispensable for identifying and mitigating these risks, ensuring continuity of critical operations (Hiles, 2007). The recent global challenges have intensified the need for comprehensive risk assessments (RA), impact analyses, and detailed recovery protocols that cover business, information technology (IT), production, and distribution functions (Hiles, 2007).

Specifically, in manufacturing, unique risks such as just-in-time (JIT) inventory systems and reliance on global logistics networks worsen the impact of disruptions. The globalization of manufacturing has introduced new vulnerabilities that amplify the effects of local disruptions on a global scale. (Hiles, 2007)

At Grohe Portugal, some production departments have initial business continuity plans (BCP), but these are non-unified and lack a standard approach. These plans need reassessment to ensure they are current and effective. This dissertation aims to develop a robust BCM framework tailored to the multifaceted operational structure in the manufacturing business of Grohe by identifying the most critical risks within production systems and developing proactive and reactive measures to mitigate, eliminate, or accept these risks. This framework seeks to enhance Grohe's resilience, ensuring sustained operational efficiency and brand integrity amidst potential disruptions.

1.2 Company Overview

Grohe AG is a globally recognized brand specializing in comprehensive bathroom solutions and kitchen fittings. Since becoming part of the LIXIL Corporation in 2014, Grohe has enhanced its strategic positioning in the building materials and residential equipment sectors. The product portfolio spans a wide range of applications, from sophisticated bathroom installations to functional kitchen fittings.

Grohe Portugal - Sanitary Components Ltd in Albergaria-a-Velha (AL) (hereafter referred to as 'Grohe AL' for readability) represents a critical operational node within the Grohe production network. Established in 1998, this facility plays a pivotal role in upholding the brand's core values: quality, technology, design, and sustainability. The facility is instrumental in transforming raw materials into Grohe's hallmark products through a series of meticulously designed production stages. Critical processes, such as Foundry, Machining, Grinding and Polishing, Plating, Physical Vapor Deposition (PVD), and Assembly, form the backbone of the manufacturing life-cycle. Collectively, these stages ensure the delivery of Grohe's hallmark of quality, merging functionality with aesthetic appeal. The precision of the Foundry and Machining stages lays the foundational components, while Grinding and Polishing, along with advanced techniques like Plating and PVD, further enhance the products' durability and finish. The Assembly process unites these components, resulting in final products renowned for their design and sustainability.

The seamless integration and operation of these processes are crucial not only for maintaining product quality but also for upholding Grohe's market reputation. Therefore, they are integral to the BC planning framework, ensuring resilience against operational disruptions. The role of each function in delivering the brand's promise of quality and innovation underscores the necessity for meticulous planning and risk management (RM) to maintain uninterrupted operations.

Regarding product specialization, the Grohe AL plant is engaged in the manufacturing and assembly of a diverse array of Stock Keeping Units (SKU). These range from "Full-Process" SKUs, undergoing comprehensive pre-processing and assembly, to assembly-only products that include components sourced both internally and externally. Importantly, the plant also serves as a supplier of pre-processed components to other Grohe facilities, such as the one in Lahr, Germany. This multifaceted role highlights the plant's essential contribution to Grohe's global SC, underlining its strategic significance within the broader organizational context.

1.3 Problem Formulation

Grohe AL is pivotal within the company, making the continuity of its operations vital. This production plant consists of interconnected departments, each operating almost as a small factory. These departments, from Foundry to Assembly, are highly interdependent, relying on each other's outputs to maintain production flows. This complexity is compounded by input sources, including raw materials, components from external suppliers, and components from other Grohe plants.

Additionally, the plant produces materials and components essential for other plants' operations. For instance, critical components manufactured in AL are supplied to plants in Germany for final assembly. This web of interdependencies underscores the critical nature of maintaining uninterrupted operations.

Analysis of the Status of Business Continuity at Grohe AL As further outlined in Section 1.4, this thesis aims to develop and implement a tailored methodology for BC planning at the Grohe AL plant. This approach is necessary due to the plant's unique processes and production equipment, which generic templates or guides do not adequately address.

At Grohe AL, top management acknowledges the critical importance of BC planning, prompting initial efforts to establish contingency plans across departments. Two foundational documents, referred to in this report as 'Document A' and 'Document B', attempt to unify continuity strategies and represent significant steps towards enhancing business resilience. Both documents are analyzed in the subsequent paragraphs.

Despite initial efforts, there remains a lack of a comprehensive, unified, and repeatable approach that aligns with industry standards, such as the International Organisation for Standardisation (ISO) 22301:2019. Responsibility for this project has been assigned to the Quality Management (QM) department, with its leader taking the lead role. These efforts align with discussions in Section 2.3.3 and Section 2.5, highlighting the critical role of top management support and the strategic placement of BCM within departments like Environment and Safety or QM.

Critical Evaluation of Existing Document A Document A is an essential foundational document within Grohe AL's BC planning efforts. It is a commendable initial step towards a structured approach to maintaining production continuity, clearly delineating roles and responsibilities and identifying a broad range of potential disruptions, demonstrating a comprehensive risk identification (RI) process.

However, the document falls short in several key areas critical for a resilient BCP framework. While it thoroughly identifies potential disruptions, it lacks detailed procedural guidance on conducting a RA, including evaluating the likelihood and impact of identified risks. This guidance is essential for prioritizing risks and efficiently allocating resources.

Moreover, Document A lacks sufficient detail on business impact analysis (BIA) procedures, which are fundamental for understanding the impacts of disruptions on critical business functions and equipment.

Procedural instructions should include specific, measurable objectives, such as defining Recovery Time Objective (RTO) and Maximum Tolerable Period of Disruption (MTPD). These metrics are vital for establishing acceptable levels of operational downtime and guiding recovery strategies.

Additionally, the document does not address the need for regular testing and maintenance of the BCP, which are crucial for ensuring its effectiveness and relevance over time. It should outline a structured approach to training and awareness programmes, ensuring staff are adequately prepared to execute their roles during disruptions.

In summary, Document A provides a preliminary framework for BC planning. However, addressing the significant gaps identified in this analysis is imperative to develop an effective methodology for BCPs. Enhancements will support Grohe AL's strategic goals, bolster organizational resilience, and ensure sustained operational continuity across various disruptive scenarios.

Critical Evaluation of Existing Document B Document B offers a comprehensive overview of departments and critical processes, identifying key equipment and potential disruption consequences. It outlines possible alternatives and recovery strategies, specifying responsibilities and response times.

The detailed listing of departments and processes ensures no crucial areas are overlooked. It provides consequences of equipment stoppage, possible alternatives, and recovery strategies, aiding quick decision-making during disruptions. Including alternative strategies, such as subcontracting and backup equipment, demonstrates proactive planning.

Despite its strengths, the sheet lacks a detailed RA, essential for prioritizing efforts. It does not include a preliminary RA or formal BIA to understand the broader impacts of disruptions. Additionally, the sheet varies in detail across departments and processes. Some entries provide specific alternatives and strategies, while others remain generic, potentially causing confusion during disruptions. Repeated strategies without additional context result in redundancy, and some alternatives are too general, needing more precise instructions. While responsibilities and response times are clear, implementation steps for alternatives and recovery strategies are not always detailed, which could impede swift action during disruptions.

In summary, Document B provides a foundation for BC planning at Grohe AL. However, addressing the identified gaps is imperative for developing a comprehensive and effective BCP. Enhancements will support Grohe AL's strategic goals, bolster organizational resilience, and ensure sustained operational continuity across various disruptive scenarios.

1.4 Research Problem, Objectives, Rationale, and Constraints

Research Problem and Main Objective In the complex landscape of global manufacturing, Grohe AL's operation presents unique challenges in BC and RM. The structure, comprising specialized departments that function like independent entities, complicates the creation of a unified BCP.

The primary objective is to devise a sustainable methodology that addresses current needs and can be applied across various operational units. This methodology will identify critical processes and machines, conduct comprehensive RA, stimulate effective risk mitigation strategies, and execute BIAs. The ultimate goal is to create the methodology for department-specific BCPs that collectively enhance Grohe AL's resilience, ensuring sustained operational efficiency and brand integrity.

Specific Objectives

1. To systematically identify and categorize critical processes and machinery within each operational department, underscoring their significance to Grohe AL's production life-cycle.
2. To conduct detailed RA for identified critical components, proposing robust mitigation strategies to safeguard against potential operational disruptions.
3. To evaluate the potential impacts of identified risks on Grohe AL's operations, prioritizing risks based on their severity and the urgency of mitigation measures.
4. To initiate the crafting of tailored BCPs for key departments, ensuring each plan addresses specific risks, recovery strategies relevant to the department's operations, and assigning responsibilities.

Rationale and Significance This research addresses the need for a dynamic and adaptable BCM framework that aligns with Grohe AL's complex operational structure. By adopting a modular approach to BC planning, the study aims to equip Grohe AL with the necessary tools to foster a culture of resilience and continuous improvement (CI). The anticipated methodology promises to enhance operational readiness and serve as a benchmark for industry-wide adoption, contributing valuable insights to BC in manufacturing.

Limitations Given the time constraints and the project's ambitious scale, a full roll-out of BCPs across all departments may not be feasible within the study's time-frame. However, establishing a clear, replicable methodology is the cornerstone of this research, providing a foundation for ongoing BC planning efforts. This approach aims to equip Grohe AL with a robust framework for future continuity planning, ensuring long-term operational resilience.

1.5 Dissertation Structure

This dissertation is organized into six chapters, each covering a critical aspect of the research on BCM in manufacturing at Grohe AL.

Chapter 1 introduces the project, outlining the background, motivation, objectives, and the structure of the dissertation.

Chapter 2 presents a comprehensive literature review, detailing the theoretical foundations of BCM, its key concepts, and the challenges specific to the manufacturing sector.

Chapter 3 explains the methodology adopted for this research, including the stages of implementation, detailed production process analysis, and the methods used for RA and BIA.

Chapter 4 discusses the results obtained from the RA and BIA, highlighting critical areas that need attention and the proposed mitigation strategies.

Chapter 5 interprets the results, identifying gaps, potential improvements, and implications for industrial engineering, along with the limitations of the study.

Chapter 6 concludes the dissertation by summarizing the key findings, theoretical and practical contributions, and suggesting future directions for research in BCM.

Chapter 2

Literature Review

This chapter critically examines the body of research on BCM, with a focus on its application in the manufacturing industry. It begins by defining and introducing BCM in Section 2.1, followed by a comparative analysis of BCM and other resilience strategies in Section 2.2. Key concepts of BCM, including the BCM life-cycle, are detailed in Section 2.3. The need for BCM and challenges specific to the manufacturing sector are discussed in Section 2.4, and a gap analysis is conducted in Section 2.5. This structure provides a comprehensive understanding of the theoretical foundations, practical applications, and areas for future research in BCM, particularly in the context of manufacturing.

2.1 Definition and Introduction to Business Continuity Management

BCM rigorously identifies and manages risks that could disrupt company operations. Although the most recent iteration, ISO 22301:2019, does not include a distinct definition of BCM, it is provided in the complementary ISO 22300:2021. In section 3.1.20 BCM is articulated as "the process of implementing and maintaining business continuity" (ISO 22300, 2021). The ISO 22301:2019 standard updates the previous version (ISO 22301:2012) but retains the core meaning of BCM from its predecessor:

"A holistic management process that identifies potential threats to an organization and the impacts to business operations those threats, if realized, might cause. It provides a framework for building organizational resilience with the capability of an effective response that safeguards the interests of its key stakeholders, reputation, brand, and value-creating activities" (ISO 22301, 2012, Section 3.4).

Traditionally, BCM has encompassed a variety of practices known under titles such as business recovery management, business recovery planning, and BC planning. These terms collectively emphasize the central goal of planning to recover from disruptions to normal organizational functions. Historically, BCM was primarily concerned with IT and focused on reacting to failures in computer and information management systems. This conventional approach involved undertaking risk and impact analyses, developing reactive recovery strategies, and training staff to implement these strategies to swiftly restore operations to their normal function. Over time, these foundational practices have evolved into the broader scope of BCM observed today, which not only aims for seamless recovery but also includes detailed rebuilding and reconstruction activities that may extend over months or years. The fundamental goal of BCM remains to enable organizations to effectively respond to threats, thereby ensuring the protection of critical business processes, services, and the assets that support them. (Hiles, 2007)

Historical evolution The evolution of BCM from its initial focus on IT disaster recovery (DR) in the 1970s to a comprehensive, strategic organizational function reflects a profound shift. Initially, BCM primarily concerned itself with safeguarding technological infrastructure, particularly corporate mainframe systems that were vulnerable to disruptions (Pheng, 2018). As noted by Swartz and Elliott (2010), the primary concern of the 1970s was the protection of these hard systems, where business disruptions were predominantly viewed as technological failures.

By the 1980s, the expansion of technological infrastructures to include end-user environments necessitated an auditing mindset within BCM. This period emphasized the integration of regulatory compliance and corporate governance frameworks, marking a transition from focusing solely on DR to ensuring systematic IT governance (Pheng, 2018).

The 1990s initiated a significant paradigm shift with the adoption of a value-based mindset, where BCM was increasingly recognized for its potential to add strategic value to the organization. Influenced by methodologies such as value chain analysis, this era highlighted the interdependencies within organizations that create competitive advantages. These insights are detailed in Swartz and Elliott (2010), who discuss the broader implications for organizational strategy. Similarly, Herbane (2010) reinforces this perspective by discussing how BCM evolved during this period to encompass not just technological resilience but also strategic organizational resilience.

As the new millennium approached, BCM continued to encompass a wider array of organizational resources and risks, such as cyber-attacks and geopolitical instability, moving beyond IT systems to include human capital and operational processes. This holistic approach was critical in fostering organizational resilience and adaptability, ensuring that businesses could withstand and recover from disruptions (Herbane, 2010). Swartz and Elliott (2010) further elaborate on this evolution, noting that BCM's role had grown to protect and enhance organizational knowledge and competitive advantage, transforming it from a protective measure to a strategic necessity.

By 2010, BCM had firmly established itself as an integral component of organizational RM frameworks. The global financial crisis of 2008 and other significant events during this period highlighted the critical need for robust BCM practices. These practices were increasingly integrated with corporate governance and strategic management, underscoring BCM's role not just in crisis management (CM) but in sustaining business operations and competitive advantage under diverse and unpredictable conditions (Herbane, 2010).

2.2 Comparative Analysis of BCM and Other Resilience Strategies

The interplay between BCM and associated disciplines such as RM, CM and DR is pivotal in understanding the holistic approach to organizational resilience. Although each discipline is distinct, they collectively contribute to the overarching aim of preserving an organization's stability and operational continuity amidst disruptions. Operating within a unified organizational safeguarding framework, BCM, RM, CM and DR each focus on specific elements of the response and readiness cycle. This distinct focus is crucial. However, the inherent overlap in their objectives underscores the need for a clear delineation from BCM, of their specific roles and how they interact within the corporate strategy.

BCM and Risk Management RM encompasses a thorough organization-wide identification and assessment of risks by evaluating their likelihood and impact and identifying appropriate responses (ISO 31000, 2018, Sections 6.4, 6.5). Figure 2.1 illustrates the RM process as outlined in ISO 31000:2018, providing a visual representation of the steps involved in identifying, assessing, and responding to risks, which are crucial for both RM and BCM frameworks. In contrast, BCM is specifically concerned with events causing significant business disruption, focusing less on the probability of such events but rather their impact and the organizational recovery time (Collier, 2009). Pheng (2018) observe that BCM initiatives are primarily directed towards mitigating risks considered intolerable by the organization.

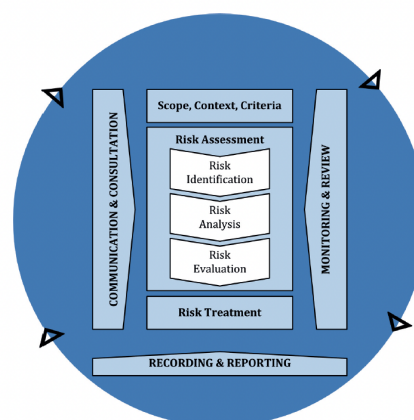


Figure 2.1: Risk Management Process. Source: (ISO 31000, 2018, Section 6.1)

BCM and Crisis Management The interplay between BCM and CM is pivotal, particularly through the incident management component of BCM, where various incidents can activate the BCM plan (Pheng, 2018). CM is defined as “the organization and coordination of activities in preparation for, and response to, events that prevent or impede normal organizational operations (thereby threatening its most important goals)” (Herbane, 2010, p. 979). These crises are characterized by a low probability, high consequence, ambiguity, and overall little time to respond (Herbane, 2010). While CM focuses narrowly on the short-term management of crises, engaging communication and public relations practitioners to manage both external and internal perceptions during a crisis, it addresses both non-physical and physical events that could affect financial performance and organizational reputation (Pheng, 2018). Cook and Anderson (2020) emphasize that although BCM is structured around pre-identified risks and continuity solutions, CM deals more broadly with strategic and tactical responses to crises, including aspects outside the typical scope of BCM. According to Pheng (2018), BCM, conversely, encompasses a broader scope that extends beyond immediate crisis responses to include maintaining operational continuity and building long-term resilience through detailed planning and preparation. Such strategic and proactive planning in BCM contrasts with the often reactive nature of CM, underscoring its importance in organizational strategy (Pheng, 2018).

BCM and Disaster Recovery There is a fundamental distinction between DR, which primarily addresses technology-based issues triggered by external factors, and BCM, which aims at the continuance of the entire business during unforeseen events (Swartz and Elliott, 2010). According to Pheng (2018), DR plans constitute specific responses activated during a disaster, forming a subset of the broader BCM framework.

In conclusion, the distinct delineation of BCM from RM, CM, and DR is fundamental to understanding its unique role within organizational resilience frameworks. While BCM intersects with RM, CM, and DR, it extends beyond their scopes by providing a comprehensive framework that ensures continuity of critical business functions and operational resilience.

2.3 Key Concepts of BCM

BCM relies on key concepts that build a resilient organizational framework. Integral to these concepts is the BCM life-cycle (see Figure 2.2), a cyclic process of CI that an organization navigates repeatedly to enhance its resilience (The Business Continuity Institute, 2013).

The BCM life-cycle consists of several key stages:

- **Policy and Programme Management**

This stage marks the inception of the BCM life-cycle and lays the fundamental groundwork for all subsequent BCM activities. It revolves around developing the organization’s BC policy, a crucial document that embodies the organization’s approach to continuity practices.

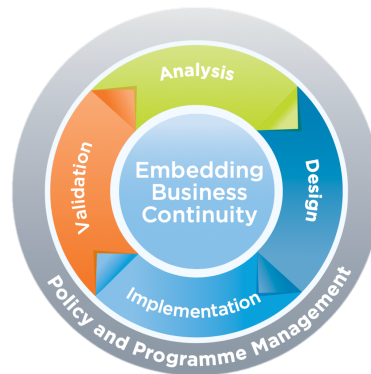


Figure 2.2: The BCM life-cycle. Source: The Business Continuity Institute (2013)

Formulated by top management, this policy articulates overarching principles and directives that govern BCM activities, clarifying the programme's purpose and objectives while setting expectations for its governance and scope (The Business Continuity Institute, 2013).

Additionally, BCM programme management involves assigning responsibilities and roles, ensuring that the policies are not only implemented but also dynamically maintained and adapted in response to evolving organizational needs and external changes (Hiles, 2007).

This will be explored in greater depth in Section 2.3.2, which will delve into the specifics of executing the defined policies and the ongoing management of the BCM programme.

- **Embedding BCM**

This phase is crucial for fostering a sustainable, resilient mindset towards disruptions, enhancing the BCM programme's effectiveness. A well-embedded BCM culture ensures continuous observation, updates, and improvements, making resilience a constant priority rather than a one-time project (The Business Continuity Institute, 2013).

Further details on embedding BCM within organizational culture, including specific techniques and strategies for BCM awareness and engagement, will be discussed in Section 2.3.2, focusing on practical applications and organizational behavior.

- **Analysis**

This phase involves a thorough evaluation of organizational operations to identify vulnerabilities that could disrupt critical functions. It prioritizes essential services and their recovery timing post-disruption. As The Business Continuity Institute (2013) suggests, this assessment informs targeted BC strategies, ensuring effective resource allocation to protect vital operations. Hiles (2007) emphasizes understanding stakeholder needs and the impact of potential disruptions to craft tailored continuity strategies addressing specific organizational dependencies.

Methods used during this phase are discussed in Section 2.3.3, illustrating their role in maintaining operational continuity.

- **Design**

This phase involves developing BC strategies and plans to address identified risks, ensuring effective management and recovery from disruptions (The Business Continuity Institute, 2013). The Business Continuity Institute (2013) stresses designing strategies for recovery within acceptable time-frames and capacities. Similarly, Hiles (2007) advocates for adaptable strategies to ensure practicality and effectiveness across various scenarios.

Further details on this phase are in Section 2.3.4.

- **Implementation**

This stage involves putting BC strategies and plans into action, developing comprehensive management frameworks including incident management, BC, and DR plans (Hiles, 2007). According to The Business Continuity Institute (2013), implementation requires detailed planning, resource allocation, and communication channels to support operational continuity and incident management. It ensures personnel training and coordination mechanisms are in place for effective plan execution.

The practical application and effectiveness of these strategies validate the operational readiness of an organization's BCM efforts. Detailed activities and stakeholder engagement strategies during this phase are further explored in Section 2.3.4.

- **Validation**

The final phase of the BCM life-cycle focuses on exercises, testing, and reviews to ensure BCPs function as intended and meet organizational objectives. This phase confirms that BCPs are effective in practice and align with international standards and stakeholder expectations (The Business Continuity Institute, 2013). According to Hiles (2007), it involves evaluating the BCM programme, identifying areas for enhancement, and ensuring strategies align with evolving organizational objectives.

Detailed exploration of validation processes is discussed in Section 2.3.5, emphasizing their strategic importance for maintaining operational readiness and compliance.

BCM's architecture is complex, encompassing interrelated elements designed to safeguard organizational integrity. Key concepts include the Business Continuity Management System (BCMS), RA, BIA, and BCP. These elements enhance the organization's ability to sustain operations during and after disruptions and ensure holistic protection and recovery.

Subsequent sections will detail each concept's significance, operational mechanisms, and integration within the broader BCM framework and life-cycle.

2.3.1 Business Continuity Management System

As delineated in Section 2.1, BCM includes management processes to ensure BC during disruptions. ISO 22301:2019 conceptualizes BCMS by integrating two fundamental concepts. Firstly, a management system is depicted as "a set of interrelated or interacting elements of an *organization* to establish *policies* and *objectives* and *processes* to achieve those objectives" (ISO22301, 2019, Section 3.16). Secondly, BC is defined as the "capability of an *organization* to continue the delivery of *products and services* within acceptable time frames at predefined capacity during a *disruption*" (ISO22301, 2019, Section 3.3). Synthesizing these concepts, BCMS is a comprehensive framework ensuring business resilience and continuity of critical functions during crises.

The BCMS adopts the Plan-Do-Check-Act (PDCA) cycle to promote CI and adaptability. The PDCA model, used in standards like ISO 14000 for environmental management and ISO 9000 for QM, demonstrates its universality and effectiveness (Hiles, 2007). In ISO22301 (2019), the PDCA cycle is operationalized through:

- **Plan:** Establishing BC policies, objectives, and processes, as outlined in Clauses 4 to 10 of ISO22301 (2019), which cover requirements for establishing the BCMS context, leadership roles, and strategic objectives;
- **Do:** Implementing and operationalizing the BCMS to manage risks, which includes establishing competence and communication on an as-needed basis with interested parties (ISO22301, 2019, Clause 7);
- **Check:** Monitoring and reviewing performance against BC objectives, defining BC needs, and determining how to address them (ISO22301, 2019, Clauses 8-9);
- **Act:** Continuously improving and adapting the BCMS based on feedback and observations, identifying and acting on non-conformities and opportunities for CI (ISO22301, 2019, Clause 10).

This cyclical approach ensures BCMS is a proactive, strategic methodology for bolstering resilience, demonstrating a commitment to sustaining critical business operations through any crisis (ISO22301, 2019).

With BCMS as the backbone of continuity planning, it is imperative to delve into the organizational context's nuances. Section 2.3.3 expands on the crucial role of risk analysis in understanding and identifying specific threats and vulnerabilities an organization faces.

2.3.2 Establishing BCM: Integration and Organizational Culture

Effective BCM requires strong leadership and commitment from top management, ensuring alignment with the organization's strategic directions. Top management should integrate BCM into business processes and ensure necessary resources are available (ISO22301, 2019, Sec. 5.1).

Stakeholder engagement is crucial for BCM success, ensuring all parties understand and execute their roles effectively. According to Hiles (2007), effective communication strategies are essential for instilling responsibility and awareness among stakeholders. Engagement from a variety of stakeholders, including insurers, auditors, and government, influences BCM due to its role in corporate governance (Swartz and Elliott, 2010).

Defining the scope of BCM is fundamental for its effectiveness and applicability. This scope should be clearly defined to establish "the boundaries and applicability of the BCM" (ISO22301, 2019, Sec. 4.3.1). Clarity ensures effective resource allocation and continuity planning. The iterative nature of defining this scope keeps the BCMS relevant and comprehensive, addressing internal and external changes.

Initial BCM communications should ensure clear understanding across the organization. Effective training and updating of BCM policies and procedures enhance preparedness and resilience against disruptions. As Swartz and Elliott (2010) emphasize, training and awareness programmes are integral, making BCM part of the organization's strategy, not as a separate entity.

The BC policy, formulated by top management, should align with the organization's mission and strategic goals. This policy should provide a framework for setting BC objectives and include a commitment to meet applicable requirements (ISO22301, 2019, Sec. 5.2.1). Senior management must guide BCM efforts across all staff levels, establishing the organization's aims, principles, and approach (Pheng, 2018). A well-formulated BCM policy supports BCM processes and articulates the organization's approach, setting objectives, roles, and responsibilities. Top management's involvement in communicating this policy underscores its importance and encourages a unified approach (Pheng, 2018).

Implementing BCM requires a comprehensive approach considering four main components, as identified by Pheng (2018):

- **Policies:** Senior management must establish policies that guide BCM efforts, outlining the organization's aims, principles, and approach, and providing the rationale for BCM processes, people, and infrastructure;
- **Processes:** A set of activities with clear outcomes, deliverables, and evaluation criteria to achieve BCM policy objectives, including change control and documentation processes;
- **People:** Involvement of various business units is essential for overseeing BCM efforts, with clearly defined roles and responsibilities to ensure effective participation;
- **Infrastructure:** Resources must be allocated to support critical business functions against potential risks, requiring an understanding and application of available technology, equipment, and physical facilities.

Each of these four components supports the comprehensive development of BCM through its life-cycle, including policy and programme management, embedding BCM, analysis, design, implementation, and validation (The Business Continuity Institute, 2013; Pheng, 2018). This structured approach ensures BCM integration into core functions and alignment with strategic objectives.

Incorporating insights from Swartz and Elliott (2010), BCM goes beyond recovery, embracing proactive planning that aligns with corporate governance and stakeholder expectations. This approach is vital for establishing BCM as a core business function, enhancing resilience and maintaining a competitive advantage during disruptions.

In conclusion, successful BCM implementation requires strong leadership, comprehensive planning, effective communication, and robust stakeholder engagement. By embedding BCM into the organizational culture and aligning it with strategic objectives, organizations can ensure they are well-prepared to manage and recover from disruptions effectively.

2.3.3 Understanding the Organisation and Risk Assessment

Clear definitions of 'risk assessment' and 'risk analysis' are essential to avoid ambiguity. This report adopts definitions from Rausand (2020) and ISO 31000 (2018). RA involves planning, preparing, performing, and reporting a risk analysis, including evaluating results against risk acceptance criteria (Rausand, 2020). ISO 31000 (2018) further defines it as encompassing RI, risk analysis, and risk evaluation (RE) (ISO 31000, 2018, Section 6.4.1), as illustrated in Figure 2.1.

Understanding the Organisation Before structured RA processes, understanding an organization's operations is crucial. Swartz and Elliott (2010) highlight the importance of internal analysis to understand how activities impact recovery priorities, essential for effective BCPs. This analysis should cover the organization's products, services, activities, resources, and existing linkages and dependencies. Starting with an examination of products or services, this approach assesses the potential impacts of disruptions on these elements and their interrelated resources (Swartz and Elliott, 2010).

Building on this initial analysis, Wallace (2018) recommend extending the examination to include internal and external resources and dependencies supporting organizational outputs. They advocate a multi-layered approach to analyze operational processes, identifying critical nodes and vulnerabilities. Integrating detailed analyses of internal and external environments allows RM strategies to address specific needs and vulnerabilities more precisely (Wallace, 2018).

As described by Wallace (2018), risk analysis is stratified into five layers:

- **External risks**, including natural disasters and large-scale events affecting both the organization and the wider community;
- **Localized risks** to specific facilities, focusing on buildings and essential services;
- **Data systems risks**, highlighting vulnerabilities in IT and data infrastructures;

- **Departmental risks**, assessing operational risks within each department;
- **Individual risks** at the workspace level, affecting personal productivity and local management.

Risk Identification Following the layered analysis and the Scope of RM, RI initiates the RA process to systematically recognize and describe risks and opportunities influencing the organization's objectives. This stage involves comprehensive data gathering from historical records (HR), theoretical analyses, informed opinions, and stakeholder feedback to ensure a well-rounded risk profile (ISO 31000, 2018, Section 6.4.2). Pheng (2018) categorize threats by origin—external, internal unintentional, or internal intentional—enhancing RA specificity.

Hiles (2007) describe common RI methods, including checklists, workshops, brainstorming sessions, and interviews. These methods facilitate collaborative RI, engaging multiple stakeholders for diverse perspectives. Workshops provide dynamic platforms for interactive discussions, allowing participants to explore risks in depth and reach consensus on prioritization and treatment strategies (Hiles, 2007).

This methodical identification lays the groundwork for subsequent risk analysis and evaluation stages, ensuring RM strategies are precisely tailored and relevant. Continual RI, emphasized by Hiles (2007), highlights preventive measures, increases staff awareness, and ensures RM integration into strategic planning and decision-making processes. This integration is crucial for maintaining an up-to-date and effective RM framework within the organization.

Risk Analysis Risk analysis, following RI, is imperative in the RA process. It explores the nature, sources, consequences, and likelihood of identified risks using qualitative, quantitative, and semi-quantitative techniques to evaluate their potential impact (Meyer, 2013; ISO 31000, 2018). This comprehensive approach helps prioritize risks based on severity and likelihood (ISO 31000, 2018, Section 8.2).

Top management involvement is paramount in this phase to define the relevance of likelihood and impact factors tailored to the organization's industry and objectives. Aghabegloo et al. (2024) highlight that meetings with top management enhance criticality analysis and align risk mitigation strategies with organizational goals. This collaboration fosters a deeper understanding among managers of potential risks and necessary countermeasures, facilitating informed decision-making and resource allocation for RM. The process should not be static; as organizational contexts and industry landscapes evolve, the factors considered in risk analysis should be periodically reviewed to maintain relevance and effectiveness (Aghabegloo et al., 2024, Sec. 3.2.1).

To address the complexities and specific needs of the organization, the selection of the risk analysis method is influenced by the scope and objectives of the assessment. This strategic choice ensures the analysis provides actionable and relevant insights, critical for developing robust risk mitigation strategies (Meyer, 2013). These methodologies are categorized into three main approaches—qualitative, quantitative, and semi-quantitative—each offering distinct advantages depending on the analysis context and requirements (Meyer, 2013, Table 4.3, p. 94):

- **Qualitative Analysis:** Utilizes expert judgment, scenario planning, and subjective methods, valuable for preliminary RAs when precise data is scarce. It categorizes risks into severity levels such as low, medium, or high. Lester (2017) supports this approach for evaluating risks using historical data and expert opinions. Simple techniques like a risk matrix can further determine if risks need additional management efforts. While flexible and easy to apply, its main limitation is the dependency on subjective perceptions, which may not account for all variables comprehensively (Meyer, 2013);
- **Quantitative Analysis:** Employs numerical data and statistical tools for a detailed evaluation of risk probabilities and impacts. Useful for precise prioritization and financial or operational impact assessments, it offers detailed insights into potential risks and their implications. This approach is structured and data-driven, ensuring reliability but requiring significant time and resources. Accuracy depends on the validity of the data and models used (Meyer, 2013);
- **Semi-quantitative Analysis:** Combines elements of qualitative and quantitative techniques. Suitable when some numerical data is available but complete precision is not necessary. It uses numerical values to rank or score risks, offering a more nuanced assessment than purely qualitative methods. This approach provides a middle ground, using indicative values that lack the statistical rigor of full quantitative methods but offer greater detail than qualitative assessments (Meyer, 2013).

The choice between qualitative, quantitative, and semi-quantitative approaches should be guided by the organization's specific needs, data availability, and the required precision in RE. Each method has strengths and limitations, and a combined approach often leverages the advantages of each while compensating for their weaknesses (Meyer, 2013).

After determining the suitable risk analysis method, several techniques can be utilized to further analyze and understand identified risks (Meyer, 2013):

- **HAZOP** (Hazard and Operability Study): A qualitative technique that identifies potential risks and their effects by methodically questioning every aspect of the design, useful for complex operational processes, especially in chemical and processing industries;
- **FMEA** (Failure Mode and Effects Analysis): A semi-quantitative technique that assesses potential failure modes within a system, classifying their impact based on severity, occurrence, and detection ratings to prioritize risks and implement corrective actions;
- **What-if Analysis:** A qualitative method that explores hypothetical scenarios to identify potential risks and their consequences, typically used in brainstorming sessions for early project development;
- **Risk Matrix:** A semi-quantitative tool combining likelihood of occurrence with severity of impact to categorize and prioritize risks, facilitating decision-making for resource allocation in RM;

- **Event Tree Analysis:** A quantitative method mapping out possible outcomes of an initiating event in a tree format, useful for analyzing cascading effects of potential failures in complex systems;
- **Fault Tree Analysis:** A quantitative technique using a tree-like model to deduce failure paths to a particular system failure from logical combinations of lower-level failures, effective in pinpointing root causes in high-risk industries like aerospace and nuclear energy.

Integrating these methods and techniques within the risk analysis phase identifies and categorizes risks, aiding organizations in developing targeted risk mitigation strategies. This systematic and structured approach ensures a solid foundation for the subsequent RE phase.

Risk Evaluation RE compares and evaluates the results of risk analysis against the organization's criteria to determine the significance of each risk. This step is crucial for deciding the necessity and extent of risk treatment actions, considering factors like risk appetite, regulatory requirements, and business objectives to ascertain if risks are acceptable or need mitigation (ISO 31000, 2018, Section 8.3).

Building on this assessment, Wallace (2018) advocate understanding the potential impacts of identified risks and the effectiveness of existing controls. They recommend developing a detailed risk list to identify which risks must be addressed within the BCP, categorizing risks by likelihood and impact to facilitate a structured, prioritized risk treatment strategy.

Further refining this process, Wallace (2018) emphasize differentiating between mitigable and unavoidable risks, preparing strategies to minimize damage, and tailoring RE to the organization's context and strategic objectives. This aligns mitigation strategies with operational capabilities.

RE also considers practical aspects like the financial implications of potential downtime, assessing both tangible and intangible losses to justify investments in risk mitigation measures (Wallace, 2018).

In practice, various tools facilitate the RE process, with the risk matrix being a notable example. Meyer (2013) and Lester (2017) highlight the risk matrix as a tool to visualize and prioritize risks. It assigns values to the probability and impact of each risk, deriving an exposure rating to focus on critical risks while maintaining vigilance over lesser risks that could escalate unexpectedly. This tool is invaluable for qualitative and semi-quantitative assessments, guiding resource allocation and RM priorities (Meyer, 2013).

Integration with Business Continuity Management RA is the cornerstone of an effective BCMS, enabling systematic identification, analysis, and evaluation of risks. This process tailors BC strategies to address the most significant threats to operational stability. Integrating RA into BCM ensures strategic and efficient resource allocation, vital for maintaining critical functions during disruptions. A comprehensive RA enhances resilience by enabling proactive management of potential disruptions and sustaining operational continuity. This integration aligns with best practices, such as ISO 2230:2019, and supports CI of BC capabilities (ISO22301, 2019). The iterative nature of this integration ensures the BCMS adapts over time, reflecting changes in the internal and external environment, including business processes, technological upgrades, new threats, opportunities, and outcomes from tests and exercises, maintaining its relevance and efficacy in a dynamic landscape (The Business Continuity Institute, 2013).

2.3.4 Business Continuity Planning and Implementation

BC planning is at the core of the 'Design' phase of the BCM life-cycle (see Section 2.3), encompassing BIA and the development of BCPs.

DR and BC planning are interconnected processes for preparing organizations for disruptive events. Disaster recovery planning (DRP) focuses on resuming operations after disruptions like earthquakes or software malfunctions. However, many executives underestimate the importance of DR due to the tendency to view disasters as improbable (Meyer, 2013).

In contrast, BC planning provides a comprehensive approach, ensuring continuity not only after major disasters but also for smaller disruptions like key staff illness, SC issues, and other recurring challenges (Meyer, 2013). Given its broader scope and proactive nature, BC planning is crucial for building resilience and minimizing disruption impacts on operations, reputation, and revenue.

In this report, BC planning is used over DRP due to its broader meaning and greater significance for this work.

Business Impact Analysis Central to BC planning is the BIA, a fundamental component of the BCM framework. According to ISO22301 (2019), BIA is the "*process of analysing the impact over time of a disruption on the organization*" (ISO22301, 2019, Sec. 3.4). BIA evaluates the effects of disruptions on operations, helping to quantify impacts and prioritize critical processes. It assesses the operational and economic consequences of disruptions, identifies critical operations, qualifies dependent assets, and specifies recovery time-frames (Torabi et al., 2014).

Hiles (2007) emphasizes that BIA is the most fundamental product of the BCM life-cycle, providing essential data for prioritizing and justifying continuity measures. It forms the foundation of the organization's recovery strategy by highlighting mission-critical activities, establishing dependencies, and setting a risk appetite. A structured BIA process uncovers overlooked requirements, justifying the initial cost and effort (Hiles, 2007). However, conducting a BIA requires considerable resources and is valuable only if the organization is prepared to act on its findings, underscoring the need for readiness to implement suggested measures (Meyer, 2013).

Based on a comprehensive RA (see Section 2.3.3), the organization uses BIA to identify the impact of each event, allowing for the prioritization of continuity plans based on a 'worst first' order. This prioritization considers both the frequency and severity of incidents, ensuring resources are allocated where they are most needed for maximum risk mitigation.

As illustrated in Figure 2.3, the BIA includes internal and external analyses that guide the overall business impact evaluation, setting objectives, identifying risks, prioritizing them, and developing scenarios. This structured approach ensures a comprehensive understanding of potential disruptions and lays the groundwork for generating the BCP (Swartz and Elliott, 2010).

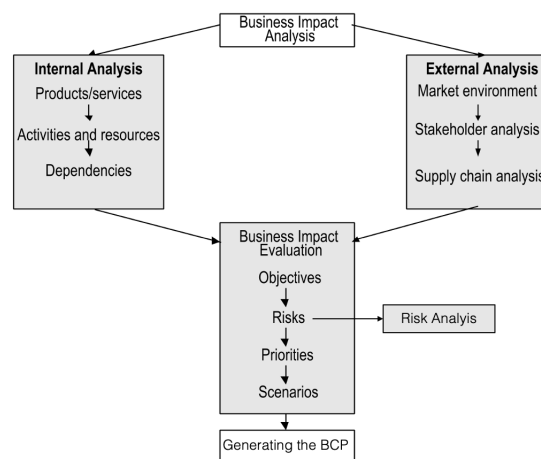


Figure 2.3: BCP Development. Source: Adapted from Swartz and Elliott (2010)

To ensure a comprehensive understanding of business impact, the BIA can be enhanced by determining the RTO and MTPD for key products and their associated critical functions. According to ISO 22300 (2021):

- **RTO** is defined as "the period of time following an *incident* within which a *product or service* or an *activity* is resumed, or *resources* are recovered" (ISO 22300, 2021, Sec. 3.1.203);
- **MTPD**, also known as Maximum Acceptable Outage (MAO), is "the time it would take for adverse impacts, which can arise as a result of not providing a product/service or performing an activity, to become unacceptable" (ISO 22300, 2021, Sec. 3.1.151).

These definitions provide a clear framework for establishing recovery timelines and the urgency of response actions.

Implementation of BCP Following the design and development of the BCP, the 'Implementation' phase involves putting these plans into action. It ensures theoretical strategies are transformed into practical actions and procedures during an incident. This phase requires detailed planning, resource allocation, training, and establishing communication protocols to support continuity and recovery strategies effectively (The Business Continuity Institute, 2013).

Key activities during this phase include:

- **Training and Awareness:** Ensuring all relevant personnel are familiar with the continuity plans and understand their roles during a disruption. This includes regular training sessions and simulations (Gibb and Buchanan, 2006);
- **Resource Management:** Allocating necessary resources to support critical functions during a disruption, meeting all logistical and operational needs (Hiles, 2007);
- **Plan Activation Procedures:** Establishing clear triggers and thresholds for activating the continuity plans and outlining the activation steps (The Business Continuity Institute, 2013).

The effectiveness of these plans depends on regular updates and revisions, considering changes in the organizational environment and feedback from training exercises and simulations, as emphasized in the PDCA cycle discussed in Section 2.3.1 (Hiles, 2007).

Continuity Strategies and Business Continuity Plan The BCP is a strategic and tactical document outlining the organization's responses during a disruption. It aims to maintain or swiftly resume critical functions, minimizing impacts on operations, reputation, and revenue. The BCP identifies essential functions and resources, including personnel, IT, infrastructure, and communication mechanisms. (Hiles, 2007)

ISO22301 (2019) further details in Sections 8.4.2 and 8.4.3 the structure of a BCP, which should encompass:

- A strategic framework to continue or recover prioritized activities within predetermined time-frames;
- Thresholds and processes for activating and scaling the response to a disruption;
- Protocols to ensure delivery of products and services at agreed capacities under adverse conditions;
- Methods to manage the immediate aftermath of a disruption, focusing on welfare, loss prevention, and environmental impacts.

Meyer (2013) highlight that while many organizations recognize the need for DR, they often underestimate the likelihood of a disaster, leading to inadequate planning. The BCP must be practical and accessible for rapid implementation during disruptions. Reflecting the dynamic nature of BCM discussed in Section 2.3.1, the BCP is regularly updated to align with the evolving risk landscape, ensuring readiness and resilience. These updates are part of the 'Act' phase of the PDCA cycle, integrating CIs based on regular reviews and feedback within the BCMS framework (ISO22301, 2019).

2.3.5 Validation of BCM Programme

'Validation' is the final phase in the BCM life-cycle, focusing on testing, exercising, and reviewing the BCPs to ensure they are functional and effective. This phase confirms that the plans meet predefined business requirements and comply with international standards and best practices (The Business Continuity Institute, 2013).

Exercises and Testing Regular testing and exercising of the BCPs are essential to assess its effectiveness and staff readiness. These activities help identify gaps and provide opportunities for CI. Exercises can be categorized into desktop and simulation exercises. Desktop exercises, such as plan walkthroughs, are ideal for learning purposes and less experienced staff, while simulation exercises are suited for seasoned staff and test established routines and instructions (Gibb and Buchanan, 2006; Hiles, 2007).

Hiles (2007) recommend starting with component testing to verify individual components before progressing to large-scale simulation exercises incorporating multiple elements or the entire plan. The Business Continuity Institute (2013) emphasize that testing should assess plan effectiveness and ensure staff are familiar with their roles and responsibilities during a disruption.

Maintenance Regular updates and revisions are crucial to ensure BCPs remain relevant and effective. These updates consider changes in the organizational environment and feedback from training exercises, aligning with the PDCA cycle discussed in Section 2.3.1 (Hiles, 2007). Maintenance includes updating contact details, adjusting recovery strategies, and revising procedures based on lessons learned.

Audit and Review Continuous review and auditing of the BCM programme ensure its relevance and effectiveness over time. Audits evaluate compliance with standards, training programme effectiveness, and overall BCP readiness (Hiles, 2007). According to Swartz and Elliott (2010) and Hiles (2007), a BCM audit should assess underlying business assumptions, testing, and exercises, focusing on the BIA. Benchmarking against standards like ISO 22301:2019 indicates 'good' BCM practices but requires a tailored audit framework based on organizational maturity (Hiles, 2007).

Self-assessments are cost-efficient for creating awareness, identifying improvement areas, and capturing measurable output. Despite limitations like biased findings and varying skills, they can be useful if expectations and purposes are clearly communicated. However, they should not replace independent audits (Cook and Anderson, 2020).

In conclusion, successful implementation and validation of a BCM programme require a clear understanding of organizational objectives and adaptability to changing realities. By integrating continuous training, testing, and reviewing practices into the BCM framework, organizations can enhance resilience and preparedness for any disruption (Hiles, 2007).

2.4 The Need for BCM and Challenges in Manufacturing

Manufacturing presents unique challenges for BCM due to the interdependence between business, IT, production, and distribution functions. Traditionally, BCM has focused on IT and DR (see Section 2.1), but manufacturing recovery encompasses additional complexities not often found in other sectors (Hiles, 2007). For example, a week-long power outage at Tesla's German gigafactory, caused by an arson attack, halted production, preventing the manufacture of approximately 1,000 cars per day and causing hundreds of millions of euros in damages (Steitz, 2024). Similarly, Bosch Ovar in Portugal faced a complete shutdown due to a power outage caused by a strike of EDP workers, highlighting the vulnerability of manufacturing sites to utility disruptions and the extensive financial implications of such events (Lusa, 2024). These incidents underscore the critical need for comprehensive BC and recovery plans that cover all functional areas of manufacturing enterprises.

As Musson notes in Hiles (2007), a key challenge is determining where to place the emphasis for recovery planning. While emphasis is often placed on business and IT recovery strategies, if production or distribution is unavailable, the company cannot deliver products, even if business functions are recovered. The increasing link between these functions demands that recovery plans cover all of them, possibly as separate sections involving different methodologies and strategies (Hiles, 2007).

Compared to the IT sector, manufacturing recovery is more complex due to the interdependence between business, IT, production, and distribution functions. These complexities include the following (Hiles, 2007):

- **Globalization:** Increases global interdependence, introducing SC vulnerabilities due to outsourcing, production in third-world countries, and extended logistics chains;
- **JIT systems:** Increase vulnerability to SC disruptions due to reliance on minimal inventory levels;
- **Government regulations:** May necessitate re-certification after a disruption, delaying recovery efforts;
- **Manufacturing operations:** Depend heavily on IT systems linking production closely with business functions;
- **SC Vulnerability:** Manufacturing relies heavily on SCs that can be disrupted by natural disasters, geopolitical instability, or supplier insolvency;
- **Asset Dependency:** High-value machinery and equipment are vital to manufacturing processes. Their failure can halt production entirely;
- **Regulatory Compliance:** The manufacturing sector is subject to stringent regulations that mandate adherence to environmental, health, and safety standards;

- **Skilled Labor Shortage:** Disruptions affecting specialized labor can severely impact production timelines.

Developing effective continuity strategies for manufacturing requires a comprehensive understanding of potential risks, exposures, and impacts. This necessitates an in-depth RA and BIA, as detailed in Section 2.3.3, to identify primary hazards like natural disasters, equipment failures, and SC disruptions, as well as secondary hazards like transportation delays or community infrastructure failures (Hiles, 2007).

This thorough RA and BIA should cover the main facility and its critical processes, other facilities producing products/services for the main facility, key suppliers and logistics partners, and community infrastructure. The analysis provides the foundation for tailored recovery strategies categorized into pre-incident, post-incident, and procedural strategies (Hiles, 2007):

- **Pre-incident:** Implemented before a disaster to mitigate the impact, including seismic design/retrofitting, alternative fuel suppliers, and buffer stocks;
- **Post-incident:** Include utilizing spare capacity within the organization, shutting down marginal product lines, and outsourcing to subcontractors;
- **Procedural:** Aim to facilitate reconstruction or maintain credibility through alternative operating procedures and coordination with local authorities.

Overall, BCM in manufacturing requires a comprehensive understanding of organizational objectives and the ability to adapt plans to changing realities. A holistic approach that includes training, testing, and reviewing practices is essential to maintain resilience and effectively respond to disruptions.

2.5 Gap Analysis

This section examines significant gaps in the practical application of BCM in the manufacturing sector and the knowledge gap among companies, drawing on recent research and expert insights. Bethany Warren, an associate member of the Business Continuity Institute (BCI) and BC and resilience manager at The Coca Cola Company, highlights a scarcity of practical guides and case studies on BCM in manufacturing, hindering professionals from devising effective BCM strategies tailored to this context (Riglietti and Warren, 2023).

Although ISO 22301 certification is not mandatory, the ISO Survey of Certifications indicates whether recent global disruptions (like COVID-19, war, and SC issues) have increased awareness and application of BCM standards. According to the ISO Survey, 2,205, 2,559, and 3,200 certificates were issued for ISO 22301 worldwide in 2020, 2021, and 2022, respectively, representing a 25.05% increase from 2021 to 2022, as shown in Table 2.1).

Table 2.1: Number of ISO 22301 certificates. Source: (ISO/CASCO, 2020, 2021, 2022)

# of certificates in 2020	# of certificates in 2021	Change in (%) 2020-2021	# of certificates in 2022	Change in (%) 2021-2022
2,205	2,559	16.05	3,200	25.05

Similarly, as shown in Table 2.2, more certificates have been issued to the top ten countries since the pandemic outbreak. Notably, China became one of the top ten countries for ISO 22301 certificates. Asian countries like China, Thailand, India, and Singapore lead in increasing BCM certificates. In contrast, European Union countries such as Greece, Italy, and Spain have fewer certificates, with 207, 126, and 106 issued respectively in 2022. Despite Germany's strong presence in various businesses, especially heavy manufacturing, it lags in the number of certificates issued, as does Portugal.

Table 2.2: Top ten countries for ISO 22301 certificates, including Germany and Portugal for company relevance. Source: (ISO/CASCO, 2020, 2021, 2022)

2020		2021		2022	
The UK	336	The UK	447	The UK	455
India	169	Korea, Republic of	176	India	228
Singapore	160	India	159	China	225
Turkey	136	Turkey	147	Greece	207
China	107	China	134	Korea, Republic of	172
UAE	96	UAE	113	UAE	130
Korea, Republic of	95	Singapore	111	Italy	126
Thailand	82	Greece	95	Singapore	110
Philippines	78	Thailand	81	Spain	106
Greece	77	Italy	70	USA	90
Spain	77				
...	...	...	...	...	...
Germany	33	Germany	49	Germany	65
Portugal	10	Portugal	12	Portugal	11

Industry-wise, the top five industrial sectors have remained almost the same over the past three years, with more certificates issued for IT, other services, transport, storage and communication, and the financial sector, as shown in Table 2.3. The sector to which Grohe belongs, Basic Metal and Fabricated Metal Products, shows limited formal adoption of BCM practices, with only 46 certifications. However, the lack of formal certification does not necessarily mean the absence of BCM practices; it may indicate that these practices are not fully integrated into organizational frameworks in a standardized or formally recognized manner.

Table 2.3: Top five industrial sectors for ISO 22301 certificates, including Basic metal & fabricated metal products for company relevance. Source: (ISO/CASCO, 2020, 2021, 2022)

2020		2021		2022	
IT	309	IT	388	IT	549
Other Services	161	Transport, storage and communication	357	Transport, storage and communication	446
Transport, storage and communication	119	Other Services	234	Other Services	351
Financial inter-mediation, real estate, renting	65	Financial inter-mediation, real estate, renting	173	Financial inter-mediation, real estate, renting	302
Electrical and optical equipment	40	Electrical and optical equipment	69	Electrical and optical equipment	117
...	...	...	...	...	...
Basic metal & fabricated metal products	23	Basic metal & fabricated metal products	33	Basic metal & fabricated metal products	46

Extensive research on resilience and BC predominantly focuses on Supply Chain Management (SCM) and IT. This emphasis is justifiable, as the SC critically supports material input and finished goods distribution in manufacturing, and BCM originally developed from IT disaster recovery efforts. The current geopolitical climate, with conflicts such as the Russia-Ukraine war and tensions in the Middle East affecting global SC, exacerbates this issue by increasing risk exposure and uncertainty (Riglietti and Warren, 2023).

The manufacturing sector faces unique operational complexities beyond traditional BC challenges, such as dependency on specific machinery and the intricacies of JIT production models. These factors exacerbate vulnerabilities, especially in SCs, necessitating tailored recovery strategies for immediate response and long-term recovery needs. Riglietti and Warren (2023) highlight that manufacturing organizations are particularly vulnerable due to the lack of redundancy in equipment and supplier networks, leading to significant production delays during disruptions. The sector also faces challenges like a shortage of skilled labor, heightened risks from increasingly automated and interconnected production processes (Industry 4.0), and escalated exposure to cyber threats (Riglietti and Warren, 2023).

Moreover, climate change introduces additional complexities, with more frequent and severe extreme weather events affecting production capabilities and logistic networks. This underscores the need for manufacturing firms to integrate climate resilience measures into their BCM strategies (The Business Continuity Institute, 2022).

Integrating BCM with existing frameworks like QM and safety regulations can enhance resilience, leveraging existing expertise while ensuring effective implementation and maintenance. Manufacturing organizations must bridge the gap between theoretical BCM frameworks and practical application by addressing specific challenges and enhancing governance structures (Riglietti and Warren, 2023).

In summary, the gap analysis reveals that while theoretical foundations of BCM are well-established, the manufacturing sector faces unique challenges complicating practical implementation. Addressing these challenges through research, tailored case studies, and sector-specific BCM guidelines would significantly enhance manufacturing resilience against a broad spectrum of risks (Fani and Subiadi, 2019; Riglietti and Warren, 2023).

2.6 Conclusion of Literature Review

This chapter has systematically explored various facets of BCM, critically analyzing its application and integration. Furthermore, it has established a strong theoretical foundation for the subsequent development of a comprehensive BCP methodology for Grohe AL. Each section has provided a deeper understanding of BCM's role in enhancing organizational resilience and strategic response capabilities.

Definition and Introduction to BCM (Section 2.1) established the fundamental concepts and standards governing BCM, emphasizing its necessity for safeguarding critical business operations against potential disruptions.

Comparative Analysis of BCM and Other Resilience Strategies (Section 2.2) differentiated BCM from related disciplines such as RM, CM, and DR, illustrating the unique and overlapping aspects that contribute to organizational resilience.

Key Concepts of BCM (Section 2.3) delved into the core components that constitute the BCM framework. This included discussions on the BCM life-cycle and its phases, from policy and programme management to embedding BCM into corporate culture.

The Need for BCM and Challenges in Manufacturing (Section 2.4) highlighted specific challenges faced by the manufacturing sector, such as SC vulnerabilities and the need for a robust continuity strategy to ensure operational resilience.

Gap Analysis (Section 2.5) identified existing gaps in the literature and practice, particularly in the practical application of BCM in the manufacturing context, and suggested areas where further research and development are needed.

Chapter 3

Methodology

This chapter outlines the methodology and approach adopted in this thesis and details the methodological framework. Section 3.1 elaborates on the various steps of the BCP implementation methodology, including literature and standards review, production process analysis, initial meetings and scope definition, formation of the project team and initial RA, detailed RA review and BIA, and updating the BCP. Section 3.2 provides an analysis of the production process. Finally, Section 3.3 discusses measures taken to ensure the study's quality, covering scope, context, criteria, RI, risk analysis, and RE processes and explains the application of the BIA.

3.1 Stages of Methodology Implementation

The implementation of the BC methodology required several preliminary steps. As shown in Figure 3.1, the steps include conducting a comprehensive literature and standards review, performing a detailed production process analysis, conducting interviews with department representatives, meeting with university and company supervisors to align the project's scope and objectives, forming a comprehensive project team for initial RA, executing the RA, conducting a BIA, and updating the overall BCP.

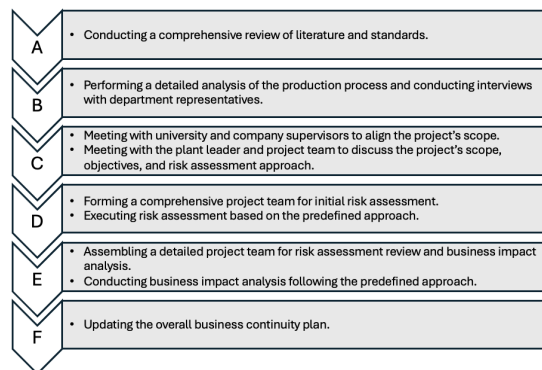


Figure 3.1: Stages of Methodology Implementation

Stage A - Literature and Standards Review A comprehensive review of relevant literature and standards was conducted to build a solid foundation for the BCP. This involved identifying key academic sources, industry standards, and best practices pertinent to BC. The focus was on understanding BCP methodologies, including their development, implementation, and evaluation. Standards such as ISO 22301:2019 and guides from the BCI were examined to ensure alignment with global best practices. Insights from this review provided a robust framework for subsequent BCP development stages.

Stage B - Production Process Analysis A thorough analysis of the production process was performed to understand operational dynamics and potential risks within the manufacturing environment. This stage aimed to familiarize with each department's workflow and their critical contributions to the final product. The analysis involved reviewing workflow documentation, conducting site visits, and interviewing department representatives.

The primary objective was to document the process flow and key dependencies to identify areas that could significantly impact operations if disrupted. Insights from Stage A, combined with observations and interviews, enabled the identification of critical points and potential vulnerabilities. This analysis provided a solid foundation for understanding the manufacturing process and its potential risks, informing subsequent BCP development stages. The findings and details of this stage are further discussed in Section 3.2.

Stage C - Initial Meetings and Scope Definition Initial meetings were essential to align the project's scope and objectives with academic and industrial stakeholders. A key meeting involved the core BCP team and the plant leader to update on progress, discuss preliminary findings, and propose the RA approach. This step was crucial for securing top management's support and verifying the project's direction.

During this meeting, the scope of the risk analysis was defined, focusing on critical areas of the production process, specifically targeting the Top 50 SKUs and production stoppages exceeding the MAO of five working days. This threshold helped define significant risks, ensuring that the most impactful areas were addressed first, following the RM process outlined in Chapter 2 (Figure 2.1). Additionally, a broader meeting with the plant leader and department heads emphasized the importance of BC and communicated specific objectives to the leadership team. The detailed methodology of defining scope and objectives is further explained in Section 3.3. Any disruptions shorter than five days were deemed manageable within the existing operational flexibility.

Stage D - Formation of Initial Project Team and RA Forming a comprehensive project team, including the core BCP team and the Pre-Process operations leader, was essential for a multidisciplinary initial RA. The RA followed a predefined methodology to identify critical machinery and equipment, assess potential risks, evaluate their likelihood and impact, and prioritize them based on criticality. This stage involved meetings and brainstorming sessions to gather input from team members and stakeholders. Further details are discussed in Section 3.3.

Stage E - Detailed RA Review and BIA A detailed review of the initial RA from Stage D is followed by a comprehensive BIA. Specialized project teams, including the core BCP team and department leaders, scrutinized identified risks in greater detail. In-depth analyses were conducted to determine potential impacts on business operations, resulting in a prioritized list of risks and a detailed BIA. This provided a clear understanding of potential disruptions and informed effective mitigation strategies. The process and results of the BIA are detailed in Section 3.3.2.

Stage F - Updating the BCP and Related Documentation The final stage involved updating the overall BCP and related documentation. This process incorporated insights and findings from previous stages to enhance the plan's comprehensiveness and effectiveness. The updated BCP aimed to reflect current best practices, ensuring robust strategies for maintaining business operations during disruptions. This stage also involved revising and completing additional documentation to support the BCP, ensuring all critical information was accurately recorded and accessible for future reference.

3.2 Detailed Production Process Analysis

Building on the preliminary steps in Stage B of Section 3.1, the manufacturing process for the Top 50 SKUs encompasses several critical stages from raw material input to final assembly and distribution. This section provides a detailed analysis of each department involved in the production process, divided into three overarching processes: Pre-Process, Assembly, and Distribution. Figure 3.2 illustrates the overall manufacturing process flow, highlighting key stages and material flows.

Pre-Process The Pre-Process stage involves initial processing of raw materials and preparation of components, including Foundry, Machining, Grinding and Polishing, and Plating.

Foundry: The Foundry is the initial stage where raw materials (zinc and copper) are processed to brass. It involves three main sub-processes: Central Melting, Core Shooting, and Casting. Central Melting melts raw materials to form a homogeneous liquid metal, using external raw materials like pure metals or ingots, and internal raw materials from scrap parts. Core Shooting creates core molds from a blend of sand, resin, and hardener, shaping the molten metal into specific forms. Casting pours the molten metal into molds, where it solidifies into the desired shape.

Machining: After Casting, the components are transferred to the Machining department. This stage involves precision cutting, shaping, and finishing of the metal parts to meet specific tolerances and design specifications. Machining ensures each component adheres to strict quality standards and dimensions required for subsequent processes.

Grinding and Polishing: Post-machining, the components undergo Grinding and Polishing. Grinding removes excess material and smooths surfaces, while polishing enhances the surface finish and prepares the components for Plating. This stage ensures the parts are free of imperfections and have a smooth, high-quality finish.

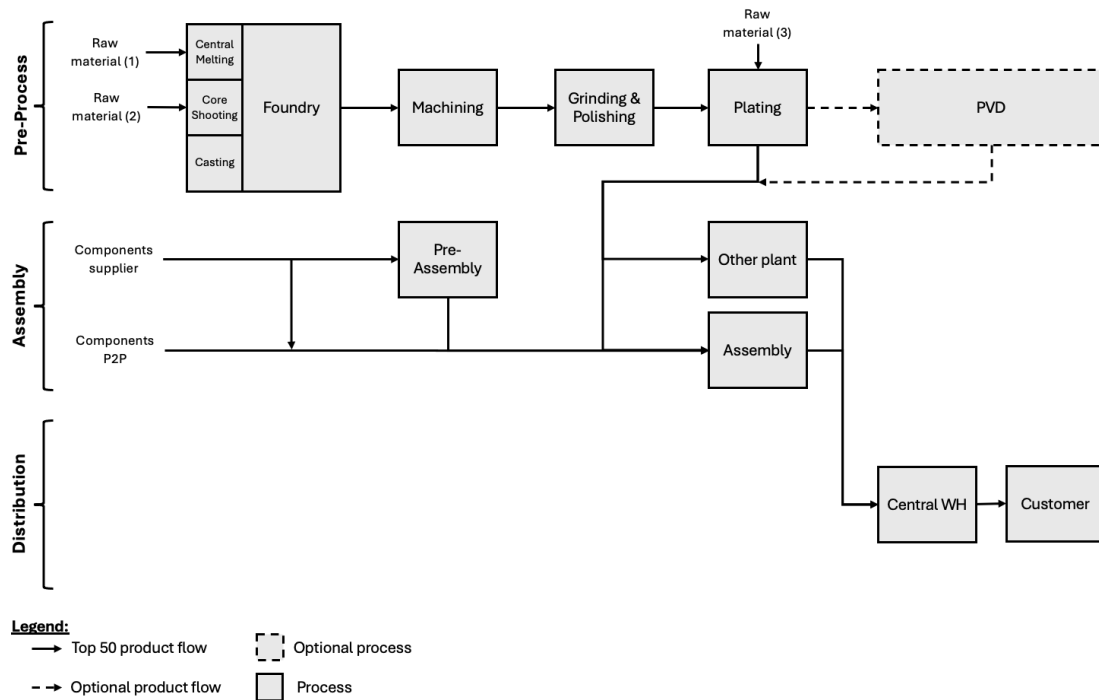


Figure 3.2: Manufacturing Process Flow for Top 50 Products

Plating: The Plating department applies a protective and decorative coating to the components. This process involves cleaning the parts to remove any contaminants, followed by electroplating, where a thin layer of metal (such as nickel and chrome) is deposited onto the surface. Plating provides corrosion resistance, enhances appearance, and improves durability.

After Plating, there are three possible material flows. The first, though not applicable to the Top 50 SKUs, is PVD for enhanced surface properties. The second is sending the plated components to other plants for further processing or integration. The third option is for the plated components to continue directly to the Assembly process.

Assembly The Assembly stage includes sub-departments like Laser Printing, Cartridges, and Pre-Assembly. These sub-departments handle critical tasks such as marking and labeling components, assembling internal cartridge components, and preparing preliminary assemblies. Their coordinated efforts are essential for the final assembly operations, where all components are brought together to form the finished products.

Laser Printing: As part of the Assembly department, the Laser Printing process marks and labels components with critical information like model numbers, batch numbers, and branding. It involves two key stages: laser engraving and paint application. The laser roughens the surface in the desired pattern, such as logos or regulators, and then the selected paint is applied to these areas for clear presentation and effective color coding, such as for hot and cold water indicators.

Cartridges: Cartridge components are critical to the functionality of many sanitary products. This process involves the precise assembly of internal components like seals, valves, and casings.

Thermostatic cartridges, which regulate water temperature in mixer showers, are particularly important as they maintain a consistent blended temperature despite variations in incoming water supplies. These components undergo thorough testing before installation. Notably, these cartridges are exclusively produced in AL and supply the entire Grohe group.

Pre-Assembly: Here, preliminary assembly operations partially assemble components into sub-units, streamlining the final assembly process.

Assembly: The Assembly department is where the final assembly of products occurs. Components from the Plating department, along with parts from external suppliers or plant-to-plant (P2P), are gathered in Pre-Assembly. Sub-units from Pre-Assembly and components from the internal warehouse (WH) are combined to form the final products. This stage involves fitting, fastening, testing, and final packaging to ensure all products meet quality and functionality standards. The Assembly department is crucial for preparing final products for distribution and use. It is structured into various faucet sub-units, including Kitchen, Basin & Bidet, Thermostats, and other specialized lines for specific product categories.

Distribution The Distribution stage involves storing and managing final products before shipment to customers.

Central WH and Distribution: Once assembled, final products are transported to the central WH for storage and management before being shipped to customers.

3.3 Risk Assessment and Business Impact Analysis - Methodology

This section details the application of the RA and BIA processes, following the methodology outlined in Section 2.3.3. It describes the techniques used, justifies their selection, and explains their implementation.

The flowchart in Figure 3.3 summarizes the methodology steps described in the subsequent sections 3.3.1 and 3.3.2. The chart provides a visual representation of the process flow, from SKU identification and machine/equipment identification to RI, evaluation, and the final integration into the BCP.

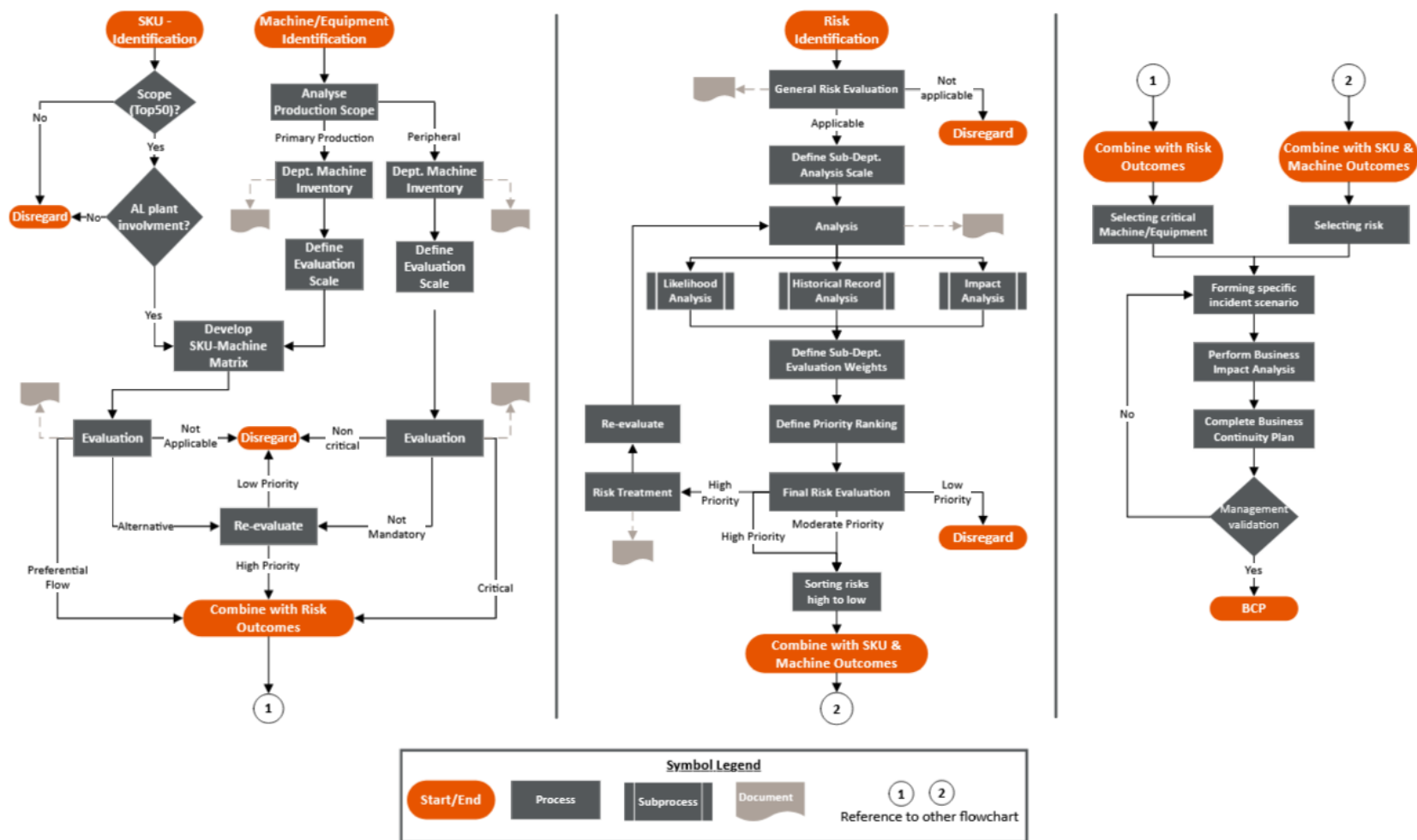


Figure 3.3: Flowchart summarizing the methodology steps for developing the BCP, including SKU identification, machine/equipment identification, RI, evaluation, and integration into the BCP.

3.3.1 Risk Assessment - Methodology

This subsection outlines the methodology used for the RA process. It includes defining the scope, context, and criteria, as well as detailing the steps taken to identify, analyze, and evaluate risks within the manufacturing facility.

Scope, Context and Criteria - Application As described in Stage C in Section 3.1, the project scope targeted critical areas, processes, and machines within the manufacturing facility. Specifically, the analysis focused on the Top 50 SKUs as defined centrally. However, not all Top 50 SKUs were included in this analysis. Only those SKUs where the body is produced and the finished SKU is fully assembled in AL, or where the body is produced in the Pre-Process in AL but assembled in other plants, were considered.

The project involved detailed process analysis and development of flowcharts to understand dependencies and vulnerabilities within the production workflow. A comprehensive SKU-Machine Matrix was created to accurately identify the machines involved in producing the Top 50 SKUs. This matrix categorizes each SKU by its primary, alternative, and non-production possibilities per department, ensuring thorough coverage of critical production machinery. It helps identify potential bottlenecks, exclusivities, and redundancy within the production process, facilitating a robust RA. An example of this matrix is provided in Appendix A.

In addition to primary production machinery, supporting and peripheral equipment are indispensable for producing the Top 50 SKUs. These include machinery and tools assisting the main production process or ancillary devices and systems supporting the infrastructure and environment, such as legally required exhaust devices. Evaluation criteria, detailed in Table 3.1, were established to determine the inclusion of supporting equipment in the RA based on their criticality. Only equipment scoring 2 or 3 on a scale from 1 to 3 was included in further analysis.

Table 3.1: Evaluation criteria for supporting/peripheral equipment.

Score	Category	Description
1	Non-Critical	Equipment with minimal impact on production if disrupted.
2	Not Mandatory	Equipment that is beneficial but not essential, causing minor disruptions if absent.
3	Critical	Equipment vital for production, with significant impact if disrupted.

Throughout the project, clear and consistent communication was maintained with all stakeholders. Regular consultations with department leaders and key personnel gathered insights, validated findings, and ensured alignment with the project's objectives. This collaborative approach facilitated a thorough RA and the development of effective mitigation strategies.

The RI process involved compiling a comprehensive risk register, attached in Appendix B. Initially, most risks were derived from Document A, as discussed in Section 1.3, and included common risks. Additional risks were subsequently added. Each risk was provided with a brief description to ensure all stakeholders have a clear understanding of the potential risks.

Each risk was evaluated to determine its consideration in subsequent RA stages, following the methodology outlined in Stage C of Section 3.1. The identified risks and their descriptions were compiled into a risk register, ensuring a systematic approach to managing potential disruptions.

Risk Analysis - Application The risk analysis process involved defining likelihood, impact, and HR criteria tailored to the study's context. As discussed in Section 2.3.3, identifying these criteria is necessary for conducting the risk analysis.

The chosen scales for likelihood, impact, and HR offer several advantages. The likelihood scale, using a numeric range from 0 to 3, simplifies the evaluation and communication of results. Clear definitions for each category provide a straightforward framework to assess risk probability. Criteria for evaluating the likelihood of each risk, including detailed categorization and descriptions, are presented in Table 3.2.

Table 3.2: Evaluation criteria for likelihood with categorization and descriptions.

Score	Category	Description
0	Not applicable	Non-existent or so unlikely that it does not warrant preparation within the current planning scope (e.g., less than once in 10 years).
1	Low	Slight chance of occurrence, with few precedents, and it may only happen under unusual circumstances (e.g., once in 5-10 years).
2	Moderate	Reasonable chance of occurrence (e.g., once in 1-5 years).
3	High	Highly likely, with frequent incidents or foreseeable due to current trends or impending events (e.g., more than once a year).

The impact scale ranges from 0 to 10, providing a detailed approach to assess the severity of impacts. This granularity helps differentiate between minor and catastrophic impacts more precisely. Detailed descriptions for each impact category ensure thorough evaluation of potential consequences and align with common industry practices and standards, facilitating benchmarking and comparison. Criteria for assessing the impact of each identified risk, with comprehensive categorizations and descriptions, are summarized in Table 3.3.

Table 3.3: Evaluation criteria for impact with categorization and descriptions.

Score	Category	Description
0	No impact	- No noticeable interruption to operations; no financial loss.
1	Minor impact	- Minimal operational disruptions that are resolved using existing protocols; financial impact is within the range of routine fluctuation.
2		- Minor operational disruptions requiring minimal intervention; financial impact slightly above routine fluctuations.
3		- Operational disruptions are noticeable but manageable within existing processes; financial impact manageable with little intervention.
4	Moderate impact	- Disruptions necessitate management attention; financial impact is significant but not exceeding the company's risk tolerance threshold.
5		- Noticeable disruptions requiring management intervention; financial impact approaching the company's risk tolerance threshold.
6		- Significant disruptions requiring extensive management and possibly BCP activation; financial impact considerable but contained.
7	Major impact	- Significant disruptions with long-term effects; financial losses challenging the company's risk tolerance and impacting strategic goals.
8		- Severe operational disruptions with long-term consequences; financial losses substantial and impacting strategic objectives.
9		- Extensive operational disruptions with prolonged effects; financial losses critical, impacting overall business strategy and performance.
10	Catastrophic impact	- Operations critically compromised, causing prolonged recovery; financial losses exceeding the company's tolerance, threatening survival.

Evaluating the HR over the past 5 years provides relevant data to understand risk frequency based on recent trends. A numeric scale from 0 to 3 quantifies and compares the frequency of past incidents, aiding in assessing risk recurrence. Historical data helps predict future occurrences, offering a data-driven approach to RM. Criteria for defining and categorizing the HR are detailed in Table 3.4.

Table 3.4: Evaluation criteria for HR of the past 5 years with categorization and descriptions.

Score	Category	Description
0	Not Occurred	No occurrence of the event in the past 5 years.
1	Low	Occurred once in the past 5 years.
2	Moderate	Occurred 2-3 times in the past 5 years.
3	High	Occurred 4 or more times in the past 5 years.

After assigning likelihood, impact criteria, and HR per department, each risk is classified to determine its significance, as shown in Appendix C. This approach identified the most critical risks within each area, recognizing that these can vary based on the manufacturing process and location. The goal is to determine which risks necessitate contingency plans or mitigation actions.

Risk Evaluation - Application The RE process systematically assesses identified risks by quantifying their likelihood, impact, and HR using predefined scales. Possible scores were detailed in Tables 3.2, 3.3, and 3.4, respectively. Each risk is assigned a priority score (PS), calculated based on the weighted contributions from these factors, as detailed in Table 3.5.

Table 3.5: Evaluation Score Weights and Maximum Possible Scores

Evaluation Factor	Weight	Max. Possible Score
Likelihood	0.35	1.05
Impact	0.45	4.50
Historic Record	0.20	0.60
Total	1.00	6.15

The PS for each risk per department is computed using a custom scoring formula that accounts for the varying relevance of different risks and impacts to the organization. The PS is given by Equation 3.1:

$$PS = (\text{Likelihood} \times 0.35) + (\text{Impact} \times 0.45) + (\text{HR} \times 0.20) \quad (3.1)$$

In refining the traditional RE approach, this methodology incorporates HR into the equation to factor in the frequency of occurrences. This ensures that risks with a history of occurrence are given enhanced priority, reflecting their persistent relevance and potential impact on operations. By assigning a significant weight of 0.45 to the impact and using a scale from 0 to 10, the equation is distinctly impact-focused. This weighting underscores the importance of the potential severity of risk outcomes in overall risk prioritization, aligning with the strategic objective to mitigate the most consequential risks effectively. The specific weights assigned to each risk factor, including their maximum possible scores, are detailed in Table 3.6, illustrating how each component contributes to the overall risk score.

Table 3.6: Thresholds for BIA Inclusion Based on Priority Scores

Priority	% of Max Score	Score Range Lower Limit	Score Range Upper Limit
High	75% - 100%	4.61	6.15
Moderate	37.5% - 74.99%	2.31	4.61
Low	0% - 37.49%	0.00	2.31

Based on the calculated PS, risks are classified into three priority levels for inclusion in the BIA. These priority levels are delineated in Table 3.6, with thresholds determined by the percentage of the maximum possible score. A visual representation of the priority levels according to the thresholds is provided in Appendix D.

These thresholds help distinguish risks that must be addressed immediately (High Priority), those needing significant attention but are less urgent (Moderate Priority), and those requiring monitoring or minimal action (Low Priority).

3.3.2 Business Impact Analysis - Methodology

Following the evaluation of prioritized risks for each department, as described in Stage E of Section 3.1, a BIA was conducted. This analysis focused on all business departments, emphasizing risks with 'Moderate' or 'High' priority levels, as detailed in Table 3.6, and considering the MAO of five days. The approach was top-down, starting with the highest priority risks per department and systematically addressing each significant risk.

The BIA team comprised the core contingency group along with department leaders. Key stakeholders provided insights into potential impacts and downtime estimates. Engagement involved interviews and brainstorming sessions with Pre-Process, Assembly, and Distribution personnel, ensuring diverse perspectives.

The impact assessment criteria employed during the BIA included:

- **Operational Impact:** Evaluating the effect on production processes, including potential downtime and loss of output;
- **Regulatory Impact:** Considering legal and regulatory consequences, including compliance with industry standards and regulations.

During regular meetings with the assembled teams for each department, the potential impacts of identified and prioritized risks were thoroughly discussed. The structured approach included the following steps:

1. Identifying realistic scenarios that could occur due to each risk, focusing on those likely to disrupt operations for more than five working days;
2. Re-evaluating the risk if discussions indicated that the initial analysis was either too severe or underestimated, leading to possible adjustments in the evaluation;
3. Stating the specific operational impacts based on the identified scenarios, acknowledging that multiple scenarios per risk could occur;
4. Discussing and brainstorming immediate actions required in response to the identified risks and assigning responsibilities for these actions;
5. Discussing and brainstorming recovery strategies and assigning responsibilities for implementing these strategies.

The findings from the BIA are meticulously documented, consolidating all aspects of the contingency plans into a single, cohesive report.

Chapter 4

Results

This chapter presents the findings of the BC planning efforts at Grohe in AL. Section 4.1 includes the scope, context, criteria, SKU identification, and machine and equipment identification. Additionally, it provides a comprehensive understanding of Grohe's SC dependencies and vulnerabilities through a detailed Bill of Material (BOM) analysis, focusing on supplier distribution and alternative suppliers. Section 4.2 outlines the BIA results, evaluating the potential impacts of disruptions on critical business functions and equipment, with emphasis on plant-wide and department-specific risks.

4.1 Risk Assessment - Results

The RA process yielded several critical findings for developing the BCP. The flowchart in Figure 3.3 (Section 3.3) visually summarizes the RA steps of SKU identification and machine/equipment identification. The results from each step are detailed, highlighting significant findings and their implications for the BCP.

4.1.1 Scope, Context and Criteria - Results

SKU Identification As outlined in Section 3.3.1, the focus of this analysis is on the Top 50 SKUs, which are centrally determined by the Grohe group and distributed across all plants. The analysis distinguishes between two types of Top 50 SKUs relevant to this study:

- **SKUs Assembled in AL:** Among the 15 Top 50 SKUs assembled in AL, seven undergo the entire process from Foundry to Assembly, while eight receive the body from Grohe P2P or external suppliers and only undergo final assembly in AL;
- **SKUs Produced for Lahr (Germany):** Additionally, there are eight Top 50 SKUs from the Lahr plant, where the body is produced in the Pre-Process at AL and then supplied to Lahr for final assembly.

Thus, the AL plant's production, encompassing both Pre-Process and Assembly, affects 23 of the Top 50 SKUs. This section distinguishes between Pre-Process, Assembly, and Full-Process SKUs, highlighting variations in the process flow within the AL plant.

Two ABC analyses were conducted using a classical approach to emphasize the importance of these 23 SKUs. This method focuses solely on output metrics, excluding factors like strategic importance and profit margins used by Grohe to define the Top 50 SKUs. Strategic importance involves company goals, brand positioning, and market expansion, while profit margins consider profitability based on production costs and selling prices. SKUs produced solely in other plants are not included in this analysis.

The graphical representations and corresponding tables for both ABC analyses are displayed in Figures E.1, E.2, E.3 and E.4 of Appendix E. The main results and interpretations are briefly described below:

- **First ABC Analysis (Output Pieces):** All available SKUs were sorted in descending order by total output pieces for the fiscal year (FY) 2024. The categories were defined as follows:
 - **A:** 80% of output pieces, comprising 11.41% of all SKUs.
 - **B:** 15% of output pieces, comprising 18.88% of all SKUs.
 - **C:** 5% of output pieces, comprising 69.71% of all SKUs.
- **Second ABC Analysis (Output Value in €):** All available SKUs were sorted in descending order by total output value in euros for FY 2024. The categories were defined as follows:
 - **A:** 80% of output value, comprising 15.09% of all SKUs.
 - **B:** 15% of output value, comprising 21.88% of all SKUs.
 - **C:** 5% of output value, comprising 63.03% of all SKUs.

The results from both analyses indicate that all of the Top 50 SKUs from AL fall into the A category, highlighting their significance in production volume and value.

The SKU-Sub-Department matrix in Appendix F visually represents the production flow for SKUs through various sub-departments. This matrix shows distinct paths for SKUs assembled in AL, which receive bodies from internal production, P2P, or external sources, and those produced for the Lahr plant. SKUs undergoing full production in AL pass through all sub-departments from Central Melting to Assembly, except for PVD. In contrast, SKUs for Lahr primarily involve Pre-Process stages at AL before being shipped to Lahr for Assembly, bypassing Pre-Assembly and PVD processes.

Thermostatic bodies produced for P2P follow a slightly different process in Assembly. While these SKUs enter the Assembly process in the Thermostat area mainly for testing and quality assurance, the assembly lines test the bodies with cartridges for temperature regulation and leakproofness. This ensures compliance with required specifications. Only after passing these tests and receiving the mandatory quality and warranty stamp are they sent to other plants, without final packaging.

Machine and Equipment Identification As shown in Figure 3.3 (flowchart 1), identifying critical equipment within each department is crucial for understanding potential production impacts and focusing analysis resources on essential machinery. This involves an asset-based examination of the production scope and a comprehensive inventory of primary, peripheral, and supporting equipment, ensuring all critical components are meticulously accounted for and evaluated.

The analysis revealed several key insights within the management scope, including MAO of five days and a strict focus on the Top 50 SKUs. These SKUs account for around 20% of the total output but ensure that if high-output machines fail, other resources can prioritize the Top 50 SKUs by pausing less critical products. Key insights from this analysis include:

- **Critical Machinery and Equipment:** The Plating line was identified as critical, as disruptions here could significantly impact production due to its role as a bottleneck for several SKUs. The assembly lines, particularly the WH and cartridge sites, are critical for final assembly and testing. Cartridge production is vital since many Top 50 products rely on these cartridges, which are exclusively produced in AL and are too specific for outsourcing. In departments like Machining and Grinding/Polishing, the critical factor is often the SKU-specific tools rather than the machines themselves. However, most tools have spare parts or can be repaired by the internal maintenance team within five days;
- **Supporting Equipment and Systems:** Supporting equipment is also critical, including the compressed air network, hot and cold water systems, water treatment systems, and exhaust devices. Exhaust devices, ensuring compliance with legal regulations, were evaluated and included in the RA based on their criticality.

SKU-Machine Matrix The SKU-Machine Matrix was developed based on insights from SKU Identification and Critical Equipment Identification. This comprehensive matrix categorizes each SKU by its primary, alternative, and non-production possibilities within each department.

In Appendix A, an exemplary SKU-Machine Matrix for the Grinding & Polishing, and Plating departments is presented, illustrating its structure and development process. The detailed results of the extensive matrix, encompassing all departments, are further elaborated in Figures G.1 to G.7 of Appendix G. This appendix provides a comprehensive overview of the production flow for each SKU through various sub-departments, highlighting critical dependencies and process pathways. The matrix identifies the primary, alternative, and non-production possibilities for each SKU, offering insights into potential bottlenecks and dependencies.

One significant insight from this analysis is the degree of redundancy within the production system. The analysis showed moderate to high redundancy in most processes and departments. While certain SKUs rely on specific machines, most departments have multiple machines that can be adjusted to produce specific SKUs. For instance, if the primary furnace for Central Melting fails, casting machines with storage ovens can still melt the metal/alloy to specifications. However, some areas lack sufficient redundancy. Support from other plants or outsourcing is viable for non-unique processes, but this is not consolidated for the Top 50 SKUs, leading to potential delays.

Critical redundancy gaps were analyzed in Subsection 4.1.2, focusing on material supply and product assembly.

4.1.2 Bill of Material Analysis

The BOM analysis provides a comprehensive understanding of Grohe’s SC dependencies and vulnerabilities. The selected SKUs require approximately 1,600 components, highlighting the complexity of Grohe’s manufacturing operations. This section examines the supplier distribution, the count and percentage of components per SKU by country, and the inclusion of alternative suppliers.

Supplier Distribution by Country Figure 4.1 illustrates the distribution of suppliers by country, with a color-coded map and accompanying table. The analysis shows that Germany has the highest supplier count (570), indicating a significant reliance on German suppliers. This concentration can streamline logistics and quality control but also poses a risk if there are geopolitical or economic disruptions in Germany.

Portugal also has a substantial supplier base (484), plus 216 from AL internal work-in-progress materials. This regional concentration offers strategic advantages due to proximity to the plant but poses risks from regional disruptions such as natural disasters or political instability. China and Italy are also critical, with 138 and 113 suppliers respectively, contributing significantly to Grohe’s global SC. Disruptions, particularly from China, could result in long lead times of several weeks. Geopolitical stability and logistics complexities should be continuously monitored.

Countries like Spain, Austria, Netherlands, Switzerland, Thailand, Turkey, Poland, and Japan have fewer suppliers, diversifying risks but potentially insufficient if major disruptions occur in larger supplier countries.

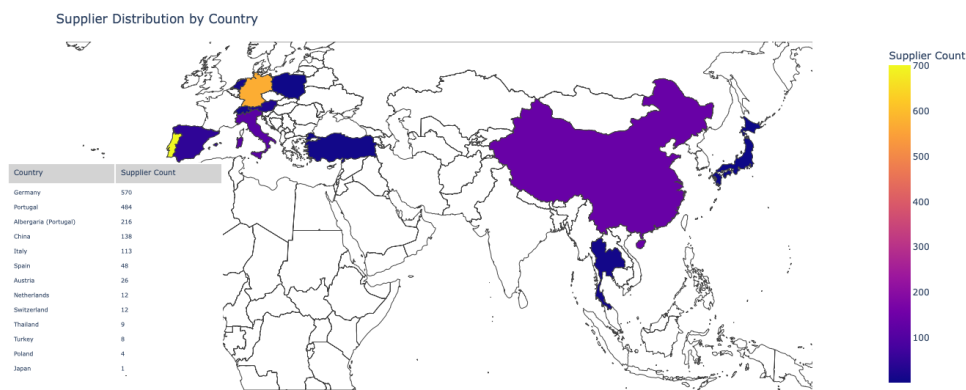


Figure 4.1: Supplier distribution for Top50 SKU by country, highlighting the number of suppliers in each country with a color-coded map and a table providing the supplier count per country.

Components and Materials by SKU Figures 4.2 and 4.3 analyze components and materials by SKU, highlighting the count and percentage by country.

Figure 4.2 shows the count and percentage of components by country for each SKU. Portugal and Germany dominate most SKUs, reflecting their crucial role in supplying materials. This dependency is both a strength and a vulnerability, as disruptions in these countries could halt production. The red dashed line represents the average count of components per SKU, which is 83.2. SKUs like '34558000', '34598000', '34788000', and '414720040' exceed this average, indicating higher complexity or dependency. The percentage of EU vs. Non-EU component suppliers highlights a reliance on EU suppliers, simplifying logistics and compliance but posing risks for EU-wide disruptions.

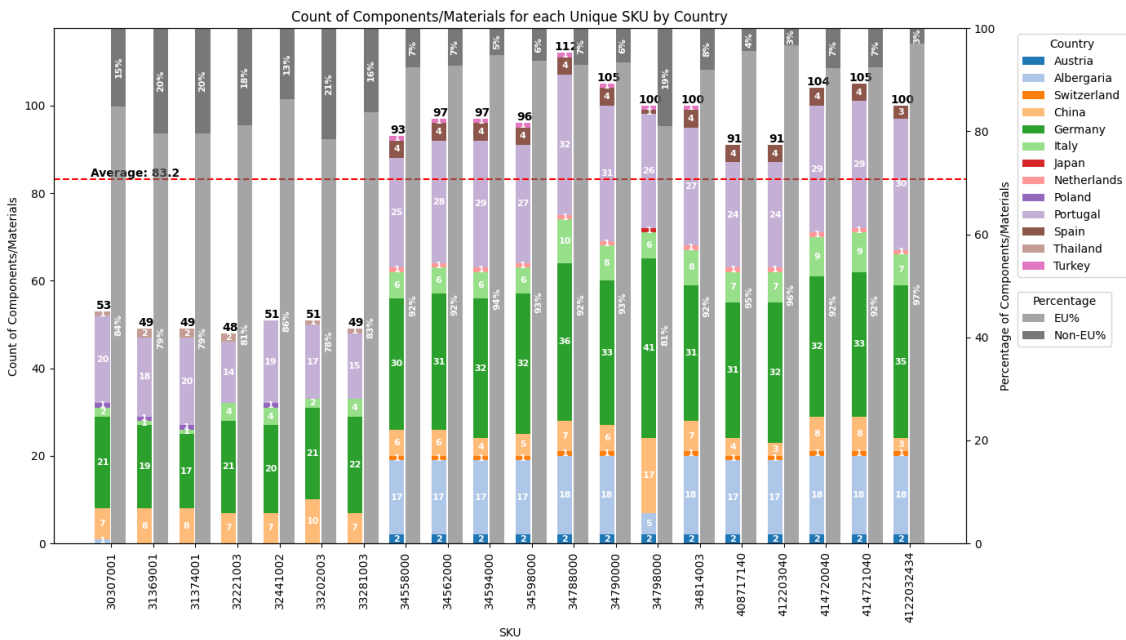


Figure 4.2: Stacked bar chart showing the count and percentage of components by country and the percentage of EU and Non-EU suppliers for each SKU.

Figure 4.3 includes data on alternative suppliers from Hong Kong, Singapore, Taiwan, and Malta, diversifying the supply base. This reduces dependency on primary suppliers but requires meticulous management to ensure quality and reliability. The visualization highlights the importance of alternative suppliers in reducing single-source risks. However, managing multiple suppliers increases complexity and requires robust supplier relationship management. Notably, all SKUs still show a lack of alternative suppliers, which remains a critical vulnerability.

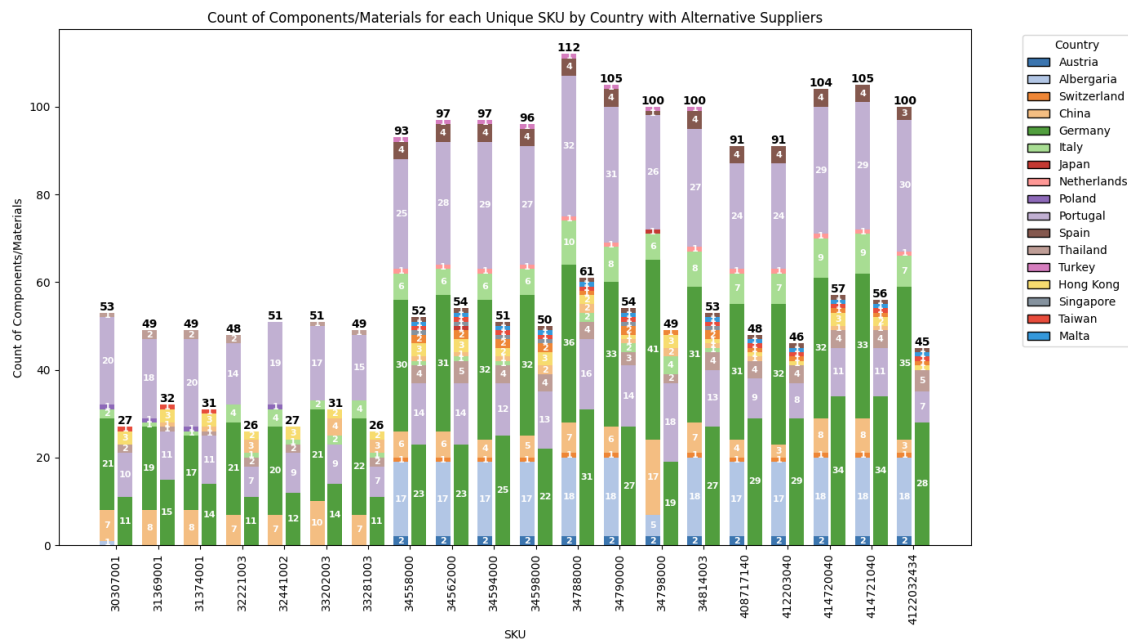


Figure 4.3: Stacked bar chart showing the count of components for each SKU by country, including first source and alternative suppliers.

Key Findings The BOM analysis identifies significant dependencies on Germany and Portugal for critical components. Disruptions in these countries could severely impact production, making it essential to develop alternative suppliers and increase inventory for critical components. While single sourcing offers cost benefits, it increases risk. Multiple sourcing provides resilience but adds complexity, suggesting a balanced approach leveraging both strategies is recommended. Lean strategies have optimized operations but increased SC vulnerability by eliminating redundancies. The analysis underscores the need to maintain adequate inventory levels and explore alternative sourcing options for critical materials to mitigate risks. Dual sourcing strategies and outsourcing certain operations enhance resilience. For example, packaging and certain critical components are sourced from multiple suppliers to ensure continuity.

4.1.3 Risk Identification, Risk Analysis and Risk Evaluation - Results

The results for RI, risk analysis, and RE were obtained by following the steps outlined in Section 3.3 and as depicted in flowchart 2 of Figure 3.3. The analysis assessed the likelihood, impact, and HR of each identified risk across all departments. This thorough evaluation highlights the most critical risks needing immediate attention and those requiring significant but less urgent action.

Risk Identification As shown in Figure 3.3 (flowchart 2), the RI process starts with the creation of a risk register (see Appendix B). This register categorizes risks into external and internal, grouping them into categories such as Natural Disasters, Societal Risks, and Utility Risks. The risk register was then reviewed with top management to determine which pre-selected risks warranted further investigation. Leveraging their knowledge of the Portuguese market and relevant expertise, top management identified the following risks as not applicable, while all other risks were deemed applicable for further analysis:

- **Societal Risks:** Bomb threats (R-04), terrorism (R-05), internal strikes (R-06), external strikes (R-07), robberies (R-08), economic crisis (R-09);
- **Supply Chain Risks:** Restricted access to a site or building (R-11).

In the subsequent analysis, certain risks were identified as affecting the entire plant rather than specific departments. These plant-wide risks include all Utility Risks, Health and Biological Risks, Human Resource Risks (R-30, R-32), and Technological Risks (R-26). Although these risks impact the entire plant, some required department-level analysis to determine their impacts, immediate actions, and recovery strategies accurately.

Risk Analysis The risk analysis assessed the likelihood, impact, and HR for each identified risk across all departments, as detailed in Section 3.3.1. This comprehensive evaluation was conducted with the core BCP team and the Pre-Process Manager, followed by revisions with department leaders. This collaborative approach led to a re-analysis of several criteria, particularly within the impact and HR assessments, ensuring a thorough understanding of each risk's potential consequences. The involvement of experienced department leaders provided valuable insights covering the past five years, enhancing the accuracy and reliability of the risk analysis.

Risk Evaluation The RE process involved a comprehensive evaluation of external and internal risks at the departmental level, using the scales outlined in Section 3.3.1. An exemplary outcome for the Assembly and WH departments is provided in Appendix C. The results across all departments highlight the most critical risks requiring immediate and significant attention, as illustrated in bar charts in Appendix H. These results are discussed in the following.

External Risks The analysis of external risks, depicted in Figure H.1 of Appendix H, reveals several key insights. Risks R-10 and R-12 are moderate to high-priority across multiple departments, indicating significant vulnerability in the plant's reliance on external inputs. All utility risks (R-13 to R-16) are consistently rated as higher moderate-priority, highlighting the critical dependence on these essential services. Environmental risks such as R-01 and R-02 show low priority, reflecting localized vulnerabilities based on geographical location and operational context. Despite frequent and severe bushfires in Portugal, effective mitigation strategies have reduced this risk mainly to limited access to the plant.

Internal Risks As depicted in Figure H.2 of Appendix H, no department identified any internal risk as high-priority. However, several risks, including R-20, R-28, R-30, and R-32, were ranked as moderate to higher moderate priorities across multiple departments. This highlights the critical need to maintain operational integrity and prevent disruptions.

Conversely, risks such as R-21, R-25, R-26, and R-31 were consistently ranked as low priorities across all departments. Additionally, certain risks exhibited mixed priorities across different departments due to unique processes or dependencies, specifically R-22, R-24, R-27, and R-29.

Department Level The department-level analysis provides further insights into the specific vulnerabilities and priorities of each department as shown in Figure H.3 and H.4 of Appendix H:

Foundry: The Foundry department identifies higher moderate-priority external risks related to utilities (R-13 to R-16) and SC disruptions. Environmental and health risks are low to lower moderate priority. Internally, higher moderate-priority risks include machinery breakdowns and human resource issues, while technological and infrastructure risks are lower priority.

Machining: External risks related to utilities and SC disruptions are higher-moderate priority, while environmental risks and health concerns are moderate priority. Internally, operational risks, particularly machinery breakdowns and building damages, are moderate priority. Technological and infrastructure risks are low priority.

Grinding & Polishing: Utility risks (R-13, R-15) and SC disruptions are high moderate-priority, health concerns are moderate priority, and environmental risks are low priority. Internal risks include high moderate and moderate-priority operational issues, especially fire risk and machinery malfunctions. Infrastructure and technological risks are low priority.

Plating: External risks, including utility disruptions and SC issues, are higher moderate-priority, with health risks at moderate priority. Internally, higher moderate-priority operational risks include chemical leakage, physical damages, and human resource issues. Technological and infrastructure risks are low priority.

PVD: Utility and SC risks are higher moderate-priority externally, with environmental and health concerns at moderate priority. Internally, higher moderate-priority risks include equipment reliability, IT functions, and human resource issues. Technological and infrastructure risks are low priority.

Assembly: The Assembly department identifies high-priority external risks related to raw material supply and SC disruptions, with utility and health risks as moderate priority. Internally, higher moderate-priority risks include operational, IT, infrastructure (fire or physical damages), and human resource risks. Infrastructure risks are moderate priority.

Warehouse: The WH department ranks utility risks (R-13) as higher moderate-priority externally, with health and cyber security risks as moderate priority. Internally, higher moderate-priority risks include operational issues, human resource concerns, and IT resources, while technological risks like equipment availability and fire risks are moderate priority.

4.2 Business Impact Analysis - Results

As outlined in Figure 3.3 (right side), the BIA was conducted to evaluate the potential impacts of disruptions on critical business functions and equipment, focusing on risks with 'Moderate' or 'High' priority levels.

Plant-Wide Risks As previously mentioned in Section 4.1.1, certain risks impact the entire plant and were treated differently from department-specific risks. These include disruptions in essential utilities such as electricity and water supply, as well as health and biological risks like pandemics, legionella detection, or cyber attacks. The BIA team assessed the impacts of these risks across departments. For instance, a water supply disruption could critically affect the entire plant, despite having the public water network and a limited-volume well. To mitigate this risk, a project was initiated to evaluate water consumption per department, identify local suppliers for large volumes of water (e.g., the fire brigade within the same industrial park), and establish a communication protocol, including contacting legal offices first and informing the public entity about the operation. Ensuring an uninterrupted water supply requires meticulous coordination and contingency planning, underscoring the severe impact such a disruption could have on plant operations.

Scenario-Based Analysis For department-specific risks, the BIA employed a scenario-based analysis approach, tailored to the unique characteristics and operational dynamics of each department. This method provided a detailed understanding of potential impacts and helped in developing targeted recovery strategies. One illustrative scenario involved a disruption in the natural gas supply, primarily affecting the Plating and Assembly departments, which rely heavily on gas for heating and other processes. The operational impact included the immediate termination of the plating process and water temperature testing activities in the Assembly lines for certain Top 50 SKUs. This disruption could lead to a backlog in production schedules and increased pressure on other departments to compensate for the delay. Immediate actions included coordinating with the utility provider to restore supply quickly. To mitigate this risk, a project was initiated to assess the feasibility of switching from natural gas to industrial propane gas supplied by trucks. This assessment would involve evaluating the required technical modifications, necessary equipment, and financial investment. Additionally, recovery strategies considered exploring alternative heating sources, such as electric heaters, and increasing the inventory of critical components to buffer against production delays.

Unanticipated Scenarios and Extended Investigations The BIA exercise and subsequent brainstorming sessions revealed several scenarios and impacts not previously considered in detail. Immediate actions and recovery strategies were not always readily apparent, requiring further investigation by department leaders. Some investigations were extensive, necessitating separate company projects to assess impacts and develop solutions. For example, the disruption of natural gas for heating water, as described in the previous paragraph, emerged as a critical issue. This prompted further investigation into alternative heating solutions and potential investments in backup systems. Similarly, potential electricity outages required a detailed analysis of energy consumption per area to evaluate generator feasibility. The investigation revealed insufficient generator capacity for full operational continuity, leading to a proposal for a new project to enhance the facility's backup power capabilities.

Key Findings from the BIA Key findings from the BIA underscored the importance of a proactive and comprehensive approach to BC planning. Several scenarios highlighted the need for robust backup systems and alternative solutions to maintain operational continuity. The detailed scenario analysis provided actionable insights for developing tailored recovery strategies for each department. Ensuring compliance with industry standards and regulations during disruptions requires proactive planning and temporary regulatory approvals for alternative solutions. The BIA revealed new risks and impacts, leading to a deeper understanding of departmental dependencies and vulnerabilities. Some scenarios required extensive investigations, resulting in proposals for new projects to enhance resilience.

Chapter 5

Discussion

This chapter evaluates the findings from the BCP implementation at Grohe AL, interpreting and discussing results in Section 5.1, assessing completion levels and identifying gaps in Section 5.2, discussing implications for industrial engineering and management in Section 5.3, and highlighting limitations of the study in Section 5.4. This structure provides a comprehensive overview of progress, challenges, and recommendations for enhancing business resilience.

5.1 Interpretation and Discussion of Results

The BCP implementation results at Grohe AL show a solid BCM foundation but also reveal areas for enhancement. The qualitative assessments and reliance on top management's expertise, as detailed in Section 4.1, provided a robust starting point. However, integrating more quantitative data into the RA process could improve accuracy and reliability. This involves setting clear financial impact thresholds and using detailed scenarios to quantify potential disruptions, aligning with industry best practices.

Managing critical machinery and equipment is crucial in BCP implementation. The SKU-Machine Matrix identifies essential equipment and their roles in production. This matrix is particularly useful for prioritizing maintenance, developing redundancy plans, and allocating resources effectively. Ensuring the availability and functionality of critical machinery is vital for maintaining production flow and minimizing downtime during disruptions. The current analysis indicates that unique critical machinery is not significant, but this could change with new products, and with strategic investment in new machinery and tools. As product lines and SKUs evolve, dependencies on specific machinery may increase, necessitating a more detailed examination of operational flexibilities and bottlenecks. For example, if other casting machines become essential or the PVD process gains relevance, redundancies identified in the current matrix could change substantially. Thus, the SKU-Machine Matrix is a powerful tool for continuously monitoring and adapting to changing production needs.

The analysis of dependencies and vulnerabilities within Grohe AL's SC, as shown in Section 4.1.2, reveals a significant reliance on suppliers from Germany and Portugal. This concentration streamlines logistics and quality control but also introduces vulnerability to regional disruptions. For example, as depicted in Figures 4.2 and 4.3, certain SKUs depend heavily on suppliers from these regions, posing risks in case of geopolitical or economic disruptions. The BOM analysis highlighted the need for developing alternative suppliers and balancing single and multiple sourcing strategies to enhance resilience and ensure continuous operation despite potential regional challenges.

The BIA results, detailed in Section 4.2, underscore the importance of identifying key processes and their associated recovery priorities. For instance, the critical machinery and equipment identified in the SKU-Machine Matrix, such as the Plating line and the Assembly lines, are essential for maintaining production flow. Establishing clear RTO and MAO for these processes is crucial. This can be achieved by conducting scenario-based exercises that simulate various disruption scenarios, providing a more realistic picture of potential impacts and recovery requirements.

5.2 Identifying Gaps and Potential Improvements to Business Continuity

The literature review outlined several key concepts and best practices for effective BCM, including the BCMS life-cycle, the integration of RA and BIA, and the importance of CI. The BCMS life-cycle, as described in Section 2.3, includes the following steps: Policy and Programme Management, Embedding BCM, Analysis, Design, Implementation, and Validation.

In terms of Policy and Programme Management, Grohe AL has a strong policy framework, but more detailed documentation of the BC policy and its alignment with organizational objectives is needed, as per ISO 22301:2019 (Section 2.1). Embedding BCM into the organizational culture is crucial (Section 2.3.2). While top management is involved in the RA process, further efforts are needed to embed BCM awareness across all levels through regular training and awareness programmes (Section 2.3.2). Additionally, integrating BCM into existing QM systems can streamline processes and ensure BCM becomes an integral part of the organizational culture.

The Analysis phase involves comprehensive RA and BIA. While effectively conducted, they relied heavily on qualitative assessments and top management's expertise. Best practices suggest defining clear financial impact thresholds and using detailed scenarios to enhance accuracy (Section 2.4). Integrating quantitative data would provide more precise evaluations of potential disruptions. Currently, there are no clear financial impact thresholds, a significant area for improvement. Discussions on repair or resumption times often centered on the financial resources management is willing to allocate. Adequate financial support can expedite resumption to acceptable operational levels. Moreover, a quantified approach, including evaluations of production output impact, operational efficiency losses, additional operational costs, repair expenses, and potential revenue losses, was deferred by management.

The Design phase of BCM requires comprehensive BC strategies. The methodology included identifying critical machinery and equipment, but more detailed recovery strategies and resource allocation plans are needed. For instance, critical machinery in the SKU-Machine Matrix, such as the Plating line and Assembly lines, are essential for maintaining production flow. Conducting scenario-based exercises to simulate various disruptions can realistically assess potential impacts and recovery needs. Training scenarios could involve simulating disruptions in the Assembly line to evaluate response strategies and identify recovery plan gaps. This might include reconfiguring the thermostatic lines, integrating these tools into other lines, or establishing a new assembly line from scratch.

Implementation involves putting the BC strategies into action. While Grohe AL has made progress in this area, further efforts are needed to develop structured implementation plans and communication protocols. Implementing BC strategies requires thorough planning and resource management to ensure effective execution (Section 2.3.4).

Validation, the final phase of the BCMS life-cycle, is crucial for ensuring the BCP's effectiveness. Current validation efforts have been effective in identifying gaps and areas for improvement. However, a more structured approach to testing, including both tabletop exercises and full-scale simulations, is recommended (Section 2.3.5). These exercises should involve all relevant stakeholders and be designed to test the plan's response to a range of potential disruption scenarios.

CI is a critical component of BCM, as emphasized in the literature (Section 2.3). Regular reviews and updates of the BCP are necessary to reflect changes in the internal and external environment, including organizational changes, technological advancements, and evolving threat landscapes. Industry experts recommend annual reviews (Riglietti and Warren, 2023). Grohe AL plans to follow this recommendation to ensure ongoing relevance and effectiveness. Reviews will also be conducted when critical new processes, machines for the selected SKUs, or significant scope changes occur. By adopting a PDCA cycle, Grohe AL can ensure its BCP remains effective (Section 2.3.1). Feedback from stakeholders and lessons learned from actual disruptions should be incorporated into the BCP, reflecting changes in organizational and external environments.

To address these gaps, the following steps are recommended for enhancing Grohe AL's BCMS:

- Develop a comprehensive BC policy that aligns with organizational objectives and is documented in detail, following the guidelines of ISO 22301:2019;
- Clearly allocate responsibilities for each stage of the BCMS, detailing which departments and employees are responsible for planning, implementation, and operational management, as well as authorship and plan authorization;
- Conduct regular training and awareness programmes to embed BCM awareness across all levels of the organization;
- Integrate quantitative data into the RA process by defining clear financial impact thresholds and using detailed scenarios to quantify potential disruptions;

- Identify and evaluate potential alternative suppliers, and establish contractual agreements to ensure the availability of specified production capacities in the event of disruptions to critical processes at Grohe AL;
- Implement a structured approach to validation and testing, including both tabletop exercises and full-scale simulations;
- Adopt a PDCA cycle to ensure regular reviews and updates of the BCP, incorporating feedback from stakeholders and lessons learned from actual disruptions;
- Engage with industry forums and networks to facilitate knowledge exchange and CI.

5.3 Implications for Industrial Engineering

The findings from this study have significant implications for industrial engineering and management, especially in integrating BCM into standard industrial practices. Implementing a robust BCM framework at Grohe AL demonstrates the critical role industrial engineers can play in enhancing organizational resilience and operational efficiency.

Industrial engineering focuses on optimizing complex processes and systems to improve efficiency, productivity, and quality. BCM ensures the continuity of business operations during disruptions. Integrating these disciplines can create resilient systems that are efficient and capable of withstanding and recovering from unforeseen events.

Incorporating RA and BIA into the design and management of industrial processes is essential. The study at Grohe AL underscores the importance of these analyses in identifying vulnerabilities and dependencies within the SC and production processes. For industrial engineers, RA and BIA should be integral to process design, ensuring potential risks are identified and mitigated from the outset.

Furthermore, the study acknowledges the value of a quantified approach to RM. Although the RA and BIA at Grohe AL relied mainly on qualitative assessments and top management's expertise, integrating quantitative data is recognized as best practice. Industrial engineers, skilled in quantitative methods, can apply these to BCM to create precise RAs and recovery plans. This involves defining financial impact thresholds, evaluating operational and financial implications of disruptions, and developing recovery strategies based on quantitative data. While this approach was deferred in this study due to management's decision, it represents a potential area for future enhancement.

Implementing scenario-based exercises is another critical intersection of industrial engineering and BCM. These exercises test recovery plans and identify gaps. For industrial engineers, this involves designing and conducting simulations that mimic potential disruptions, validating the BCM framework's robustness. Such exercises facilitate CI by highlighting enhancement areas and ensuring the BCM framework evolves with changing conditions. Although beyond this study's scope, they are crucial for future BCM development at Grohe AL.

Integrating BCM into existing QM systems can streamline processes and embed BCM within the organizational culture. This alignment ensures resilience is incorporated into all operations. Regular training and awareness programmes are essential to foster a culture of resilience, where each employee understands their role in maintaining BC. Conducting the project within the QM department and managing it there in the future is advantageous. The QM team's extensive RM expertise will streamline assessments, enhancing the quality and effectiveness of future BCP initiatives at Grohe AL.

5.4 Limitations of the Study

This study encountered several limitations that should be acknowledged to provide a comprehensive understanding of the research context and its findings.

Firstly, while HRs were utilized in the RA, although infrequently, the integration of more comprehensive and specific quantitative data could have significantly enhanced the accuracy of both the RA and BIA processes. The management's decision to focus primarily on qualitative assessments limited the depth of quantitative analysis. Defining clear financial impact thresholds and employing detailed scenarios would have provided more precise evaluations of potential disruptions. However, it is important to note that incorporating this approach would have required more substantial involvement from management, thereby increasing the demands on their time and leading to higher analysis costs.

Methodologically, the study faced challenges due to the team's need to familiarize themselves with the newly adopted methodology. This learning curve affected the initial workflow and the effectiveness of brainstorming sessions and meetings. It is essential to recognize that this project was not the first attempt at implementing a BCM strategy at Grohe AL, but it was the first using this particular standard-based approach. Adapting and integrating this methodology required additional time and effort, impacting the efficiency and outcomes of the project, and underscoring the complexities and demands of such an endeavor.

Practical limitations also influenced the outcomes of this study. The reliance on key stakeholders and the necessity for numerous management decisions occasionally impeded the project's progress. The management team, already engaged with daily operations and multiple concurrent projects, could only devote limited attention to this initiative. Although their involvement was crucial, the competing demands on their time and resources understandably constrained the comprehensiveness of their contributions to the BCP project.

In conclusion, the study successfully established a solid foundation for BC at Grohe AL, but several limitations were noted. Despite these challenges, the findings offer valuable insights into BCP implementation in manufacturing and highlight areas for future improvement.

Chapter 6

Conclusion

This thesis aimed to establish a robust methodology for BCP tailored to the operational requirements of Grohe AL. The primary research objectives included performing a detailed RA, conducting a BIA, and proposing strategic recommendations to enhance BC. The literature review highlighted the necessity of integrating BCM into corporate strategy, particularly within the manufacturing sector, to address unique vulnerabilities such as SC dependencies and the critical nature of specific machinery. The research methodology involved a multi-stage approach: an in-depth analysis of Grohe AL's production processes, comprehensive RI, prioritization through RA, and a detailed BIA. This structured approach provided a robust understanding of potential disruptions and their implications for Grohe AL's operations.

The findings from the RA and BIA identified several critical vulnerabilities and bottlenecks within Grohe's production processes. These insights informed the development of targeted strategies aimed at enhancing BC. Key recommendations included implementing scenario-based exercises, integrating BCM into existing QM systems, and fostering a culture of resilience through regular training and awareness programmes.

Theoretically, this research expands BCM knowledge by analyzing its application in manufacturing, reviewing key concepts, methodologies, and challenges, and deepening the understanding of BCM adaptation and implementation. Practically, the developed methodology provides a structured approach for manufacturing organizations to enhance BC capabilities. The proposed strategies and recommendations directly apply to Grohe AL and are adaptable for other manufacturing companies, helping maintain operational efficiency during adverse events.

Despite establishing a strong BCM foundation, the study faced limitations such as reliance on qualitative data due to deferred quantitative analysis and constraints from stakeholder availability. These limitations highlight areas for future research and BCM framework enhancements.

In conclusion, this thesis provides valuable insights into the practical application of BCM in the manufacturing sector. The findings and recommendations offer a clear pathway for Grohe AL to enhance operational resilience and ensure the continuity of critical business functions during disruptions. Future work should address the identified limitations, refine the RA process, and continuously update the BCP to adapt to evolving risks and operational changes.

Bibliography

- Aghabegloo, M., Rezaie, K., Torabi, S. A., and Yazdani, M. (2024). Integrating business impact analysis and risk assessment for physical asset criticality analysis: A framework for sustainable operations in process industries. *Expert Systems with Applications*, 241:122737.
- Collier, P. M. (2009). Risk and business continuity management. In Collier, P. M., editor, *Fundamentals of Risk Management for Accountants and Managers*, pages 223–228. Butterworth-Heinemann, Oxford.
- Cook, R. S. and Anderson, R. (2020). Transitioning from incident to crisis management to continuity of operations. *Journal of business continuity & emergency planning*, 14 1:46–54.
- Fani, S. V. and Subiadi, A. P. (2019). Trend of business continuity plan: A systematic literature review.
- Gibb, F. and Buchanan, S. (2006). A framework for business continuity management. *International Journal of Information Management*, 26(2):128–141.
- Herbane, B. (2010). The evolution of business continuity management: A historical review of practices and drivers. *Business History*, 52:978–1002.
- Hiles, A. (2007). *The Definitive Handbook of Business Continuity Management*. Wiley.
- ISO 22300 (2021). Iso 22300:2021(en) security and resilience — vocabulary. Standard ISO 22300:2021, International Organization for Standardization. Accessed: 2024-04-22.
- ISO 22301 (2012). Iso 22301:2012 security and resilience – business continuity management systems – requirements. Standard ISO 22301:2012, International Organization for Standardization. Accessed: 2024-04-22.
- ISO 31000 (2018). Iso 31000:2018 risk management – guidelines. Standard ISO 31000:2018, International Organization for Standardization. Accessed: 2024-04-05.
- ISO22301 (2019). Iso 22301:2019 security and resilience – business continuity management systems – requirements. Standard ISO 22301:2019, International Organization for Standardization. Accessed: 2024-04-05.
- ISO/CASCO (2020). The iso survey of certifications. Technical report, International Organization for Standardization. Accessed: 2024-05-11.
- ISO/CASCO (2021). The iso survey of certifications. Technical report, International Organization for Standardization. Accessed: 2024-05-11.
- ISO/CASCO (2022). The iso survey of certifications. Technical report, International Organization for Standardization. Accessed: 2024-05-11.

- Lester, A. (2017). 15. risk management. In *Project Management, Planning and Control - Managing Engineering, Construction and Manufacturing Projects to PMI, APM and BSI Standards (7th Edition)*. Elsevier.
- Lusa, A. (2024). Bosch de ovar sem energia elétrica devido a greve de trabalhadores da edp. Available online: <https://observador.pt/2024/03/29/bosch-de-ovar-sem-energia-eletrica-devido-a-greve-de-trabalhadores-da-edp/>; [Accessed: 10-May-2024].
- Meyer, Thierry, R. G. (2013). *Engineering Risk Management*. De Gruyter.
- Munro, Roderick A., R. G. Z. D. J. (2022). *ASQ Certified Six Sigma Green Belt Handbook (3rd Edition)*. American Society for Quality (ASQ).
- Pheng, L.S., S. L. (2018). *Business Continuity Management in Construction*. Springer Singapore.
- Rausand, Marvin, H. S. (2020). *Risk Assessment - Theory, Methods, and Applications (2nd Edition)*. John Wiley Sons.
- Riglietti, G. and Warren, B. (2023). Building resilience in shipping & manufacturing: have we made any progress? Webinar hosted by The Business Continuity Institute. Accessed: 2024-05-11.
- Steitz, C. (2024). Tesla's german gigafactory reconnected to grid after week-long outage. Available online: <https://www.reuters.com/business/autos-transportation/teslas-german-gigafactory-could-be-supplied-again-monday-says-power-firm-2024-03-11/>; [Accessed: 10-May-2024].
- Swartz, E. and Elliott, D. (2010). *Business Continuity Management: A Crisis Management Approach*. Routledge, 2 edition.
- The Business Continuity Institute (2013). *Good Practice Guidelines 2013: Global Edition*. The Business Continuity Institute.
- The Business Continuity Institute (2022). *BCI Extreme Weather Climate Change Report 2022*. The Business Continuity Institute.
- Torabi, S., Rezaei Soufi, H., and Sahebjamnia, N. (2014). A new framework for business impact analysis in business continuity management (with a case study). *Safety Science*, 68:309–323.
- Wallace, Michael, W. L. (2018). *Disaster Recovery Handbook - A Step-by-Step Plan to Ensure Business Continuity and Protect Vital Operations, Facilities, and Assets (3rd Edition)*. AMA-COM.

Contribution to Sustainable Development Goals

The purpose of this chapter is to analyze the impact of the developed BCP methodology on the United Nations Sustainable Development Goals (SDGs). This analysis identifies the relevant SDGs addressed, specific targets within these goals, and the project's contributions towards achieving these targets. Performance indicators are established to measure the project's impact effectively. The UNESCO document "Engineering for Sustainable Development: Executive Summary" highlights the crucial role of engineering in achieving these goals, providing a framework for understanding the broader impact of engineering practices.

Table 6.1 summarizes the SDGs, specific targets, contributions of the BCP methodology, and the performance indicators and metrics used to measure the project's impact on these goals.

Table 6.1: Contribution to Sustainable Development Goals and Performance Indicators

SDG	Goal	Contribution	Performance indicators and metrics
9	9.1	The methodology focuses on enhancing the resilience and sustainability of Grohe AL's manufacturing infrastructure through detailed RAs and BIAs. This ensures critical processes can withstand and recover from disruptions, supporting reliable industrial infrastructure essential for economic stability and human well-being.	Implementation rate of BCM strategies, reduced operational downtime during disruptions, and improved production process efficiency and resilience.
9	9.4	The BCP methodology integrates sustainable practices and resilience planning into Grohe AL's operational framework. It identifies dependencies on electricity, gas, and water and develops strategies to reduce their consumption, ensuring alternative supplies during disruptions.	Implementation of energy-efficient technologies, comprehensive sustainability reporting post-implementation, and improved resource-use efficiency in manufacturing operations.
12	12.6	The project encourages the integration of sustainability practices within Grohe AL's manufacturing operations, ensuring responsible and efficient operation. This promotes a circular economy by minimizing waste and optimizing resource use.	Adoption level of sustainable practices within the BCP, frequency and detail of sustainability reporting, and reduction in waste alongside improved resource efficiency.
11	11.5	The BCP methodology contributes to the economic stability and resilience of the surrounding community by ensuring continuous operation of critical manufacturing processes. This reduces the economic impact of disruptions and protects livelihoods dependent on Grohe AL's operations.	Economic impact metrics during and after disruptions, metrics on community resilience and recovery, and reduction in economic losses due to operational disruptions.

Exemplary SKU-Machine Matrix

The matrix distinguishes between preferential production paths (indicated by 'X' with a green background), alternative paths (indicated by 'X' without background color), and non-production possibilities (empty cells). Confidential product information, such as SKU names, Assembly Streams, and machine names, have been neutralized.

Product information						Sub-Department	Pre-Process Equipment/Machine																										
							Grinding 1	Grinding 2	Grinding 3	Grinding 4	Grinding 5	Grinding 6	Grinding 7	Grinding 8	Grinding 9	Grinding 10	Grinding 11	Grinding 12	Polishing 1	Polishing 2	Polishing 3	Polishing 4	Polishing 5	Polishing 6	Polishing 7	Polishing 8	Polishing 9	Preferential (Grinding & Polishing)	2 alternatives (Grinding & Polishing)	Grinding			
Plant	SKU	Body (Pre-Process)	Body (Assembly)	SKU Name	Assembly Stream	Name	Assessment																										
AL	34559000	40534038	40534040	x	x	X	X	X										X	X	X	X		3	4	X								
AL	33280003		41452538	x	x																		0	0									
AL	34562000	40534038	40614040	x	x	X	X	X										X	X	X	X		3	4	X								
AL	30374001		409557840	x	x																		0	0									
AL	33202003		405900038	x	x																		0	0									
AL	34814003	40603138	40603160	x	x	X	X	X										X	X	X	X		3	4	X								
AL	34790000	40603138	40603160	x	x	X	X	X										X	X	X	X		3	4	X								
AL	32220003		41452538	x	x													X	X	X	X		0	0	X								
AL	31563001		409557840	x	x																		0	0	X								
AL	30307001		41445638	x	x																		0	0	X								
AL	32440002		41452538	x	x																		0	0	X								
AL	34780000		41046840	x	x																		0	0	X								
AL	34594000	40534038	40534040	x	x	X	X	X															3	4	X								
AL	34780000	40602138	40602160	x	x	X												X	X	X	X		2	3	X								
AL	34580000	405340038	405340040	x	x	X												X	X	X	X		2	3	X								
Lahr	26559000	408747038	408747040	x	x	X			X	X	X	X	X					X	X	X	X		6	4	X								
Lahr	26677000	408747038	408747040	x	x	X			X	X	X	X	X					X	X	X	X		6	4	X								
Lahr	26677001	408747038	408747040	x	x	X			X	X	X	X	X					X	X	X	X		6	4	X								
Lahr	26075001	414709038	414709040	x	x	X								X	X			X	X	X	X		4	3	X								
Lahr	264030002	414709038	414709040	x	x	X							X	X				X	X	X	X		4	3	X								
Lahr	27296003	414709038	414709040	x	x	X							X	X				X	X	X	X		4	3	X								
Lahr	27675002	414709038	414709040	x	x	X							X	X				X	X	X	X		4	3	X								
Lahr	2.67E+08	408747037	4087472433	x	x	X			X	X	X	X	X					X	X	X	X		6	4	X								
						Preferential alternatives	6	5	5	4	4	4	4	4	4	4	0	0	0	0	0	0	0	9	4	2	0						
							9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	6	11	13	0						
																																	20

Figure A.1: SKU-Machine Matrix illustrating production paths through Grinding, Polishing, and Plating sub-departments.

Appendix B

Exhaustive Risk Register with Categorization of Risks and Incidents

Table B.1: Categorization of external risks and incidents with descriptions impacting manufacturing operations.

Risk ID	Category 1	Category 2	Risk / Incident
R-01	External Risks	Natural Disasters	Floods: Potential flooding impacting manufacturing facilities, leading to downtime and equipment damage.
R-02	External Risks	Natural Disasters	Bushfire: Risk of bushfires causing damage to plant infrastructure or hindering plant access and halting production.
R-03	External Risks	Natural Disasters	Hailstorms: Hailstorms damaging roofs and critical outdoor equipment, causing operational delays.
R-04	External Risks	Societal Risks	Bomb threats: Bomb threats disrupting operations and requiring evacuation of facilities.
R-05	External Risks	Societal Risks	Terrorism: Terrorist activities targeting manufacturing plants, causing destruction and halting production.
R-06	External Risks	Societal Risks	Internal strikes: Strikes by employees disrupting production schedules and delivery commitments.
R-07	External Risks	Societal Risks	External strikes: Strikes by suppliers or logistics providers affecting the supply chain and production flow.
R-08	External Risks	Societal Risks	Robberies: Theft of valuable materials or equipment leading to financial loss and production interruptions.
R-09	External Risks	Societal Risks	Economic crises: Economic downturns impacting demand and financial stability of manufacturing operations.
R-10	External Risks	Supply Chain Risks	Shortage of external resources (raw materials, components, fuel, etc.): Interruptions in the supply of essential raw materials affecting production schedules.
R-11	External Risks	Supply Chain Risks	Restricted access to a site or building: External factors preventing access to manufacturing facilities, causing production delays.
R-12	External Risks	Supply Chain Risks	Interruption of the supply chain: Disruptions in the supply chain affecting the timely delivery of materials and components.
R-13	External Risks	Utility Risks	Lack of electricity: Power outages halting production processes and affecting machinery operation.
R-14	External Risks	Utility Risks	Lack of water: Water supply interruptions affecting cooling systems and other water-dependent processes.
R-15	External Risks	Utility Risks	Lack of compressed air: Compressed air supply failures impacting pneumatic tools and machinery operation.
R-16	External Risks	Utility Risks	Lack of Natural Gas: Natural gas supply disruptions affecting heating and production processes.
R-17	External Risks	Health and Biological Risks	Pandemics: Outbreaks of disease impacting workforce availability and production capacity.
R-18	External Risks	Health and Biological Risks	Legionella detection: Detection of Legionella bacteria leading to health risks and potential shutdowns for remediation.
R-19	External Risks	Security Risks	Cyber attacks: Cyber attacks targeting manufacturing systems, causing data breaches and operational disruptions.

Table B.2: Categorization of internal risks and incidents with descriptions impacting manufacturing operations.

Risk ID	Category 1	Category 2	Risk / Incident
R-20	Internal Risks	Infrastructure Risks	Physical damage to a building: Damage to manufacturing facilities from accidents or natural events, affecting production.
R-21	Internal Risks	Infrastructure Risks	Flooding (e.g. pipe break): Internal flooding from plumbing failures damaging equipment and halting production.
R-22	Internal Risks	Infrastructure Risks	Fire/explosion: Fires or explosions causing extensive damage to plant infrastructure and equipment.
R-23	Internal Risks	Technological Risks	Damage to, loss, or corruption of IT resources: IT resource failures affecting manufacturing control systems and data integrity.
R-24	Internal Risks	Technological Risks	Computer system failures: Failures in computer systems leading to downtime and production delays.
R-25	Internal Risks	Technological Risks	Loss of important documents: Loss of critical manufacturing documentation impacting operations and compliance.
R-26	Internal Risks	Technological Risks	Breakdown in internal communication: Communication failures disrupting coordination and workflow efficiency.
R-27	Internal Risks	Operational Risks	Malfunctions (systems and equipment): Malfunctions in manufacturing systems and equipment causing production stoppages.
R-28	Internal Risks	Operational Risks	Damage to or breakdown of machinery, systems, or equipment: Machinery breakdowns leading to unplanned maintenance and downtime.
R-29	Internal Risks	Operational Risks	Chemical product leakage (Plating or PVD): Leakage of chemicals used in plating or PVD processes causing safety hazards and operational disruptions.
R-30	Internal Risks	Human Resource Risks	Lack of human resources (due to strike, accident, pandemic, etc.): Insufficient workforce availability affecting production capacity.
R-31	Internal Risks	Human Resource Risks	Accidents at work: Workplace accidents causing injuries and impacting production schedules.
R-32	Internal Risks	Human Resource Risks	Shortage of available workforce: Difficulty in hiring or retaining workers leading to understaffing and operational inefficiencies.

Appendix C

Application of Risk Analysis in Assembly and Warehouse

This figure presents a detailed risk analysis for the Assembly and Warehouse departments, evaluating pre-determined risks based on four key criteria: Likelihood, Impact, Historical Record (last 5 years), and Priority Score. The Priority Scores are calculated using these criteria and are visually represented with a color-coded system: red for High Priority (4.61 - 6.15), yellow for Moderate Priority (2.31 - 4.61), and green for Low Priority (0 - 2.31).

Risks			Assembly				Warehouse			
Category 1	Category 2	Risk / Incident	Likelihood	Impact	Historical record (last 5yrs)	Priority Score	Likelihood	Impact	Historical record (last 5yrs)	Priority Score
External Risks	Natural Disasters	Floods	1	3	0	1.7	1	3	0	1.7
External Risks	Natural Disasters	Bushfire	1	3	1	1.9	1	3	1	1.9
External Risks	Natural Disasters	Hailstorms	1	3	0	1.7	1	3	0	1.7
External Risks	Supply Chain Risks	Shortage of external resources (raw materials, components, fuel, etc.)	2	9	0	4.75	0	0	0	0
External Risks	Supply Chain Risks	Interruption of the supply chain	2	9	1	4.95	0	0	0	0
External Risks	Utility Risks	Lack of electricity	1	9	0	4.4	1	9	0	4.4
External Risks	Utility Risks	Lack of water	1	9	0	4.4	0	0	0	0
External Risks	Utility Risks	Lack of compressed air	1	9	0	4.4	0	0	0	0
External Risks	Utility Risks	Lack of Natural Gas	1	6	0	3.05	0	0	0	0
External Risks	Health and Biological Risks	Pandemics	1	5	1	2.8	1	5	1	2.8
External Risks	Health and Biological Risks	Legionella detection	2	7	0	3.85	2	7	0	3.85
External Risks	Security Risks	Cyber attacks	1	6	0	3.05	1	7	0	3.5
Internal Risks	Infrastructure Risks	Physical damage to a building	1	5	0	2.6	1	5	0	2.6
Internal Risks	Infrastructure Risks	Flooding (e.g. pipe break)	1	4	0	2.15	1	2	0	1.25
Internal Risks	Infrastructure Risks	Fire/explosion	1	6	0	3.05	1	5	0	2.6
Internal Risks	Technological Risks	Damage to, loss, or corruption of IT resources	1	8	0	3.95	1	8	0	3.95
Internal Risks	Technological Risks	Computer system failures	1	7	0	3.5	1	1	0	0.8
Internal Risks	Technological Risks	Loss of important documents	1	2	0	1.25	1	1	0	0.8
Internal Risks	Technological Risks	Breakdown in internal communication	1	1	0	0.8	1	4	0	2.15
Internal Risks	Operational Risks	Malfunctions (systems and equipment)	1	1	0	0.8	1	1	0	0.8
Internal Risks	Operational Risks	Damage to or breakdown of machinery, systems, or equipment	1	3	1	1.9	1	5	1	2.8
Internal Risks	Operational Risks	chemical product leakage (Plating or PVD)	1	1	0	0.8	0	0	0	0
Internal Risks	Human Resource Risks	Lack of human resources (due to strike, accident, etc.)	1	8	0	3.95	1	8	0	3.95
Internal Risks	Human Resource Risks	Accidents at work	1	3	0	1.7	1	3	0	1.7
Internal Risks	Human Resource Risks	Shortage of available workforce	1	6	0	3.05	1	8	0	3.95

Figure C.1: Risk analysis for Assembly and Warehouse departments, assessing pre-determined risks by Likelihood, Impact, Historical Record, and Priority Score.

Appendix D

Visualizing Risk Priority Levels with Threshold Criteria

This figure presents a three-dimensional representation of risk priority levels, illustrating the Likelihood (X-axis), Impact (Y-axis), and Historical Record (Z-axis) of various risks. The Priority Scores are calculated using assigned weights for each criterion: Likelihood (0.35), Impact (0.45), and Historical Record (0.20). The risks are categorized into three priority levels: green for Low Priority (0 - 2.31), yellow for Moderate Priority (2.31 - 4.61), and red for High Priority (4.61 - 6.15).

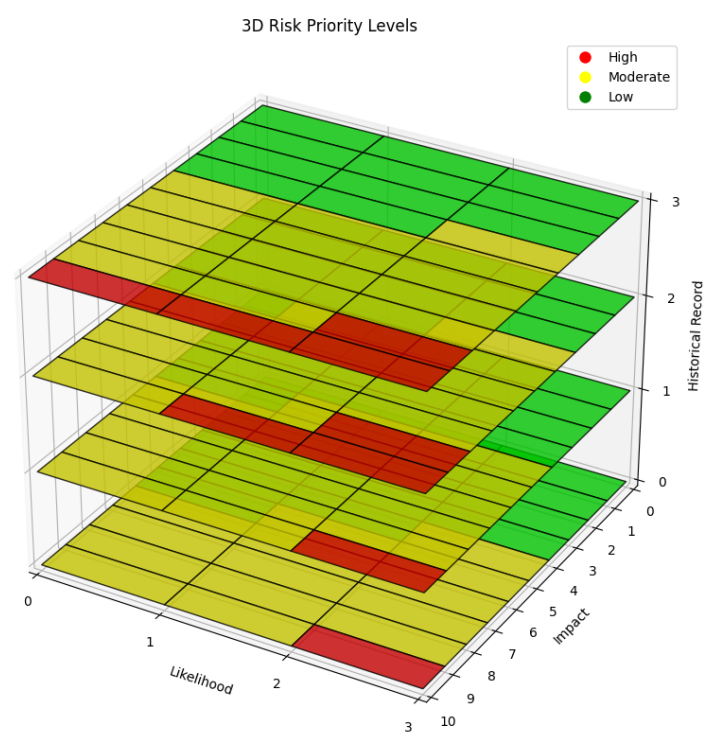


Figure D.1: Three dimensional representation of risk priority levels, illustrating Likelihood (X-axis), Impact (Y-axis), and Historical Record (Z-axis) of various risks.

Appendix E

ABC Analysis for SKUs

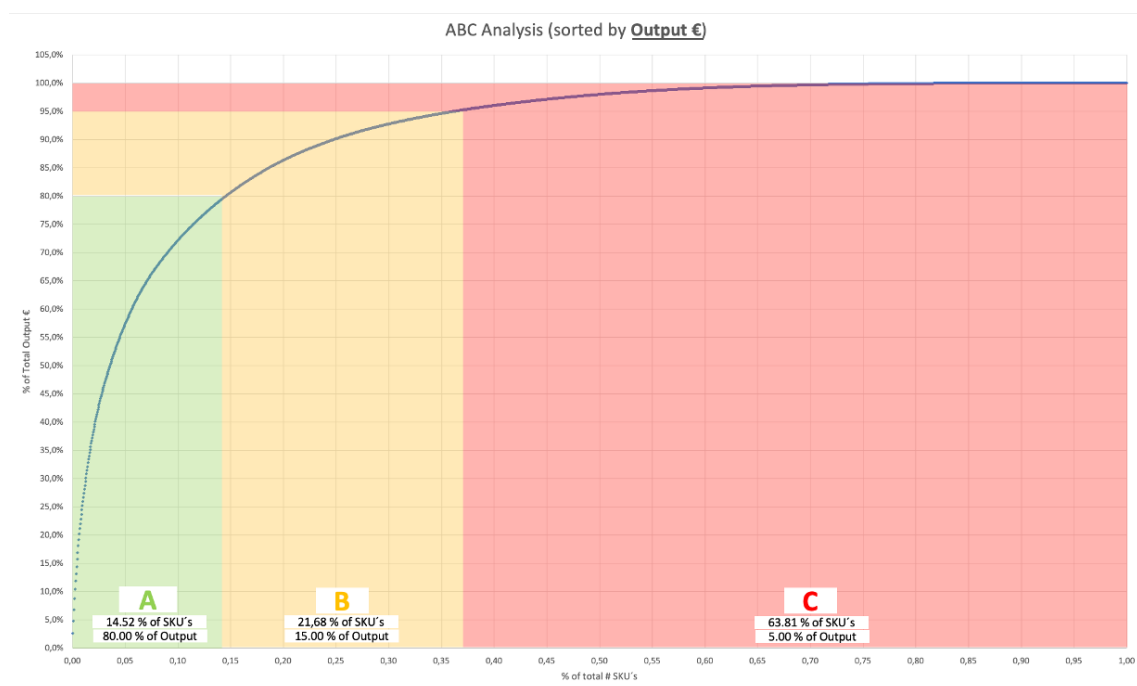


Figure E.1: ABC Analysis, sorted by Output € (X-axis: % of total SKUs, Y-axis: % of total output).

Top50 SKU Albergaria		Sorted and ABC analysed by Output €					
Top50 SKU Lahr							
Category	%Output	# SKU's	% SKU's	€	% of total €	# pcs	
A	80,00%	296	14,52%	x	x	x	
B	95,00%	442	21,68%	x	x	x	
C	>95%	1301	63,81%	x	x	x	
Total # pcs		x		Total €		x	
Total # SKU's		2 039					
SKU pos.	% of SKU	SKU	Output pcs (april23-february24)	Output € (april23-february24)	rel. Output € (april23-february24)	Cumulative [Output €]	Category
1	0,049043649%	32752000	x	x	2,59%	2,59%	A
2	0,098087298%	34558000	x	x	2,25%	4,84%	A
3	0,147130947%	34567000	x	x	1,98%	6,82%	A
4	0,196174595%	412203040	x	x	1,95%	8,77%	A
5	0,245218244%	4122032434	x	x	1,62%	10,39%	A
6	0,294261893%	33281003	x	x	1,47%	11,86%	A
7	0,343305542%	31367001	x	x	1,30%	13,16%	A
8	0,392349191%	34562000	x	x	1,28%	14,43%	A
9	0,441392840%	31374001	x	x	1,26%	15,70%	A
10	0,490436488%	33202003	x	x	1,24%	16,93%	A
11	0,539480137%	34815003	x	x	1,17%	18,10%	A
12	0,588523786%	34814003	x	x	1,10%	19,20%	A
13	0,637567435%	34817003	x	x	1,04%	20,23%	A
14	0,686611084%	21337001	x	x	0,90%	21,13%	A
15	0,735654733%	34790000	x	x	0,87%	22,00%	A
16	0,784698382%	34569000	x	x	0,86%	22,86%	A
20	0,980872977%	32221003	x	x	0,73%	25,93%	A
21	1,029916626%	31369001	x	x	0,73%	26,66%	A
22	1,078960275%	30307001	x	x	0,72%	27,38%	A
23	1,128003923%	30221002	x	x	0,71%	28,09%	A
24	1,177047572%	414721040	x	x	0,70%	28,79%	A
25	1,226091221%	408717140	x	x	0,70%	29,49%	A
26	1,275134870%	31725000	x	x	0,67%	30,16%	A
35	1,716527710%	32441002	x	x	0,56%	35,68%	A
36	1,765571359%	34765000	x	x	0,53%	36,20%	A
37	1,814615007%	34798000	x	x	0,51%	36,71%	A
38	1,863658656%	30361000	x	x	0,51%	37,21%	A
39	1,912702305%	32168000	x	x	0,50%	37,71%	A
40	1,961745954%	34594000	x	x	0,50%	38,21%	A
41	2,010789603%	34840000	x	x	0,48%	38,69%	A
42	2,059833252%	34789000	x	x	0,48%	39,17%	A
43	2,108876900%	34788000	x	x	0,45%	39,62%	A
44	2,157920549%	31854000	x	x	0,45%	40,07%	A
55	2,697400687%	414720040	x	x	0,36%	44,48%	A
56	2,746444335%	32665003	x	x	0,35%	44,83%	A
62	3,040706229%	34598000	x	x	0,32%	46,83%	A
63	3,089749877%	24172KF1	x	x	0,32%	47,15%	A
297	14,565963708%	23301000	x	x	0,07%	80,03%	B
298	14,615007357%	30371A00	x	x	0,07%	80,10%	B
299	14,664051005%	32628A11	x	x	0,07%	80,16%	B
300	14,713094654%	31518000	x	x	0,07%	80,23%	B

Figure E.2: Calculation table for ABC Analysis, sorted by Output €.

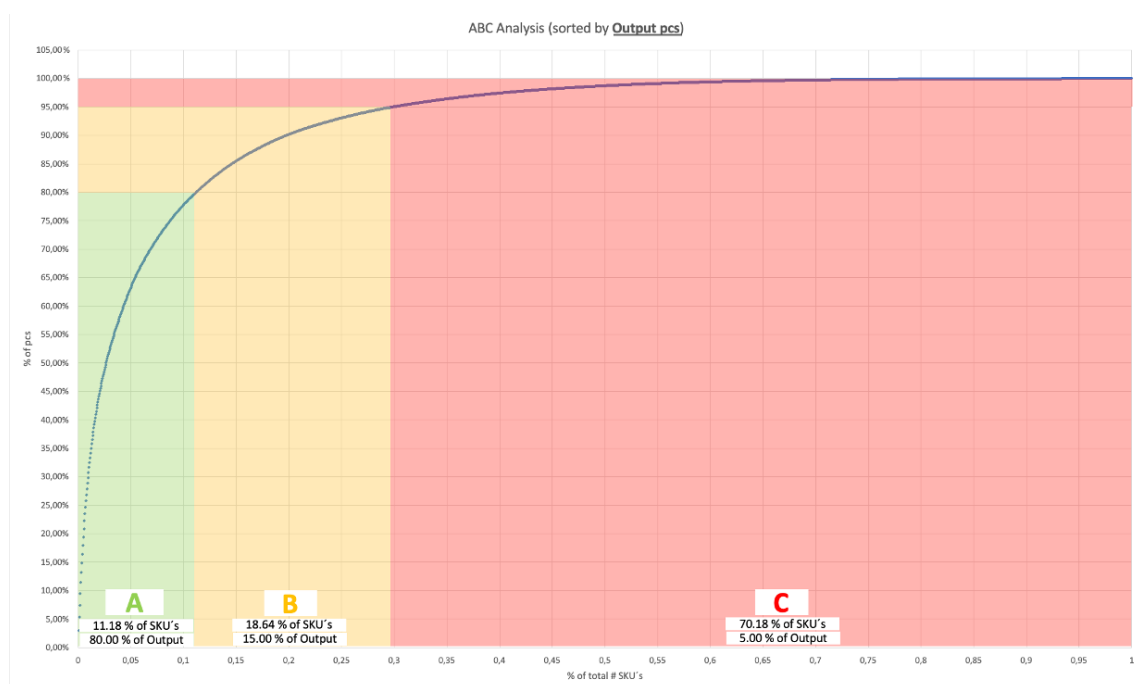


Figure E.3: ABC Analysis, sorted by Output pieces (X-axis: % of total SKUs, Y-axis: % of total output).

Top50 SKU Albergaria

Top50 SKU Lahr

Sorted and ABC analysed by Output pcs

Category	%Output	# SKU's	% SKU's	# pcs	€	% of total €
A	80,00%	228	11,18%	x	x	x
B	95,00%	380	18,64%	x	x	x
C	>95%	1431	70,18%	x	x	x

Total # pcs

Total # SKU's

Total €

x

SKU pos.

% of SKU

SKU

Output € (april23-february24)

Output pcs (april23-february24)

rel. Output pcs (april23-february24)

Cumulative [Output pcs]

Category

1	0,000490436	32752000	x	x	2,95%	2,95%	A
2	0,000980873	29800000	x	x	2,36%	5,31%	A
3	0,001471309	33281003	x	x	2,15%	7,46%	A
4	0,001961746	34558000	x	x	2,06%	9,52%	A
5	0,002452182	29805000	x	x	1,88%	11,41%	A
6	0,002942619	31367001	x	x	1,77%	13,18%	A
7	0,003433055	412203040	x	x	1,71%	14,89%	A
8	0,003923492	33202003	x	x	1,56%	16,45%	A
9	0,004413928	31374001	x	x	1,55%	18,00%	A
10	0,004904365	21337001	x	x	1,45%	19,45%	A
14	0,006866111	34562000	x	x	1,16%	24,64%	A
15	0,007356547	31368001	x	x	1,12%	25,75%	A
16	0,007846984	47439000	x	x	1,05%	26,81%	A
17	0,008337420	32221003	x	x	1,05%	27,86%	A
18	0,008827857	30221002	x	x	0,99%	28,85%	A
19	0,009318293	4122032434	x	x	0,97%	29,82%	A
20	0,009808730	34815003	x	x	0,92%	30,74%	A
21	0,010299166	31369001	x	x	0,89%	31,63%	A
22	0,010789603	34817003	x	x	0,87%	32,50%	A
23	0,011280039	34814003	x	x	0,84%	33,34%	A
24	0,011770476	32843002	x	x	0,83%	34,17%	A
27	0,013241785	32441002	x	x	0,73%	36,53%	A
28	0,013732222	30307001	x	x	0,72%	37,25%	A
29	0,014222658	34790000	x	x	0,67%	37,92%	A
30	0,014713095	34587000	x	x	0,64%	38,56%	A
33	0,016184404	34798000	x	x	0,59%	40,37%	A
34	0,016674841	408717140	x	x	0,58%	40,95%	A
35	0,017165277	34569000	x	x	0,58%	41,53%	A
38	0,018636587	414721040	x	x	0,52%	43,18%	A
39	0,019127023	31555001	x	x	0,52%	43,70%	A
45	0,022069642	34594000	x	x	0,43%	46,40%	A
46	0,022560078	34561000	x	x	0,41%	46,82%	A
79	0,038744483	34788000	x	x	0,27%	57,70%	A
80	0,039234919	3282000A	x	x	0,27%	57,97%	A
86	0,042177538	414720040	x	x	0,26%	59,53%	A
87	0,042667974	23462001	x	x	0,25%	59,78%	A
108	0,052967141	34598000	x	x	0,21%	64,59%	A
109	0,053457577	13937000	x	x	0,21%	64,80%	A
229	0,112309956	30469000	x	x	0,09%	80,07%	B
230	0,112800392	48220000	x	x	0,09%	80,15%	B
231	0,113290829	3148110C	x	x	0,09%	80,24%	B

Figure E.4: Calculation table for ABC Analysis, sorted by Output pieces.

Appendix F

SKU-Sub-department Matrix

Product information				Full Process																
Plant	SKU	Body (Pre-Process)	Body (Assembly)	Pre-Process Sub-Departments										Assembly Sub-Departments						
				Central Melting	Core Shooting	Casting	Cutting	Shot Blasting	Machining	Grinding	Polishing	Plating	PVD	Pre- Assembly	Laser Printing	Cartridge	Kitchen	Basin & Bidet	Thermostat	
AL	34558000	405941038	405941040																	
AL	33281003	/	414952538																	
AL	34562000	405941038	406141040																	
AL	31374001	/	409557840																	
AL	33202003	/	405908038																	
AL	34814003	406013138	406013140																	
AL	34790000	406013138	406013140																	
AL	32221003	/	414952538																	
AL	31369001	/	409557840																	
AL	30307001	/	415445838																	
AL	32441002	/	414952538																	
AL	34798000	/	410948840																	
AL	34594000	405941038	405941040																	
AL	34788000	406012138	406012140																	
AL	34598000	405940038	405940040																	
Lahr	26538000	408747038	408747040																	
Lahr	26677000	408747038	408747040																	
Lahr	26677001	408747038	408747040																	
Lahr	26075001	414708038	414708040																	
Lahr	26403002	414708038	414708040																	
Lahr	27296003	414708038	414708040																	
Lahr	27615002	414708038	414708040																	
Lahr	266772430	408747037	4087472433																	

Figure F.1: SKU-Sub-Department Matrix: Shaded cells indicate SKU presence in sub-departments.

Appendix G

SKU-Machine Matrix Analysis

This appendix presents the quantitative results of the SKU-Machine Matrix, which illustrates the distribution of preferential and alternative machinery across various sub-departments involved in the production process for different SKUs. Each of the following figures highlights the machinery allocation in key areas.

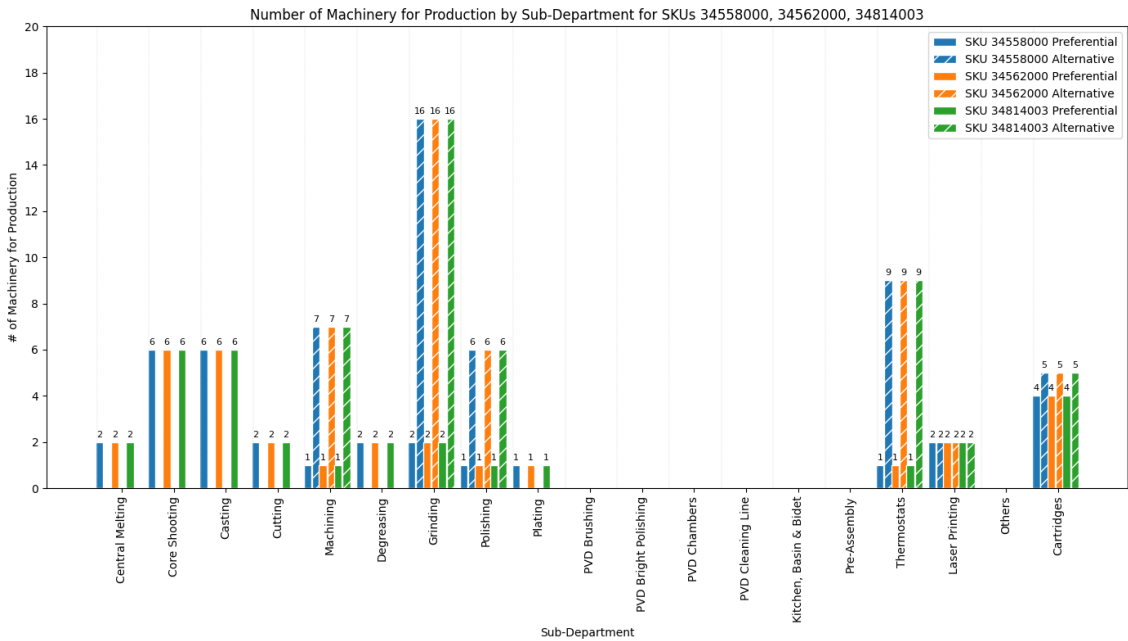


Figure G.1: SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 34558000, 34562000, and 34814003.

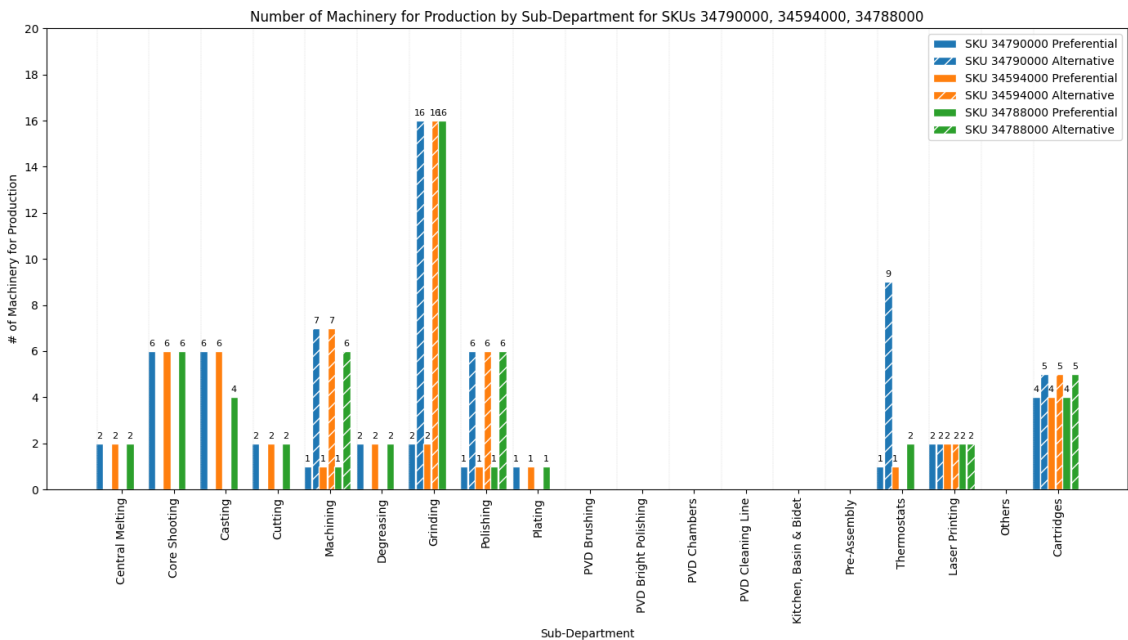


Figure G.2: SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 34790000, 34594000, and 35788000.

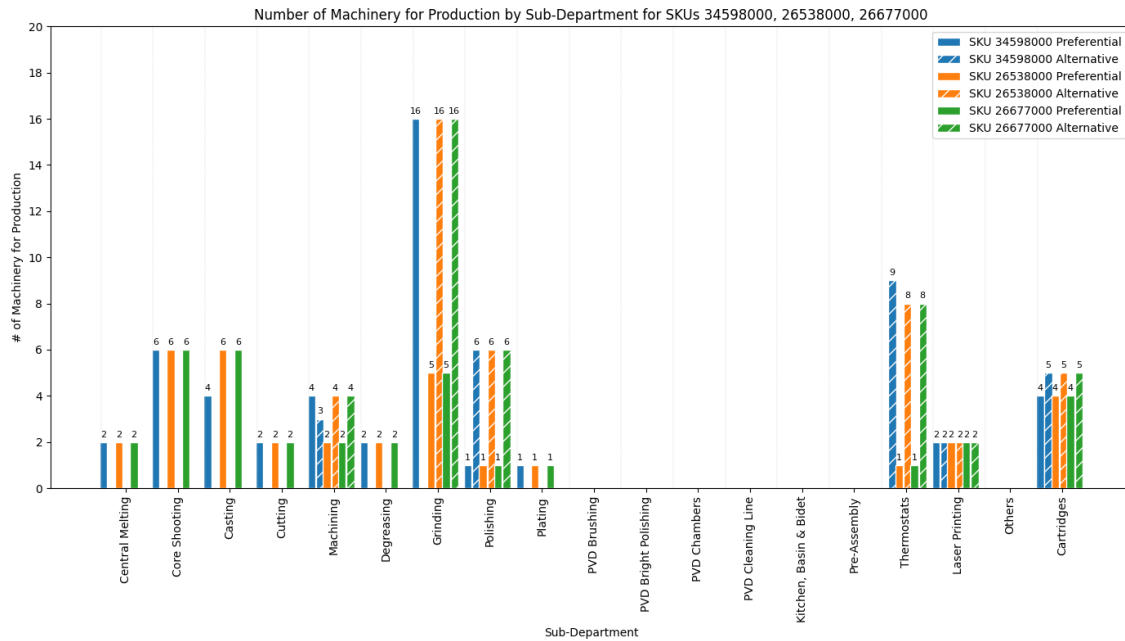


Figure G.3: SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 34598000, 26538000, and 26677000.

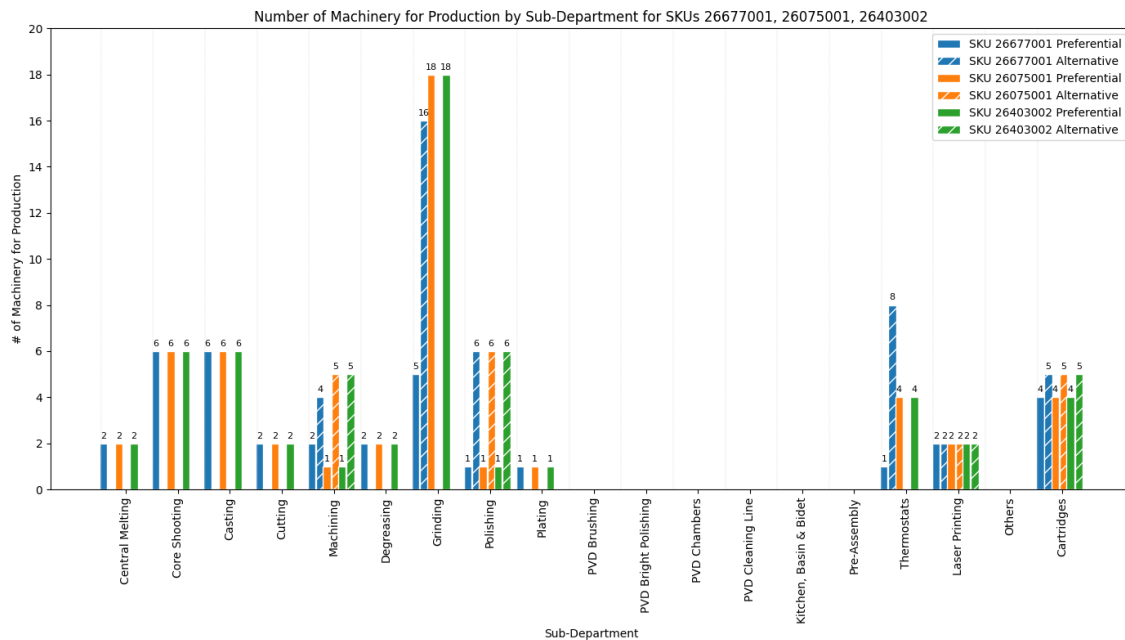


Figure G.4: SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 26677001, 26075001, and 26403002.

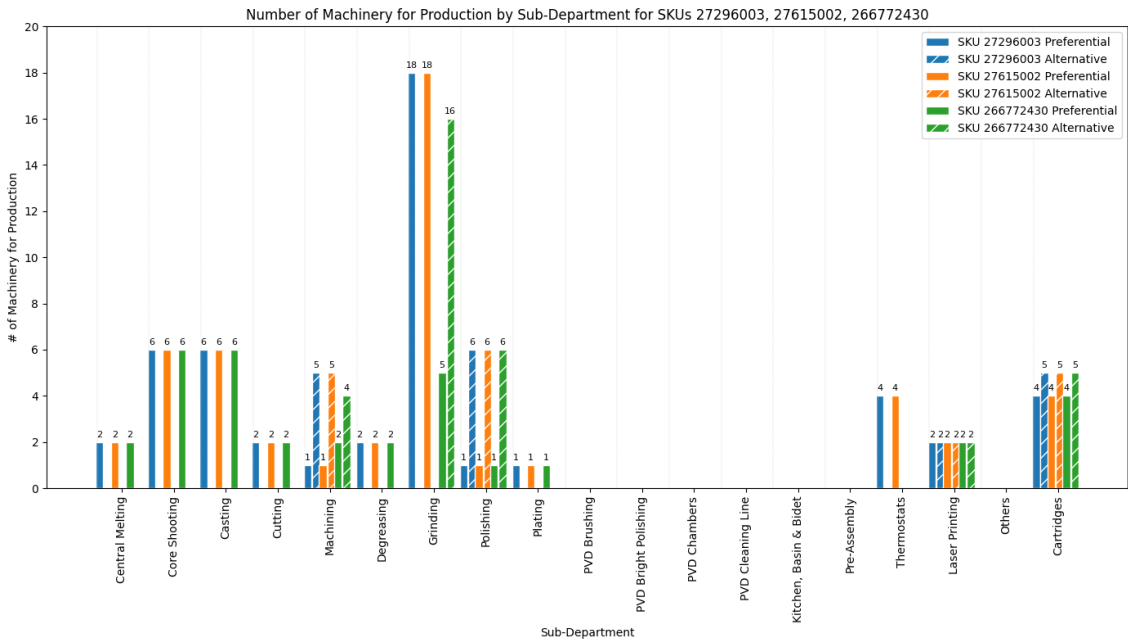


Figure G.5: SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 27296003, 27615002, and 266772430.

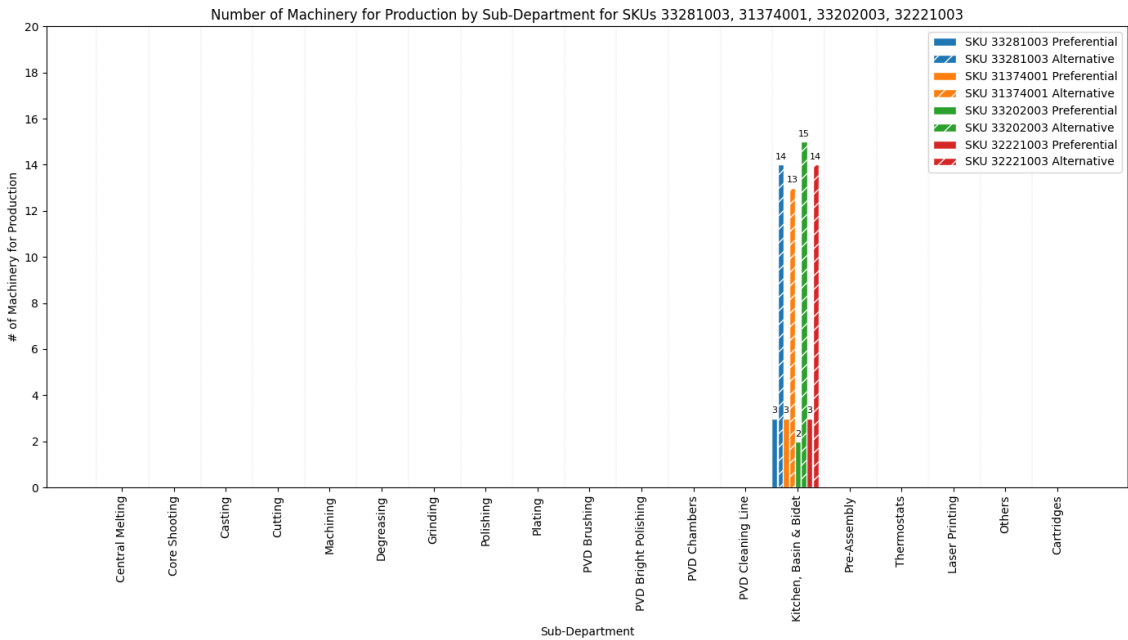


Figure G.6: SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 33281003, 31374001, 33202003, and 32221003.

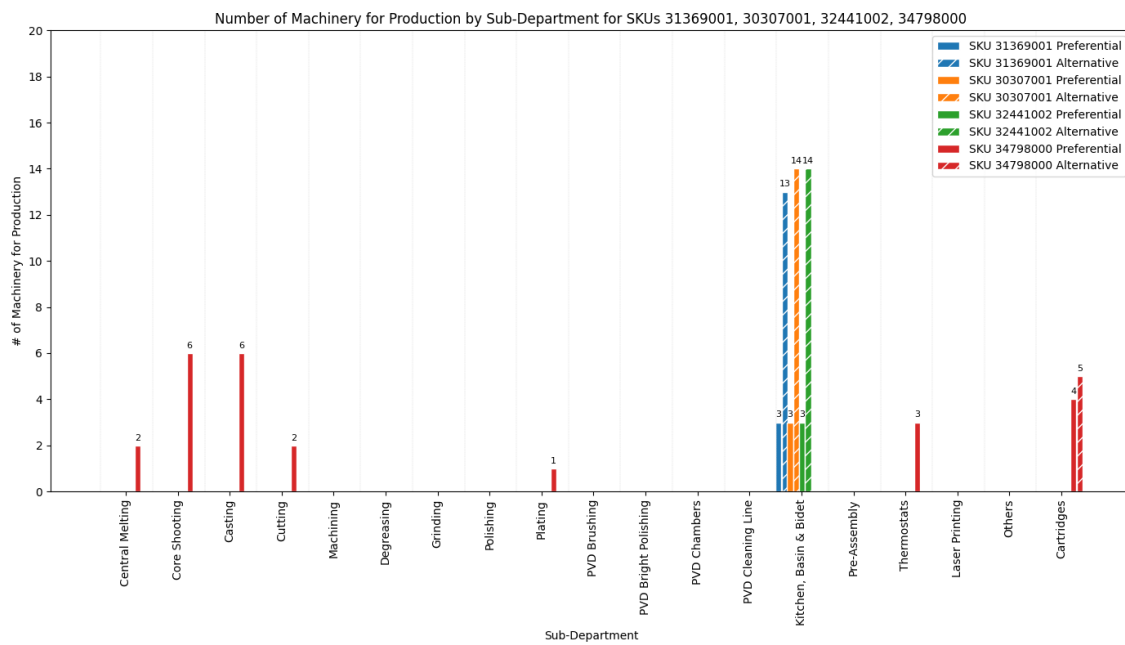


Figure G.7: SKU-Machine Matrix: Number of Machinery for Production by Sub-Department for SKUs 31369001, 30307001, 32441002, and 34798000.

Appendix H

Visualizing Risk Priority Levels with Threshold Criteria

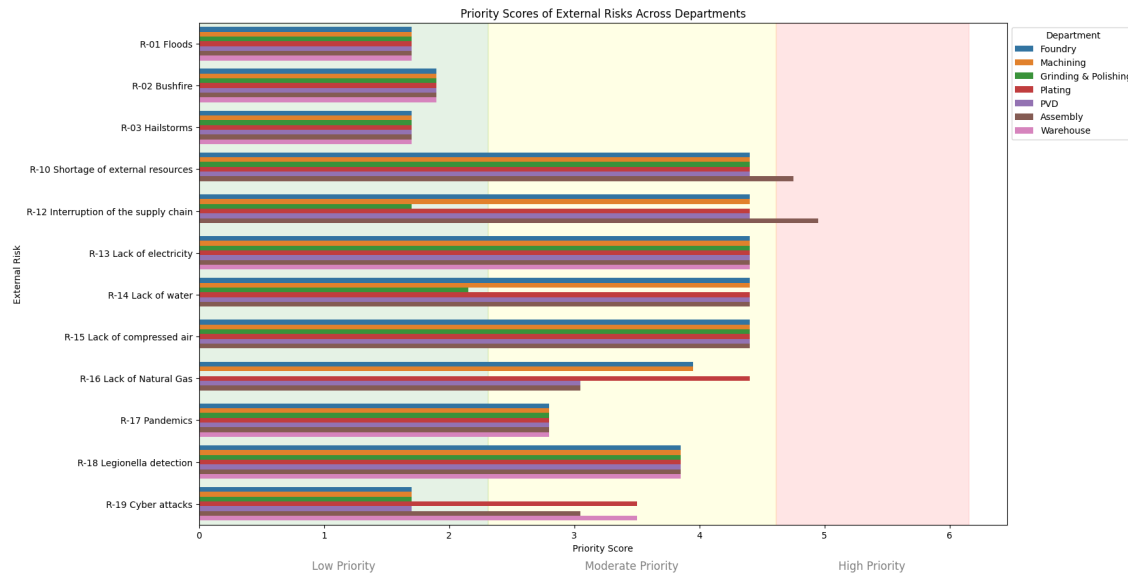


Figure H.1: Priority scores for various external risks across different departments.

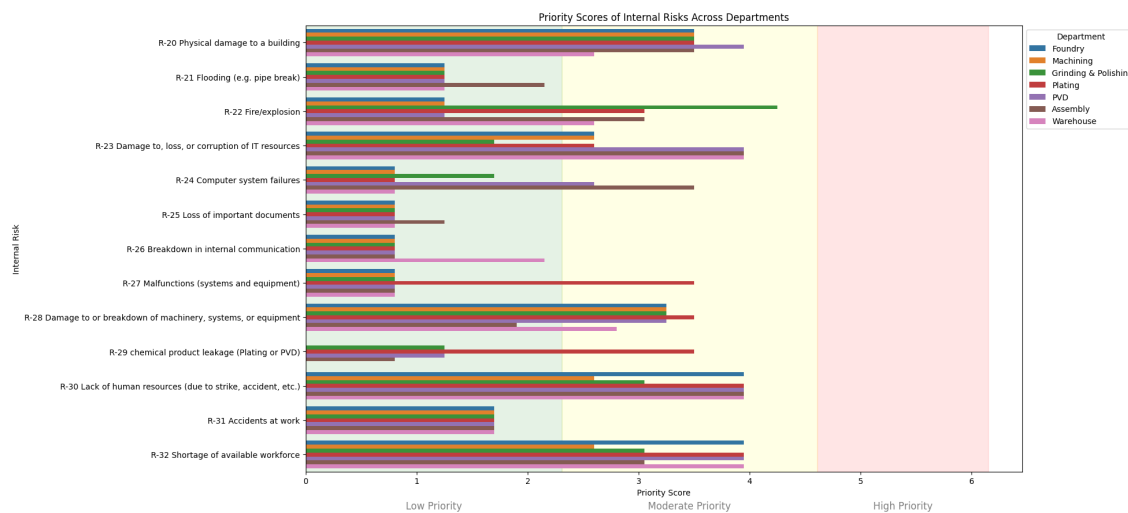


Figure H.2: Priority scores for various internal risks across different departments.

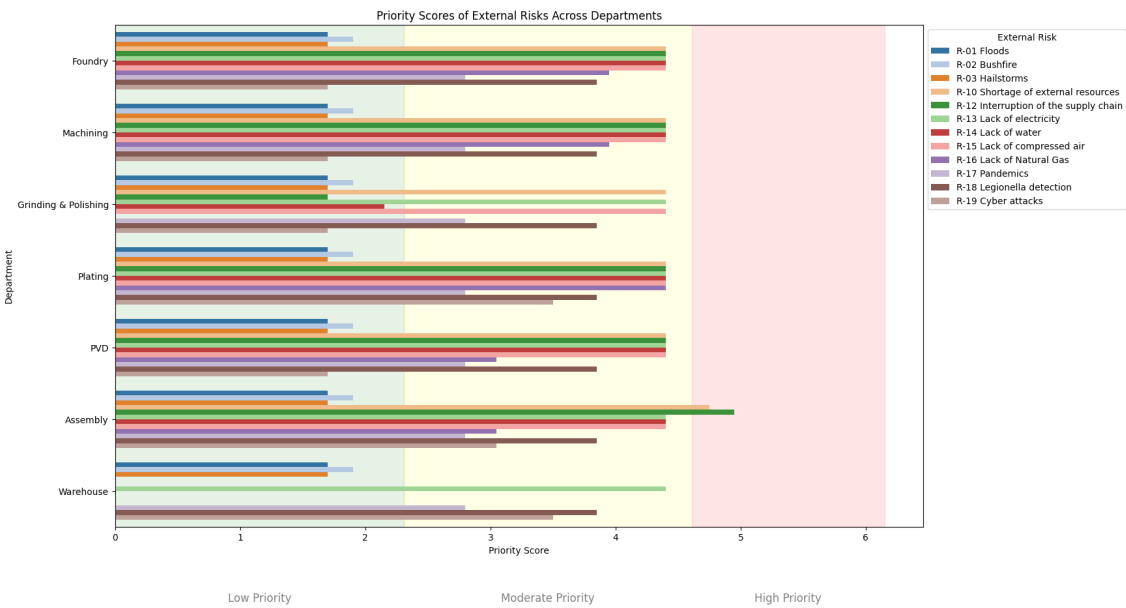


Figure H.3: Priority scores for various departments across different external risks.

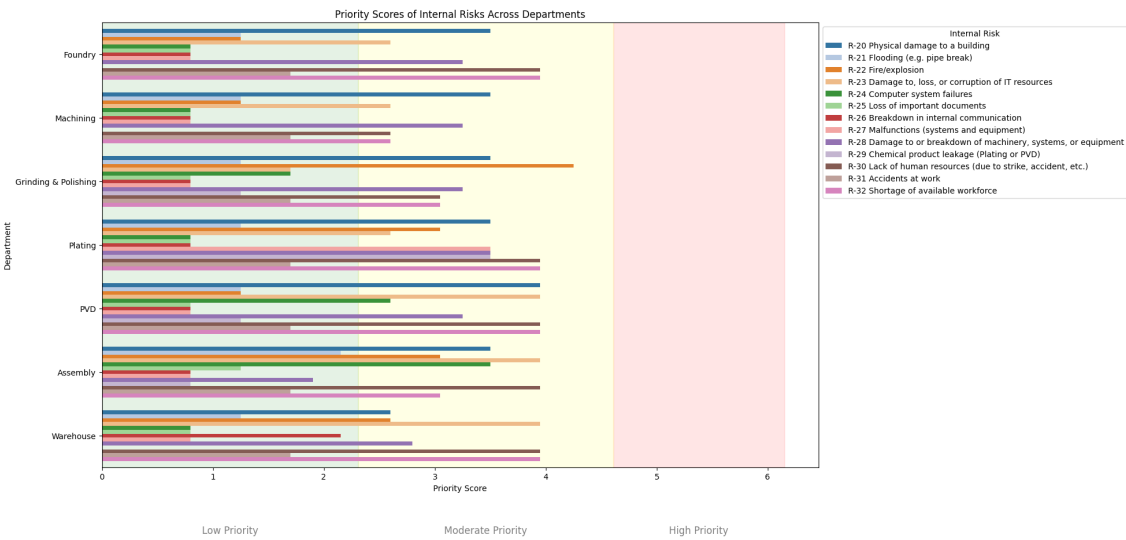


Figure H.4: Priority scores for various departments across different internal risks.