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ASSESSMENT AND ENHANCEMENT OF ORGANIZATIONAL RESILIENCE IN COMPLEX INDUSTRIAL ENTERPRISES IN UNCERTAIN ENVIRONMENT

Doctoral Dissertation

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PROCENA I UNAPREĐENJE REZILIJENTNOSTI ORGANIZACIJE U SLOŽENIM INDUSTRIJSKIM PREDUZEĆIMA U NEIZVESNOM OKRUŽENJU

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"Change brings opportunities.
On the other hand, change can be confusing."

Michael E. Porter (1947): American academic known for his theories on economics.

PROLOGUE

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ABSTRACT

Under uncertain economic conditions, an organization's ability to bounce back after severe disruptions, or simply resilience, can be considered one of the most important characteristics for maintaining successful business operations. The aim of this research is to propose an algorithm for the assessment of organizational resilience in industrial companies and to conduct an analysis of the relationship between the organizational resilience factors and the recovery times of key performance indicators.

Since the variables that are part of the research are subject to a high degree of uncertainty, they are modeled using fuzzy set theory. The methodology used for the research is an extended fuzzy Delphi, where the fuzzy geometric mean is used as an aggregation operator. The relationship between the organizational resilience factors and the recovery time of the key performance indicators is based on a correlation analysis.

The proposed model is based on real data from a complex industrial company. The main finding of the study is that the calculations indicate a significant negative correlation between the variables discussed and a completely practical framework for organizational resilience (Huber et al. 2023).

Keywords: Key Performance Indicators; Resilience Factors; Recovery Time; Fuzzy Delphi Technique; Resilience Management Model Framework

REZIME

U neizvesnim ekonomskim uslovima, sposobnost organizacije da se oporavi nakon ozbiljnih poremećaja, ili jednostavno rezilijentnost, može se smatrati jednom od najvažnijih karakteristika za održavanje uspešnog poslovanja. Cilj ovog istraživanja je da se predloži algoritam za procenu rezilijentnosti organizacije u industrijskim preduzećima i da se izvrši analiza odnosa između faktora rezilijentnosti organizacije i vremena oporavka ključnih indikatora performansi.

Pošto su promenljive koje su deo istraživanja podložne visokom stepenu neizvesnosti, modeliraju se korišćenjem teorije fazi skupova. Metodologija korišćena za istraživanje je prošireni fazi Delfi, gde se kao operator agregacije koristi fazi geometrijska sredina. Odnos između faktora rezilijentnosti organizacije i vremena oporavka ključnih indikatora učinka zasniva se na korelacionoj analizi.

Predloženi model je zasnovan na stvarnim podacima složenog industrijskog preduzeća. Glavni nalaz studije je da proračuni ukazuju na postojanje značajne negativne korelacije između promenljivih o kojima se raspravlja i potpuno nov praktični okvir za procenu organizacione rezilijentnosti (Huber et al. 2023).

Ključne reči: Ključni indikatori performansi; Faktori rezilijentnosti; Vreme oporavka; Fazi Defhi Tehnika; Okvir modela za upravljanje rezilijentnošću

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LIST OF ABBREVIATIONS

APQC	American Productivity & Quality Center
AQMM	Aachen Quality Management Model
ASIS	American Society for Information Science
AT	Working Days
AWI	Approved Work Item
BCMS	Business continuity management systems
BI	Business Intelligence
BIA	Business Impact Analysis
BS	British Standards
BSI	British Standards Institution
CEO	Chief Executive Officer
COSO	Committee of Sponsoring Organizations
CSR	Corporate Social Responsibility
DAX	German Share Index
DIN	German Institute for Standardization
DIS	Draft International Standard
DM	Decision Makers
DS	Dansk Standard
DTS	Draft Technical Specification
EFQM	European Foundation for Quality Management
ERM	Enterprise Risk Management
ESG	Environment, Social, Governance
eTOM	enhanced Telecommunications Operations Map

FI	Functionality Indicators
FL	Functionality Level
GRI	Global Reporting Initiative
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
ITIL	Information Technology Infrastructure Library
KPI	Key Performance Indicator
MADM	Multi-Attribute-Decision-Making
n. d.	no date
NGO	Non-Governmental Organization
NIST	National Institute of Standards and Technology
OECD	Organization for Economic Co-operation and Development
PCF	Process Classification Framework
RADAR	Results - Approach - Deployment - Assessment - Refinement
RF	Resilience Factors
RL	Resilience Level
RMMF	Resilience Management Model Framework
SCOR	Supply Chain Operations Reference
SDG	Sustainable Development Goals
SGMM	St. Gallen Management Model
SP	Sub-process
SPB	Special Publication
SPC	Security, Preparedness and Continuity
SPEC	Specification
SPICE	Software Process Improvement and Capability Determination
TC	Technical Committee
TFN	Triangular Fuzzy Number
TQM	Total Quality Management
TR	Technical Report

TrFN	Trapezoidal Fuzzy Number
TS	Technical Specification
UN	United Nations
UNDRR	UN Office for Disaster Risk Reduction
VCA	Value Chain Analysis
VRM	Value Reference Model
VUCA	Volatility, Uncertainty, Complexity and Ambiguity
WD	Working Draft
XT	Extreme Threat

"It is not the strongest of the species that survives, not the most intelligent that survives.

It is the one that is the most adaptable to change. Change brings opportunities."

Charles R. Darwin (1809 to 1882): British natural scientist.

1 INTRODUCTION

The history of our economy and society is characterized by technological breakthroughs. This pioneering spirit was fueled by great visions and enthusiasm, but also by the hurdles that had to be overcome. Thanks to their well-developed and modern roads, the Romans were able to cover long distances across Europe in a short space of time. The introduction of printing made books open to the general public for the first time, laying the foundations for more widespread literacy. The steam engine had a substantial impact in replacing laborious human activities and ultimately led to a success story of global proportions through its worldwide spread (Grove 2024).

With the onset of industrialization, however, new challenges arose, particularly due to the monotony of industrial series production and the resulting one-sided strain on workers. During the 20th century, many jobs were upgraded thanks to the development of the personal computer. Industrial robots were increasingly used on the store floor and were able to take over more and more tiring routine tasks (Grove 2024; Klein & Migliazzi 2021; Röhe 2022; Schnitzhofer 2021).

While all these developments were observed with a mixture of skepticism and great astonishment by a broad public, we have probably experienced the most drastic technological changes in the history of mankind since the advent of the Internet. These changes are based on the almost limitless possibilities of global data exchange and real-time communication, supported by constantly increasing server performance and the growing variety of self-learning algorithms in artificial intelligence (Grove 2024; Klein & Migliazzi 2021; Röhe 2022; Schnitzhofer 2021).

In a constantly changing environment, organizations today are constantly moving between two opposing poles: On the one hand, it is necessary to strengthen their security measures, identify risk factors at an early stage and proactively counteract potential threats. On the other hand, they must have sufficient flexibility to be able to maintain their core business for a certain period of time, even during unforeseen events (Duchek 2019). The increasing complexity of the VUCA world requires a targeted approach to change measures in organizations in order to optimize both security and flexibility (Drath & Heller 2018). This acronym, which was first used in 1987 and is based on the leadership theories of Warren Bennis and Burt Nanus (Sawan 2020), describes the characteristics of contemporary asymmetric warfare, which is characterized by the following conditions (Gläser 2020):

- ***Volatility:*** *Describes the intensity of fluctuation over a period of time;*
- ***Uncertainty:*** *Describes the unpredictable nature of events;*
- ***Complexity:*** *Is influenced by the number of influencing factors and their mutual dependence or interaction;*

- ***Ambiguity:*** *Describes the inherent ambiguity of a situation or information.*

Originally used in military terminology, this term can be easily transferred to the modern world: Economic and financial crises, a multipolar world order, pandemics, and complex and widely ramified supply chains, coupled with the immense pressure to innovate brought about by digitalization, have the potential to fundamentally change our lives (Röhe 2022). Above all, however, the focus is on developing a culture that makes the organization more resilient (Drath & Heller 2018).

The pertinent questions are therefore: Will industrial companies be resilient to internal and external changes and possible crises in the future? What framework conditions are necessary to ensure the required resilience? And is organizational resilience in highly complex industrial companies able to withstand the challenges of a VUCA world (Röhe 2022)?

In this chapter, we first look at the meaning of resilience as it is currently known in the literature. We then expand the term to include the specific aspects that will be dealt with in the course of this work. We then turn our attention to the various facets and the overarching objective of this work. Finally, the research design outlines the detailed foundation that will enable industrial companies to successfully manage future crises (Kolb 2006; Röhe 2022).

1.1 Resilience: The Ability to Manage Crises

The word *"resilience"* originally comes from Latin. It is derived from the verb *"resilire"*, meaning *"to bounce back"* or *"to spring back"* (Jaggi 2023; Röhe 2022; Übermeister 2023). The opposite of resilience is vulnerability, often referred to as *"fragility"* (Haas 2022). At the core of the concept is the idea that certain entities are capable of returning to their original state after a disruption (Bhamra et al. 2011; Karidi et al. 2018; Stone & Rahimifard 2018; Urban 2018).

Although the topic of resilience is becoming increasingly topical in many disciplines, no generally recognized definition of the term has yet been established. The definition often needs to be adapted, especially when used in different fields of study (Sanchis et al. 2020). The different contexts have led to different conceptualizations. The question therefore arises as to whether these approaches compete with one another or rather complement each other (Kulkarni 2020; Linnenluecke 2017). If you take the concept of resilience back to its core, the term describes the *"[...] capacity of a system [...] to deal with change and continue to develop. It is about the capacity to use shocks and disturbances like a financial crisis or climate change to spur renewal and innovative thinking (Lade 2015)."* While on the one hand it is about withstanding negative influences such as crises, shocks or disruptions, resilience also implies deriving added value from these challenges in the medium and long term (Baumgartl 2022).

According to the International Standards Organization (ISO), resilience is defined as *"[...] the ability of an organization to anticipate, prepare for, respond to and adapt to change, even in a complex and dynamic environment, in order to ensure its survival and growth (ISO 2017)".* Resilience in the ISO sense is therefore understood to mean acting appropriately in a changing environment, taking into account both gradual and abrupt changes. The focus is not only on coping with threats, but also on recognizing opportunities (Bernard et al. 2022).

The British Standards Institution (BSI) defines resilience in a similar way as *"[...] the ability of an organization to anticipate, prepare for, respond and adapt to incremental change and sudden disruptions in order to survive and prosper (Kerr n. d.-A)."* In addition to *"sudden disruptions"*, this definition also includes incremental changes and the strategies for coping with them. According to BSI, an organization should act in a long-term and sustainable manner. According to BSI, organizations that continuously improve and develop are particularly successful if they focus on future opportunities instead of primarily focusing on threats. This opportunity-oriented approach is the key element in arming oneself against adverse circumstances or shocks (Bernard et al. 2022; Kerr n. d.-A).

According to Weiss et al. (2018), the understanding of resilience has been adapted, further developed, and applied at various times in different contexts:

- ***In materials science:*** *Here it refers to materials that return to their original state after deformation, similar to a spring (Timoshenko & Goodier 1970);*
- ***In ecology:*** *It concerns ecosystems that can maintain their basic structure through self-regeneration after environmental changes (Folke et al. 2004);*
- ***In the social sciences:*** *This is about societies that maintain their basic identity after external disruptions such as wars (Norris et al. 2008);*
- ***In the engineering sciences:*** *The term refers to technical systems that maintain or restore their functionality in the event of malfunctions (Cimellaro et al. 2010);*
- ***In clinical psychology,*** *it refers to people who do not develop mental illness despite traumatic experiences (Richardson 2002);*
- ***In economics:*** *It is about companies that maintain their existence despite the shocks they have experienced and return to a growth path (Sheffi & Rice 2005).*

Although the term resilience is applied differently in different contexts, it has a common core: It is always about entities returning to a state that preserves or reshapes their identity and establishes a balance after a disruption (Thun-Hohenstein et al. 2020; Weiss et al. 2018). However, two major points of criticism remain: Firstly, no clear instructions for action that stand out from the usual management tasks in organizations can be derived. Secondly, there is insufficient differentiation from the topic of risk management. In general, *"risk"* is understood as the possibility *"[...] that something turns out differently than expected (Paetzmann 2008)"*. If this deviation is positive, it is referred to as an *"opportunity"* or *"risk in the broader sense"* (Lück 2000). However, if the risk has exclusively negative effects, it is also defined as *"[...] the possibility of unfavorable future developments"* (Bernard et al. 2022; Duchek 2019; Eggerman & Konradt 2000).

In practice, risk management focuses primarily on identifying and limiting negative risks. These are anticipated, evaluated, and addressed depending on their potential damage. The focus here is on transparent decision-making and the resulting comprehensible actions. In this study, resilience management as defined by Duchek (2019) and Röhe (2022), among others, is seen as an addition to risk management. It focuses in particular on events which cannot be anticipated or contained. In this context, resilience describes a company's ability to arm itself against unexpected events. Events like this can be so serious that they threaten the existence of an organization. Besides the concepts outlined above, professional resilience management also implies that sustainable skills can be developed from resistance to threats. These can not only

increase the company's competitiveness, but also open up positive opportunities (Bernard et al. 2022; Pedell 2014; Pedell & Seidenschwarz 2011).

But how do you prepare for negative events that are unpredictable and whose consequences can threaten a company's existence? Even if the definition is clear, it remains uncertain how industrial companies can actually achieve this resilience. According to Wink (2016), two elements must be taken into account when analytically determining resilience: Firstly, there must be a disruptive influence, an adverse circumstance or a shock. Secondly, the successful handling of such an event is crucial (Bernard et al. 2022).

1.2 Objective

Management systems in agile organizations are currently undergoing significant change processes. This transformation is driven primarily by complex, semi-autonomous and decentralized organizational structures and a diverse product portfolio with numerous variants (Kulkarni 2020). These structures are caught between customer-specific wishes and increasing regulatory requirements. The interactions between the various management systems and overall company performance are often unclear. There is a shortage of development beyond traditional quality and process management (Duchek 2019). Instead of investing in innovative, integrated solutions, resources are primarily allocated to mere maintenance. Another obstacle is the lack of awareness of this issue at top management level, which results in a loss of transparency and clear decision-making criteria. ISO and other standards are often seen as mere, annoying customer requirements, whereby the potential is overlooked (Drath & Heller 2018).

In an agile market environment, conversion rates, leads and key performance indicators (KPIs) are crucial. However, companies often lack models and success factors that are aligned with these KPIs. Many of the current ISO-based management systems are not adequate for agile and fast-changing organizational units in global markets, especially in the area of operational excellence. Therefore, it is crucial to critically assess and strengthen organizational resilience in complex industrial companies (Drath & Heller 2018).

Example
"Management aims to maximize market share, sales and profits, a goal also pursued by competitors. Shareholders focus primarily on the share price and the annual dividend payout. Employees, on the other hand, are looking for self-fulfillment and job security. Suppliers want a long-term partnership with companies and strive for an attractive contribution margin. Customers hope for more favorable prices and superior product functionality. Municipalities or cities attach importance to high business tax revenues and the creation or preservation of jobs, whereas legal authorities insist on strict compliance with all legal requirements (Drath & Heller 2018)."

Table 1-1: Interested Parties in the Corporate Context (Drath & Heller 2018)

Companies are complex by nature. The diverse interactions and diverging interests of the interested parties mean that cause-and-effect relationships are often ambiguous. This can result in systems developing in unexpected and unpredictable directions (Drath & Heller 2018). Many industrial companies also pursue a decentralized organization in which business units operate semi-autonomously. Despite their independence, these units must interact efficiently. Due to their product diversity, business units often operate with decoupled management

systems and KPIs. Nevertheless, it is essential to maintain an efficient management system, especially in view of increasing audit activities by customers and in the regulatory environment. Although such systems form the basis for business relationships, they are often seen as a burden (must do it) rather than an opportunity, which is also due to the uncertain links between management systems and business performance (Drath & Heller 2018).

The objective of the dissertation is to propose a methodology for assessing and improving organizational resilience in complex industrial systems. The focus is on the development of a model respectively framework for assessing organizational resilience at the business process level. This approach takes into account the constant dynamic interactions between the KPIs of the process and the resilience factors (RF). Techniques such as MADM and the Fuzzy Delphi Technique are used to analyze and evaluate these relationships.

1.3 Structure of Work

This thesis describes how the organizational resilience can be assessed and improved in complex industrial companies in uncertain environments (Duchek 2019). The first chapter is dedicated to a detailed discussion of the term *"resilience"* and the paradigm of the underlying research design.

Chapter two is entirely dedicated to contextualizing the problem. It presents a case study from the practice of a manufacturer of precision instruments and discusses the consequences that a lack of resilience can have. In addition, the resulting research gaps, and hypotheses to be investigated are presented in detail. Finally, the chapter summarizes the key issues.

The first substantive chapter (refer to Chapter 3) is dedicated to the evaluation of relevant literature used for the thesis. The focus is on the following aspects in particular: (1) Presentation of business activities, including business models, business process frameworks and KPIs; (2) Discussion of organizational resilience through models and evaluation criteria; (3) Presentation of the decision-making process, in particular through modelling using fuzzy sets theory and the challenges of group decisions. The structure of the literature analysis is based on the thematic division of the thesis.

The fourth chapter describes the applied research methodology in detail. The central focus of the work is on manufacturing companies in industry. The process of delivering physical products is broken down into its individual sub-processes. The framework of the American Productivity & Quality Center (APQC) is used to identify and define these sub-processes (APQC 2024-A). This is followed by a thorough analysis of the performance concept and the KPIs in order to determine the most suitable KPIs at an early stage of the implementation process. This section also describes the evaluation of the organizational resilience model in the context of the *"Deliver Physical Products"* process. The fuzzy Delphi method is presented as a suitable method for problem solving, whereby the classic Delphi model is further developed through the integration of type I fuzzy sets (Faghihi 2018).

The following fifth chapter describes the real implementation of the proposed model. The model is tested using real data from a complex industrial company that deals with the production of complex technical products (Aleksić 2022-A). The model is verified by statistical analysis. In the case of an existing correlation, the focus is on implementing the optimization

model to improve the values of the resilience factors. However, if there is no correlation between the proposed data sets, the new RFs must be defined and tested.

The results of the empirical studies, in particular the case study, are discussed in the sixth chapter in the context of the current state of research. This reveals both shared features and differences, from which both conclusions for future research and practice-oriented recommendations can be derived (refer to Chapter 7). In addition, the boundaries of the study and their impact on the validity of the results are highlighted. Finally, the central findings of the study are summarized, the limits of the proposed model are analyzed, a conclusion is formulated, and perspectives are outlined.

Before we have a closer look at the individual aspects, we must first outline the problem precisely.

"Problems on the outside are always a mirror of the problems on the inside."

Otto C. Scharmer (1961): German economist.

2 PROBLEM DEFINITION

As already outlined in chapter one, 2020 confronted companies worldwide with a considerable loss of confidence in the resilience of their organizational structures. The ability to anticipate future market changes, already weakened by a broad range of political, economic, social, and technological developments, was further exacerbated (Kerr n. d.-B; Kulkarni 2020).

Example
"In the late 19th century, milkmen in Great Britain were still delivering milk in open bottles. The cream that floated to the top quickly became a delicacy for two bird species: Titmice and robins. To remedy this problem, the milkmen began sealing the bottles with thin aluminum caps in the 1930s. Two decades later, however, nearly all the titmice in Britain - estimated at about one million - had learned to open the caps, while the robins had not developed this skill. Despite their curiosity and mobility, which is in no way inferior to that of titmice, robins failed to learn this trick. The reason for this lies in their individual lifestyle; they live as loners and vehemently defend their territory. Although robins communicate intensively with each other, this interaction is mainly for marking and defending their territory, rather than for sharing information or collective learning. As they do not form communities in which knowledge could be shared, they were ultimately denied access to the cream. This is a striking illustration of how social learning can give a species an adaptive advantage (Drath & Heller 2018)."

Table 2-1: No Cream for Robins (Drath & Heller 2018)

At breakneck speed, 2020 became a year without precedent, in which global challenges and the COVID-19 pandemic in particular sparked an unprecedented, volatile, uncertain, complex and multidimensional crisis. Many organizations were surprised by the dynamics of change, which not only entailed radical changes but also placed great demands on organizational resilience. This test also posed an unprecedented challenge for leading companies in the industry, including the world's largest manufacturer of weighing systems (Kerr n. d.-B; Kulkarni 2020).

2.1 Importance of the Resilience of an Industrial Company

In a time of continuous transformation, characterized by the dynamics of agile market environments, companies such as a manufacturer of weighing systems are in the midst of a profound realignment of their management systems. One challenge here is coping with the complexity of a decentralized organizational structure that requires collaboration with internal and external partners. It is also essential to manage the diversity of the product portfolio, which has a considerable number of variants (Tjoa et al. 2024).

In order to strengthen corporate resilience, a broader understanding of dynamic market conditions is required, which also takes into account increasing global regulatory requirements. Revising existing management systems is an important step towards meeting customer-specific, normative and legal requirements.

At the heart of the manufacturer's organizational structure is a matrix organization based on a decentralized yet integrative structure that allows the various business units a high level of autonomy (Huber et al. 2023). This structure promotes independence as well as flexibility and agility in the markets without compromising the necessary cooperation and symbiosis between the business units.

The key roles in this network are the strategic and manufacturing business units. Global logistics centers extend their competencies beyond mere logistics processes by also taking on product configurations and even production in certain cases.

Increased integration and the usage of synergistic relationships between the various business units are crucial to strengthening the company's resilience and responding to growing regulatory requirements and customer expectations. To achieve greater business resilience, top management must develop a deep awareness and understanding of the importance and potential of modern, dynamic management systems.

In order to successfully meet current and future challenges, the manufacturer strives to develop an approach that can be used as a universal model to analyze and understand the complexity of the various business units. This includes a focus on individual operating units along the value chain to enable an in-depth comparison and analysis of different approaches (Duchek 2019; Kopia 2019).

In this ongoing process, the aim is to develop a robust, transparent, and flexible management system that strengthens corporate resilience by being based on the principles of collaboration and continuous improvement. This initiative reflects the manufacturer's proactive approach to establishing itself as a resilient company in an uncertain and fast-moving market environment (Coffey 2023; Kucińska-Landwójtowicz 2018).

2.2 Research Gaps and Hypotheses

The practice-relevant research gaps indicated in the previous chapter are precisely summarized below (refer to Table 2-2). These form the basis for the definition of the research objective and the hypotheses based on it.

Research Gap	Title	Description Hypothesis
Research gaps at model level		
A	Hybrid Fuzzy Models for KPI Optimization	By using the hybrid fuzzy model, the aggregate value of the resilience factors affecting each identified KPI can be precisely determined.
B	RFs and KPI recovery time: A negative correlation	A negative correlation exists between the aggregate value of the resilience factors and the recovery time of the key performance indicators.

Research Gap	Title	Description Hypothesis
C	Heuristic optimization of corporate RFs	The application of heuristic methods enables the identification of the optimal set of strategies to improve RFs in a complex enterprise environment.
Research gap at holistic level		
D	Effectiveness of a dynamic approach to resilience management	A dynamic approach to resilience management that integrates cross-phase activities is shown to be more effective in managing disruptions and uncertainties compared to static resilience models.
E	Normative strengthening of resilience through management systems	The normative implementation of corporate resilience can be permanently anchored and improved in the company through sustainable management systems.

Table 2-2: Research Gaps

For the hypotheses proving or disproving, there is a need to develop a model for assessing business resilience at the business process level. For this purpose, the mutual relationships between the KPIs of the process and the RFs are considered by applying the fuzzy sets theory, multi-attribute decision making (MADM) techniques and the Fuzzy Delphi Technique.

The realization of the scientific objective is aimed at by implementing the following sub-objectives (Huber et al. 2023):

- *The identification and selection of a resilience model specifically suited to complex manufacturing organizations, combined with a precise assessment of organizational RFs at the level of each identified sub-process, taking into account the realization of physical products through the application of the Fuzzy Delphi Technique;*
- *The definition and selection of KPIs managed at the sub-process level of a generic process focused on the realization of physical products. This also includes the definition of the time required to restore each identified KPI after a disruption;*
- *The determination of the aggregated value of the RFs at the level of the individual KPIs by using fuzzy MADM and fuzzy aggregation operators;*
- *A scatter plot analysis of the aggregated value of RFs at KPI level and the calculation of recovery time for each KPI using regression and correlation analysis;*
- *The conception of an optimization model for the selection of strategies to improve resilience factors.*

The model is validated through tests with real data. The verification and confirmation of the research approaches takes place directly in the selected business areas of the industrial company.

"Life can only be understood backwards; but it must be lived forwards."

Søren A. Kierkegaard (1813 to 1855): Danish philosopher.

3 LITERATURE REVIEW

A significant number of literature sources suggests the use of type-one Fuzzy Sets to model uncertainties (Akram et al. 2023; Arsovski et al. 2015). For this research, type-one fuzzy sets have been chosen. These sets are characterized by their triangular membership function, granulation, and domain. Granulation selection often corresponds to the nature of the problem under investigation. Meanwhile, the domain can be determined either based on the Decision Maker (DM) assessment or by adhering to literature guidelines (Huber et al. 2023; Jin 2023; Moradi 2022).

A significant cohort of researchers endorse the use of type-one fuzzy sets. They argue that these sets offer a robust foundation for calculations that encompass uncertainties without necessitating a complex array of mathematical operations (Huber et al. 2023).

Given these considerations, methods such as the Delphi Technique incorporating type-one Fuzzy Sets are employed to address fuzzy group decision-making challenges (Habibi et al. 2015; Mabrouk 2021). The unification of diverse DM opinions into a singular consensus can be achieved through various aggregation operators (Calvo et al. 2002; Grabisch et al. 2009). Notably, when grappling with real business challenges in uncertain scenarios, the fuzzy arithmetic mean (Abdollahi et al. 2020; Dawood et al. 2021; Jani et al. 2018; Tsai et al. 2020) and fuzzy geometric mean (Aleksić et al. 2022-B; Bui et al. 2020; Huber et al. 2023; Khan et al. 2020) are most commonly utilized.

3.1 State of the Research

This section delves into an analysis of the Fuzzy Delphi Technique in comparison to its enhanced version, which utilizes Type-one Fuzzy Numbers. Both techniques are applied to address similar management problems. The comparative analysis of Fuzzy Delphi Technique applications is listed in Table 3-1 (Huber et al. 2023).

Authors	Number of DMs	Membership function shape/ granulation/ [Domain]	Aggregation operator/Defuzzification procedure/Distance of two fuzzy numbers/Consensus check for DMs assessments
Chen & Lee (2013)	-	TFN/5/[0-1]	The proposed aggregation method/Simple gravity method/-/The proposed threshold value (Chen & Lee 2013)
Habibi et al. (2015)	-	TFN/5/[0-1] TFN/7/[0-1]	The proposed aggregation procedure/Center gravity method/-/The usually used threshold (Horng et al. 2013)

Authors	Number of DMs	Membership function shape/ granulation/ [Domain]	Aggregation operator/Defuzzification procedure/Distance of two fuzzy numbers/Consensus check for DMs assessments
Liu & Chou (2016)	-	TrFN/3/[0-10]	The proposed aggregation procedure/-/-/The proposed procedure by Horng et al. (2013)
Kumar et al. (2018)	-	TFN/9/[0.1-0.9]	The proposed aggregation procedure (Kumar et al. 2018)/Center of gravity method/-/-
Jani et al. (2018)	12	TFN/7/[0-1]	Fuzzy arithmetic mean/-/Euclidean distance/Threshold value defined by Mahmoudi et al. (2017)
Singh & Sarkar (2020)	15	TFN/5/[0.1-0.9]	The proposed aggregation procedure/Center of gravity method/-/The proposed procedure based on a threshold value defined by Kumar and Dash (2017)
Bui et al. (2020)	-	TFN/5/[0-1]	Fuzzy geometric mean/Method of the maximum possibility/-/The proposed procedure for establishing equilibrium across the fundamental judgments among the expert group (Zimmermann 2011)
Khan et al. (2020)	12	TFN/5/[0-1]	Fuzzy geometric mean/Center of gravity/-/Procedure defined by Horng et al. (2013)
Abdollahi et al. (2020)	15	TrFN/5/[0-9]	Fuzzy arithmetic mean/-/The defuzzification procedure (Farhadian & Shahgholian 2015)/Distance between two consecutive rounds (Mahmoudi et al. 2017)
Tsai et al. (2020)	14	TFN/5/[0-1]	Fuzzy arithmetic mean/Center of gravity method/-/-
Dawood et al. (2021)	-	TFN/5/[0-1]	Fuzzy arithmetic mean/Center of gravity method/Euclidean distance/The consensus must be higher than or equal to 75 percent to declare an acceptable agreement among the experts (Chu & Hwang 2008); Defined threshold value; Distance between two consecutive rounds (Mahmoudi et al. 2017)
Mabrouk (2021)	-	TFN/5/[0-1]	The proposed aggregation model/The proposed defuzzification method/-/Defined the filtering threshold for the critical attributes
Aleksić et al. (2022-B)	5	TFN/7/[1-9]	Fuzzy geometric mean/-/Hamming distance/Combining the graded mean integration representation and average percent of majority opinions cut-off rate (Islam et al. 2006)
The proposed model	9	TFN/5/[0-10]	Fuzzy square mean/-/Euclidean distance/Intraclass correlation coefficient (Buck et al. 1993)

Table 3-1: Proposed Delphi Technique with Type-one Fuzzy Numbers (Huber et al. 2023)

In the papers analyzed, nearly all authors utilize Triangular Fuzzy Numbers (TFN) to depict the assessment of DMs. To date, there is no guidance in the literature on determining the granulation and the domains of the fuzzy numbers used in Delphi studies. The number of linguistic variables is largely influenced by the complexity of the issue and the number of decision-makers involved in the Delphi study. Given this, it is notable that a majority of researchers (Abdollahi et al. 2020; Bui et al. 2020; Chen & Lee 2013; Dawood et al. 2021; Khan et al. 2020; Mabrouk 2021; Singh & Sarkar 2020; Tsai et al. 2020) employ five linguistic expressions to describe uncertainties in their studies (Huber et al. 2023).

In the Delphi studies reviewed, a significant number of authors (Abdollahi et al. 2020; Bui et al. 2020; Chen & Lee 2013; Dawood et al. 2021; Habibi et al. 2015; Jani et al. 2018; Khan et al. 2020; Mabrouk 2021; Tsai et al. 2020) propose defining the domain on the set of real lines within the interval [0-1] (Huber et al. 2023).

For this research, the triangular membership function is employed to model RF value estimates for manufacturing process sub-processes, consistent with the majority of the analyzed studies (Huber et al. 2023). The literature frequently cites that TFNs can aptly represent uncertainties and inaccuracies without necessitating intricate computations (Zimmermann 2011). This research adopts five predefined linguistic terms to characterize the uncertainty under consideration, mirroring the convention in most of the reviewed papers. The domain of the TFNs outlined in this study spans the interval [0-10], following the guidance of Liu and Chou (2016) (Huber et al. 2023).

The process of consolidating DMs' evaluations into a unified assessment leverages various operators. Indeed, choosing the appropriate aggregation methods for DMs' estimates can be seen as a challenge in itself (Huber et al. 2023).

In this study, the author introduces a fuzzy quadratic mean operator. This differentiates the current research from other studies available in the relevant literature, as outlined in Table 3-1 (Huber et al. 2023).

The linguistic expression that reflects the outcome of the preceding round is derived from the shortest distance between predefined linguistic expressions and the TFN that describes the collective value of the DMs' evaluations. The Euclidean distance is a commonly employed measure in numerous studies, including this one (Dawood et al. 2021; Jani et al. 2018). However, some researchers also utilize the Hamming distance (Aleksić et al. 2022-B; Huber et al. 2023).

Assessing the coherence of DMs' evaluations relies on varied procedures (von der Gracht 2012). In this study, the method used to determine whether a consensus among DMs' opinions has been achieved is the intraclass correlation coefficient (Ferri 2005). It is evident that a sensitivity study is essential when analyzing the consensus results obtained through different methodologies.

Conclusion: In summary, with regard to the research gaps, it can be stated that so far there are no clear guidelines for determining the granularity of fuzzy numbers in Delphi studies. It is therefore of great importance to conduct empirical studies to identify this granularity more precisely.

3.2 Resilience of Companies

In summer 2023, the Transfer Center for Production Logistics and Technology Management conducted a study (Wildemann 2023) on the topic of *"Resilience in companies"*. Of the more than 460 industrial companies surveyed, only 13% stated that they felt prepared for imponderables and uncertainties. Despite the fact that 94% of respondents emphasized the relevance of resilience in the corporate context, the results revealed a significant need for action. In particular, there is a considerable backlog in key areas such as sustainability (84%), customer focus (92%), governance (71%), technology intensity (74%) and research and development activities (71%). The study also sheds light on the importance of value drivers for sustainable corporate success and analyzes resilience to risks. It makes it clear that, despite the challenges of recent years outlined in chapter one, many companies are not sufficiently resilient in key areas (Bernard et al. 2022).

To better illustrate the concept, reference can be made to Selye (1978), who divides dealing with shock events into different phases. These resilience phases provide a useful point of reference for understanding the stresses experienced by individuals and organizations and deriving the resulting coping strategies. For organizations, it is not only the resilience level of their employees that is important, but also their general performance. Viewed from the outside, this performance is often assessed based on company key figures. Based on Sheffi and Rice (2005), Biedermann (2018) provides an example of how a resilient supply chain could react. Based on Selye (1978), he divides the resilience process into four phases:

- *[1] Readiness;*
- *[2] Response;*
- *[3] Recovery;*
- *[4] Growth.*

Figure 3-1 below shows the resilience phases listed (Bernard et al. 2022).

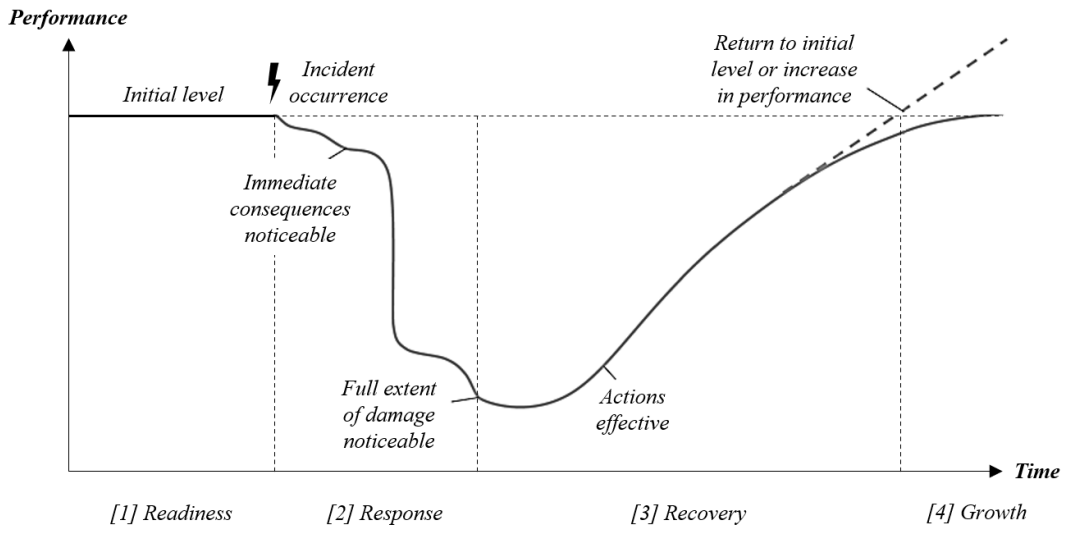

Figure 3-1: Resilience Phases
(own illustration based on Bernard et al. 2022, Beuth & Jovanović 2021 and Biedermann 2018)

After a shock event, the organization experiences a drop in performance, with the initial focus being on damage limitation. In the subsequent activity phase, measures are aimed at restoring or even exceeding the original performance level. If the performance level remains permanently low or the crisis extends over a longer period of time, the initial state can no longer be achieved. In such a case, the shock event represents a real threat to the organization's existence. A resilient company is therefore able to minimize the damage by reacting quickly and correctly and to pass through the resistance phase before a state of exhaustion sets in. If the performance level is too weak or the crisis lasts too long, the initial state is no longer reached, and the triggering shock event leads to a real threat to the company's existence. A resilient

company therefore succeeds in limiting the extent of damage by reacting quickly and correctly and exiting the resistance phase before the state of exhaustion (Bernard et al. 2022).

Conclusion: It seems that the importance of resilience in the corporate context is undeniable. Nevertheless, it is clear that companies have considerable room for improvement when it comes to dealing with shock events in a targeted and sustainable manner. The author is of the opinion that large corporations in particular have the necessary resources for this topic, but often focus too much on too few of their core competencies. Due to their size, they also tend to feel too secure about their market position and therefore often neglect the importance of corporate resilience. Comprehensive, group-wide resilience management is often overlooked. This view is supported by a study published in 2023 (Hantzsch 2023) on the feared trend reversal in corporate insolvencies in Europe. After the years of the COVID-19 pandemic, during which companies across Europe were massively subsidized, the reality of the market economy is gradually emerging again: Many companies are not sufficiently prepared for constant crises in the long term. In Western Europe, Norway, Switzerland, and the UK, 139,973 company insolvencies were registered, which corresponds to an increase of around 24% compared to the previous year of the study (2021: 112,686 cases). The situation is even more drastic in Eastern Europe (Hantzsch 2023).

3.3 Resilience Models and Concepts

Knowledge of the process of resilience is important in order to identify characteristics and resources that can help an organization to survive and recover from difficult conditions before the exhaustion phase occurs and adjust to it (Duchek 2019; Thun-Hohenstein et al. 2020). In the entrepreneurial context, the question now arises of resilience concepts that include precisely such characteristics and resources (Bernard et al. 2022).

Starting with the much-cited Kauai study (Werner 1999) and the subsequent psychological approaches to resilience, and at the latest since the work of *"Buzz"* Holling in the early 1970s, in which social ecosystems were researched, according to Karidi et al. (2018), it is now used in various research fields and sub-disciplines of the social sciences and humanities (Endress & Maurer 2015; Wink 2016). Whether in the area of civil security as the original program for dealing with natural disasters (Kaufmann 2015), in spatial research (Christmann et al. 2011; Schneider 2015), economics (Carmeli et al. 2013; Mitchell 2013), philosophical and sociological research (Gutwald 2015; Promberger et al. 2019), ecology (Bennett et al. 2014) or psychology (Davidson 2000; Norris et al. 2008): Resilience is understood as a concept that holds promising answers to different challenges and crises. This multidisciplinarity is possible primarily because the term has both a descriptive and a normative dimension (Brand & Jax 2007; Nida-Rümelin & Gutwald 2016; Schneider & Vogt 2017).

The following Table 3-2 of selected publications illustrates that this field of research is still young but is becoming increasingly interesting.

Author(s)	Year	Title
Bell, G.	2020	The Organizational Resilience Handbook: A Practical Guide to Achieving Greater Resilience

Author(s)	Year	Title
Bennis, W. G. et al.	2003	Harvard Business Review on Building Personal and Organizational Resilience
Christensen, C. M. et al.	2020	HBR's 10 Must Reads on Organizational Resilience (with bonus article *"Organizational Grit"*
Crask, J.	2021	Business Continuity Management: A Practical Guide to Organizational Resilience and ISO 22301
Everly, G. S. & Athey, A. B.	2023	Leading Beyond Crisis: The Five Pillars of Transformative Resilient Leadership
Flanagan, P. E. & Castagnera, J. O.	2022	The Four Pillars of Organizational Resilience
Fotinatos-Ventouratos, R. S. J. et al.	2023	Resilience in Modern Day Organizations
Giustiniano, L. et al.	2018	Elgar Introduction to Theories of Organizational Resilience
Holbeche, L.	2018	The Agile Organization: How to Build an Engaged, Innovative and Resilient Business
Kayes, C. D.	2015	Organizational Resilience: How Learning Sustains Organizations in Crisis, Disaster, and Breakdown
Kovoor-Misra, S.	2019	Crisis Management: Resilience and Change
Leflar, J. J. & Siegel, M. H.	2016	Organizational Resilience: Managing the Risks of Disruptive Events - A Practitioner's Guide
Lindstedt, D.	2022	Building Resilient Organizations through Change, Chance, and Complexity
Powley, E. H. et al.	2020	Research Handbook on Organizational Resilience
Rahman, H.	2021	Achieving Organizational Agility, Intelligence, and Resilience Through Information Systems

Table 3-2: Selected Publications on Corporate Resilience (own illustration)

However, research into resilience concepts in the corporate context, which aim to assess and improve organizational resilience, is still in its infancy. The characteristics and resources that are referred to as resilience factors, analogous to Bernard et al. (2022), should be described with regard to future steps. Different authors use different terms such as resilience criteria, resilience keys or resilience principles. This paper is intended to help create a stable basis for a critical discussion in complex industrial companies. The concept of corporate resilience forms an intersection between personal, systemic, and organizational resilience (Di Bella 2014).

Conclusion: Research into resilience concepts in an entrepreneurial context is comparatively new and there is a lack of comprehensive overall contexts in this area. For this reason, there is an urgent need to conduct empirical studies to analyze and describe these relationships in more detail.

3.3.1 Personal Resilience

Personal resilience enables us to successfully overcome crises by activating our own resources as well as the ones from our environment. At the same time, we recognize in challenging situations the opportunity for personal growth and progress (Morgenthaler n. d.).

Promberger et al. (2019) and Thun-Hohenstein et al. (2020) explain the concept of resilience as a psychological characteristic in an article in the Journal of Psychodrama and Sociometry. They classify RFs according to their internal and external origin and also differentiate between resources and individual characteristics. Their model makes it clear that the concept of resilience not only serves to minimize RFs, but also usefully complements conventional risk management. Alongside Bernard et al. (2022), this assessment also confirms the author's view.

Figure 3-2 below shows the resilience model according to Thun-Hohenstein et al. (2020).

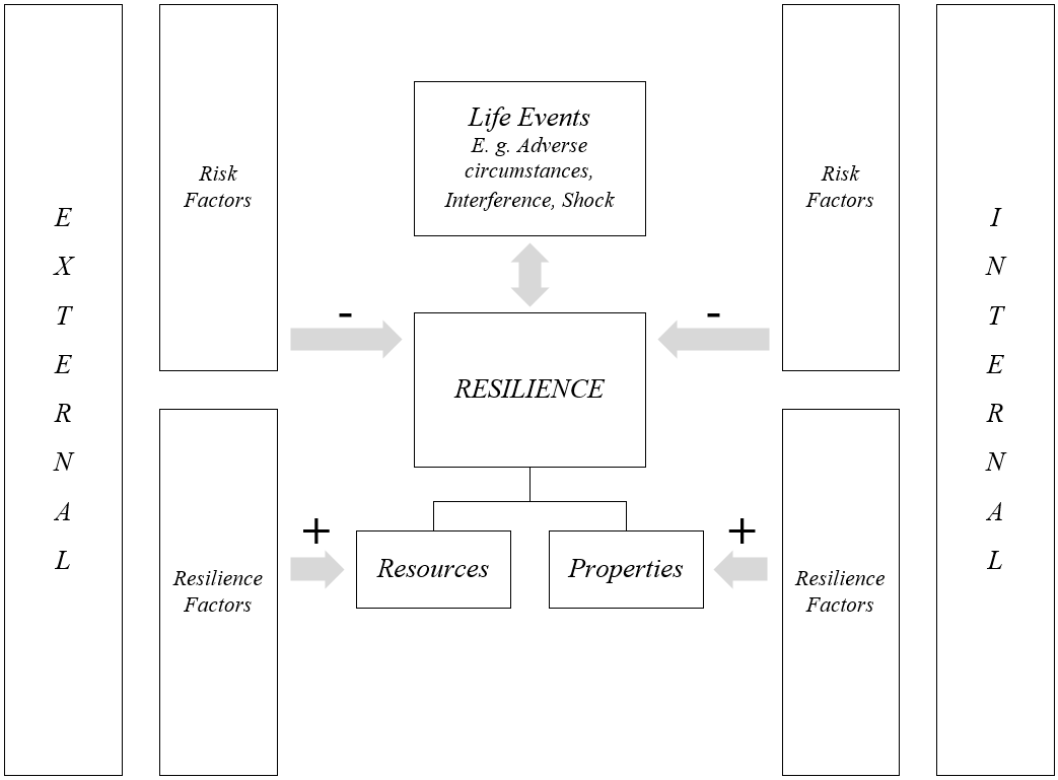

Figure 3-2: Process of Resilience
(own illustration based on Thun-Hohenstein et al. 2020)

The basic categorization of RFs can also be applied to organizational resilience. However, the complexity of organizations usually requires more differentiated analyses in order to derive specific RFs (Bernard et al. 2022).

3.3.2 Systemic Resilience

The systemic concept of resilience presupposes an internal structure or components that are linked or interdependent in a certain way. The modern understanding of holistic systems

also takes the environment into account and is applied in economics, for example in the case of economic systems, industries and, of course, organizations (Di Bella 2014).

Wellensiek (2011) presents a holistic structure, which he divides into different areas of responsibility and refers to as *"dimensions"*. He identifies four key dimensions that characterize a resilient company: Corporate culture, health and resource management, communication and structure and processes. In addition, he considers relationships, leadership, and training as further relevant aspects. These dimensions act as organizational principles of the model and can be detailed using a compass methodology as follows (Bernard et al. 2022):

Figure 3-3: Resilience Dimensions and Factors
(own illustration based on Bernard et al. 2022 and Wellensiek 2011)

The compass provides management with guidance and points the way to developing a more resilient organization (Bernard et al. 2022).

Specific RFs are identified and discussed for each dimension. In the field of corporate culture, for example, the focus is on a clear vision, identification with the company and trusting and transparent communication. In the dimension of health and resource management, factors

such as supporting employees during change processes and protection against psychosocial stress are crucial. In the context of communication, structure and processes, the focus is on transparent work and information flows, agile and adaptable action and self-awareness of strengths and weaknesses. In addition, special factors in the dimension of relationships, leadership and training are emphasized. In particular, a network-oriented approach, customer proximity, an open error culture and the ability to learn from mistakes should be promoted. Overall, Wellensiek's (2011) resilience model outlines an ideal image of a resilient organization. However, according to Bernard et al. (2022), little attention is paid to how this ideal state can actually be achieved.

Conclusion: In view of the existing research gaps, there is a lack of research work to further develop and adapt the theoretical ideal models described in the literature in a way that allows them to be implemented in organizations in a practical and implementation-oriented manner.

3.3.3 Organizational Resilience

In the early 2000s, links between resilience and corporate performance were investigated and discussed, as Drath (2016) notes. Duchek (2019) and Heller (2019) sees the ability to achieve organizational resilience as an essential competence for the future of organizations. These organizations face challenges from external factors as well as market and environmental influences. Resilient organizational competencies are defined as an organization's ability to react flexibly to situations, make informed decisions and learn from mistakes. To prepare for crises and challenges, organizations can take precautions through appropriate preparations, such as the establishment of standards and norms for greater resilience, business continuity management and risk management (Christöfl 2022; Duchek 2019; Herdman 2021).

Additional to the organizational learning fields of resilience in companies according to Rolfe (2019) as an entrepreneurial resilience model, the BSI has several organizational principles of order comparable to the following Figure 3-4. The focus is on three core elements: Process reliability, product excellence and employee behavior (British Standards Institution 2024). These elements address the basic principles of the organization and aim to provide customers with the best possible services or products through reliable processes and committed employees (Bernard et al. 2022; Kerr n. d.-A).

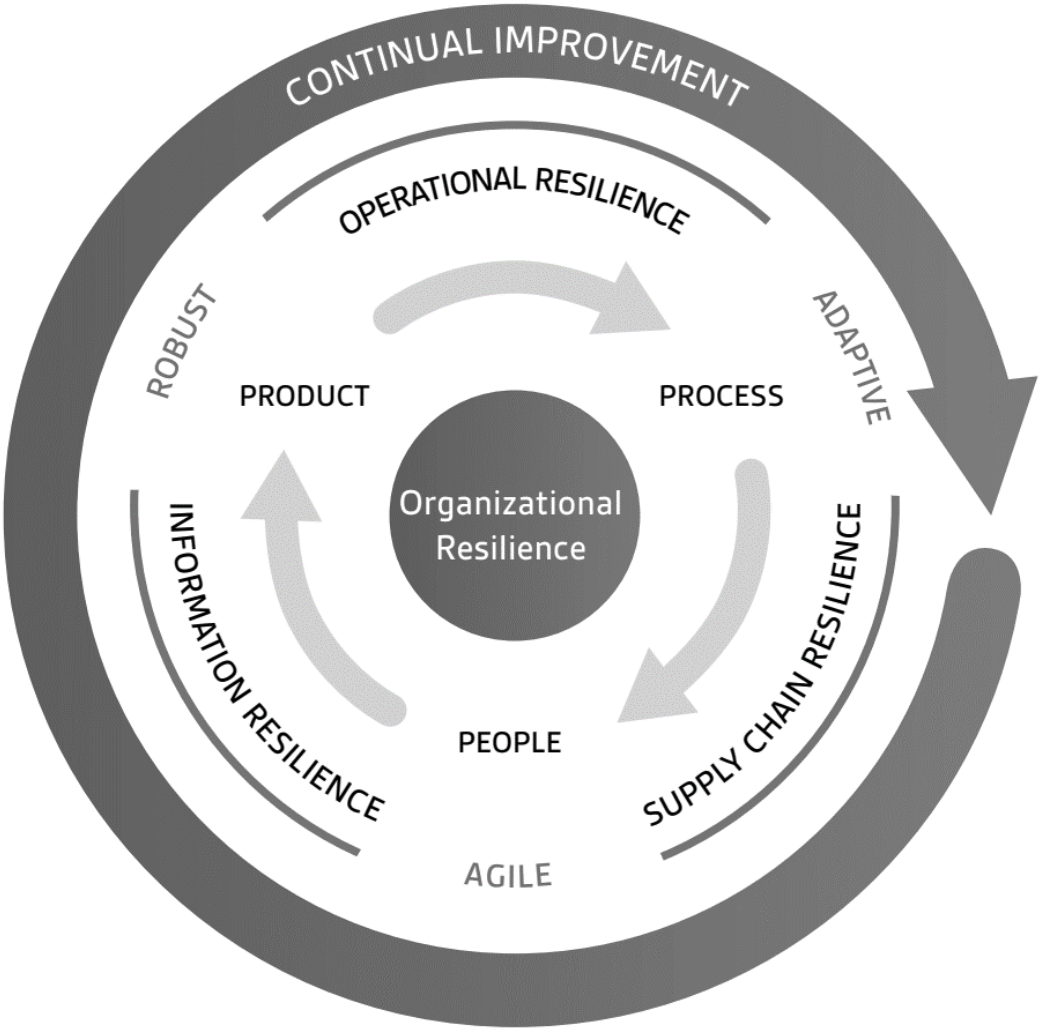

Figure 3-4: Resilience according to the British Standard Institution (Kerr n. d.-A)

Product excellence ensures continuous revenue and offers customers first-class quality. Process reliability focuses in particular on the processes that are essential for maintaining business operations. Efficient and cost-effective processes strengthen the trust of customers and other interested parties in the organization. The employee behavior element aims to promote a corporate culture that reflects both environmental awareness and social responsibility. This contributes to the positive identity of the organization. In addition, a culture of community should motivate employees and ensure their support for the organization (Gupta 2024; Huber et al. 2023).

These basic elements should not be viewed in isolation. As in previous models, they constantly interact with the external environment. For this reason, operational resilience focuses on identifying opportunities for operational improvement. The goal is to ensure that customer requirements can continue to be met in the future and that excellent products can continue to be provided. It is crucial to fully understand both the processes and the context in which they

take place (Bernard et al. 2022; British Standards Institution 2024; Huber et al. 2023; Kerr n. d. A).

Supply chain resilience also focuses on the dynamic interaction between an organization and its environment, with the aim of ensuring the global functioning of the supply chain. A company must be in a position to recognize risks within the supply chain and develop suitable alternative courses of action. This requires a precise knowledge of the supply chain network, including all the players involved and their interdependencies. In this context, information resilience focuses on continuously ensuring a secure data and information environment. Collaboration with external partners and institutions also makes it now possible to create value beyond one's own core competencies (Bernard et al. 2022; Huber et al. 2023; Kerr n. d.-A; Reeves & Whitaker 2020; Riegel et al. 2020).

As in other resilience models, the central organizing principles of the BSI also serve the purpose of establishing a clear structure and defining fields of action. Based on Bernard et al. (2022), the BSI attaches particular importance to the characteristics of robustness, agility, and adaptability in order to achieve resilient states in these fields of action.

3.3.4 Conclusion of the Discussion of Resilience Models and Concepts

In all the concepts discussed, the central concern is to break down the complex issue of resilience into individual components that have a considerable influence on a company's resilience and therefore deserve special management attention (Bernard et al. 2022; Grove 2024). Figure 3-5 illustrates that a uniform logic runs through the various theoretical resilience concepts. In addition, the concept of corporate resilience represents an intersection of personal, systemic, and organizational resilience (Di Bella 2014).

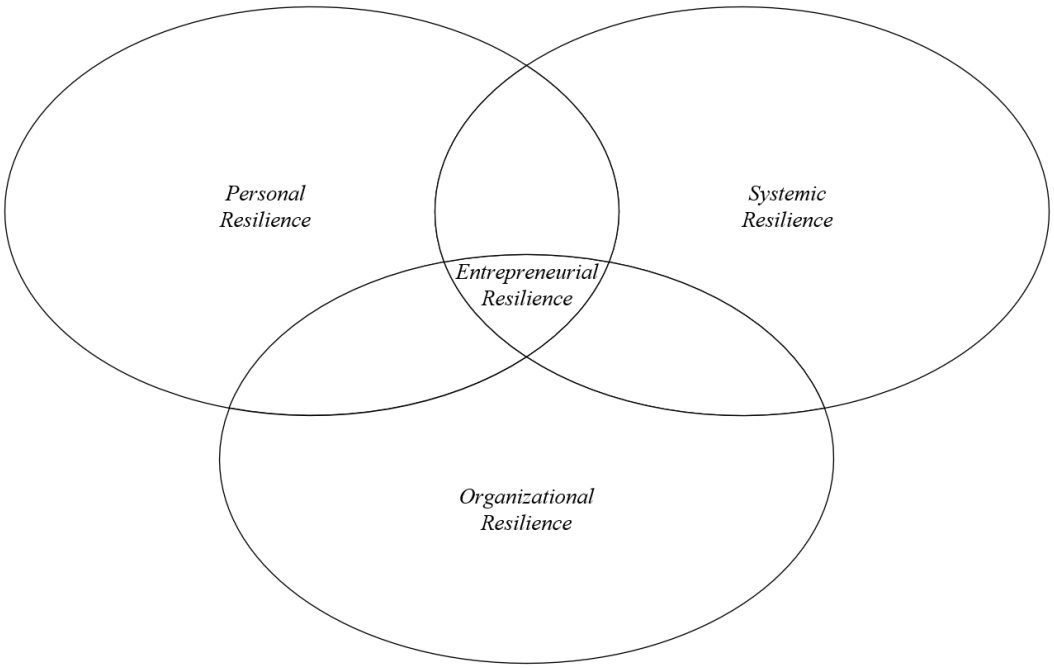

Figure 3-5: Venn Diagram on Entrepreneurial Resilience
(own illustration based on Di Bella 2014)

At the very highest level of representation, most authors formulate a framework for action. Rolfe (2019), for example, speaks of *"individuals"*, the *"organizational and operational structure"* and the *"system"*, i.e., the environment the company operates in. Similarly, the BSI refers to the elements *"people"*, *"products"* and *"processes"* (Bernard et al. 2022; Kerr n. d.-A).

They extract specific aspects from organizational practice - referred to as *"dimensions"* by Wellensiek (2011), *"fields of learning"* by Thun-Hohenstein et al. (2020) or *"fields of action"* by BSI (Kerr n. d.-A) - which they consider to be fundamental to resilience. Based on these thematic clusters, starting points are identified to promote or strengthen resilience. This is often done by describing conditions or ideals. However, they may also be special features, key attributes or criteria that characterize resilient individuals, products or processes. Alternatively, they can be factors that a company must implement in order to increase its resilience. These criteria, characteristics or factors represent a unique combination of options for action for each company, which should bring it closer to the goal of increased resilience.

Analyzing the concept of resilience and its distinction from the concept of risk in section 1.1 has shown that it is not always possible to comprehensively and realistically anticipate and assess threats in crisis situations (Huber et al. 2023; Traskevich & Fontanari 2021). Even if these threats can be identified, the probability of their appearance is often so low that developing concrete measures based on them is comparable to reading a crystal ball. For this reason, such threats are often not taken into account in the corporate strategy, even though this would be perfectly feasible (Teamhub 2023).

As crises, unlike risks, are neither reliably predictable nor controllable, the company's properties and resources should be designed in this way that they enable effective crisis management (Fecher et al. 2021). The resilience factors outlined in section 3.3 therefore play a decisive role in the successful handling of crises and needs to be developed proactively within the company (Duchek 2019).

As already explained in section 3.2, the process of resilience can be divided into different phases: Starting with the readiness phase, which is terminated by a shock event, followed by the response and recovery phase, and finally, ideally, the growth phase (Duchek 2019). It stands to reason that different resilience factors can become more important in different phases in order to overcome the respective phase-specific challenges. In contrast to literature, it should be emphasized that the resilience factors are not only assigned to the *"anticipate"* and *"cope"* phases (Bernard et al. 2022; Fecher et al. 2021). From the author's point of view and based on the discussion of various resilience models in the previous chapters, resilience management is not a static but a highly dynamic approach. It therefore requires an overall view as well as an upstream view, in which phase-specific activities are required throughout the entire process - and not just in individual concluding phases.

Conclusion: It is key to make clear distinctions between the various resilience concepts. Nevertheless, these components should be considered as a whole with regard to comprehensive corporate resilience. The Venn diagram (refer to Figure 3-5) combines these different concepts and illustrates the overall concept. However, there is a general lack of empirical research in the literature that examines and tests corporate resilience as a whole within the framework of industrial companies (King et al. 2022; Weber 2023).

3.4 Management Tools

In view of the aspects discussed so far and the design of management tools, a key question arises in the context of corporate resilience: Are companies equipped to successfully face future uncertainties? To find an answer to this question, Economist Impact conducted a comprehensive study in 2022 (The Economist Group 2022). The study was based on expert interviews and a customized survey of over 600 executives in four main regions (North America, Latin America, Europe, and Asia-Pacific) operating in highly regulated industries. The aim of the study is the provision of a clear viewpoint on how and why corporate understandings of resilience are changing and to offer suggestions on how to design, build and maintain a global business with sustainable diversity in the post-pandemic world (Huber et al. 2023).

Example
"In the 1980s, the issue of forest dieback was ubiquitous in Europe (Kahle 2008). The main cause was largely seen in acid rain caused by high sulfur concentrations in industrial exhaust gases. Spruce monocultures, which were widespread at the time, were particularly badly affected, causing considerable economic damage to the forestry industry. In the following years, far-reaching legal measures were taken to retrofit sulfur filters throughout the country, and at the very same time, the monocultures were replaced by mixed forests. As a result, forest dieback was completely halted. Simultaneously, American chestnut stands in large parts of the USA were severely decimated by the so-called chestnut blight. The chestnut forests, which were home to practically no other tree species, were the hardest hit. In contrast, forest areas in which, for example, oaks and hickory, a type of walnut tree, were also found, were largely spared the harmful fungal infestation (Drath & Heller 2018)."

Table 3-3: No Cream for Robins (Drath & Heller 2018; Kahle 2008)

Given that The Economist estimates the economic losses in 2020 and 2021 alone at an impressive USD 10.3 trillion, equivalent to around 12% of global gross domestic product, the pandemic has pushed companies to the edge of their resilience. During this period, it has become apparent that anticipation, preparation, and the skill to adapt are essential survival strategies (Grove 2024).

Management tools are at the center of entrepreneurial activities, especially in our increasingly networked and technological world (Moore & Latif 2019). However, previous approaches, which are often limited to identifying and mitigating risks, are no longer sufficient. Corporate resilience is a far more comprehensive and effective approach. This requires a view of the entire company, in which not only each business function is analyzed individually, but also the various interdependencies are considered.

A company functions like a complex, networked system in which every unit is dependent on others. A failure in one area can have far-reaching consequences and have a domino effect throughout the entire system, with potentially catastrophic damage. Therefore, it is important to develop a holistic *"management resilience"* that unites all aspects of the organization in a coordinated effort (National Academy of Sciences 2010; The Economist Group 2022).

The following chapters describe in more detail how specific management tools can be used effectively to strengthen a company's resilience in the long term.

3.4.1 Standards Related to the Domain of Organizational Resilience

First, the terms *"standards"* and *"norms"* should be defined. According to Baumann (2022) and Potts (2011), the English term *"standard"* is often incorrectly used as a synonym for *"norm"* in common parlance. A standard is a legally recognized rule established by a standardized procedure for solving specific issues. It must be developed by consensus, technically mature and useful for the user. After passing through all the instances of a standardization process, it is published.

According to DIN EN 45020:2007-03 (Standardization and related activities - General vocabulary), a *"standard"* is defined as *"[...] a document drawn up by consensus and adopted by a recognized institution, which lays down rules, guidelines or characteristics for activities or their results for general and recurrent use, aiming at an optimum degree of order in a given context."* (Beuth 2007; Kratky 2022).

A standard, however, refers to a largely uniform procedure that is recognized and often applied in certain circles. It is used in technical areas, but also in other areas such as human rights or environmental protection. A distinguishing feature of standardization is that this process is usually faster and does not necessarily involve all interest groups and the general public, in contrast to standardization. Nevertheless, standards developed in this way can later become the basis for norms (Bauman 2022).

Conclusion: In summary, the term *"standard"* is described in this paper as a legally recognized rule that has been established by a regulated standardization procedure. *"Standards"*, on the other hand, describe a unified and generally recognized procedure for the manufacture, documentation or execution of a product or process.

According to a study by the National Institute of Metrology (Physikalisch-Technische Bundesanstalt) Braunschweig and Berlin of the federal republic of Germany (Ferdinand & Prem 2020), standards represent agreed procedures and act as powerful instruments for promoting innovation, optimizing processes and minimizing risks (British Standards Institution 2020). They can have a decisive influence in various areas of resilience, which are discussed in section 3.3, particularly regarding the following aspects, among others:

- ***Early identification of relevant environmental conditions:*** *Standardized management systems enable companies to identify and anticipate internal and external influencing factors at an early stage, allowing a proactive rather than reactive response to potential risks;*
- ***Increasing resilience through efficient process design:*** *A standards-based revision of company processes not only promotes efficiency, but also resilience to disruptions (Advisera 2017; Prammer 2014);*
- ***Safeguarding international business relationships through standards:*** *Compliance with uniform criteria, including environmental and social standards, minimizes risks and promotes entrepreneurial resilience through stable, trusting partnerships.*

Standards therefore promote corporate resilience by mitigating reputational risks and ensuring economic continuity. In addition, standards create a common basis for stakeholder requirements, which simplifies and promotes recognition and cooperation between suppliers, producers, distributors, and consumers (Ferdinand & Prem 2020).

ISO/TC 292 of the International Organization for Standardization has been dedicated to promoting security and business resilience since its establishment in 2014. This technical committee works continuously to create and develop standards that help not only companies, but also countries, societies, and individuals to become more resilient and secure. Its remit goes far beyond organizational requirements and includes general societal and community resilience (Ferdinand & Prem 2020; ISO/TC 292 2014).

Conclusion: In the context of the research questions, standards play a decisive role when it comes to sustainably strengthening and improving corporate resilience in companies. Voluntary compliance with standards (although customers can also actively demand regulatory requirements from suppliers) ensures that a company's management systems are always state of the art. However, it is essential to emphasize that simply referring to standards in a business context is not enough to build an integrated management system. The efforts required for ISO

certification, for example, are an initial door opener, but require further measures to implement a sustainable system (ISO Templates 2019). In addition, there is a need for research to date that examines the normative implementation of corporate resilience in industrial companies. There is therefore a need for further studies that examine and evaluate the implementation of corporate resilience in companies in more detail.

3.4.1.1 ISO/IEC TS 33061:2021

From the author's point of view, ISO/IEC 15504:2012 (Information Technology - Process Assessment) or SPICE (Software Process Improvement and Capability Determination) or the new ISO/IEC TS 33061:2021 (Information technology - Process assessment - Process assessment model [...]) can be used for the subsequent identification and definition of sub-processes as part of the APQC. These make it possible to determine the maturity level for processes, carry out a process assessment and create an exemplary process assessment model (ISO 2021; Lopes 2024; Wagner & Dürr 2007).

Back in 2006, the original technical report was replaced by a more comprehensive international standard, which now consists of six parts. Only the second part is normative, and the remaining parts serve to explain and provide examples and information. Within this standard, a process reference model is presented that defines processes at four different organizational levels: Agreement processes, organizational processes, technical management processes and technical processes (ISO 2021; VDE 2021). Based on this reference model, a process evaluation model is developed to assess the degree of sophistication of the processes within an organization (Marrella & Weber 2022).

The evaluation model is organized in two dimensions: The process dimension and the quality/maturity dimension. The process dimension contains basic KPIs for assessing the respective processes, including basic practices and work products. The quality/maturity dimension expands the assessment to include additional KPIs covering generic practices, resources, and work products. A key aspect of the standard is that each process can achieve an individual capability level, independent of other processes. According to Tarnowski (2011), the standard therefore follows a continuous model.

Figure 3-6 below shows the structure of ISO/IEC TS 33061:2021 (ISO 2021):

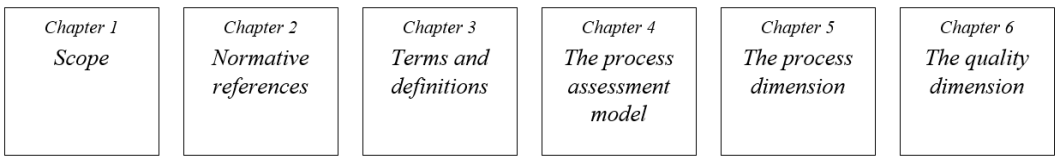

Figure 3-6: Table of Contents ISO/IEC TS 33061:2021
(own illustration based on ISO 2021)

The integration of a maturity model analogous to ISO/IEC TS 33061:2021 can serve as a strategic tool for strengthening corporate resilience. In this context, it is not necessary to

pursue full implementation of the standard. It is more important to take a risk-based approach by first determining which business processes are relevant (Yilmaz 2021). In view of constantly changing market conditions and the necessity for agile structures, iterative process model development can be flexibly expanded or adapted to meet current requirements.

Conclusion: ISO/IEC TS 33061:2021 offers a promising solution for defining sub-processes as part of APQC and for assessing process maturity levels (Interfacing 2022). It enables the creation of process assessment models and can strengthen corporate resilience at the simultaneous time. In practice, however, the author believes that it is inadvisable to implement the standard in its entirety (Fecher et al. 2021). Instead, a risk-based approach is recommended to identify the business processes relevant to the specific context. This is extremely important in view of constantly changing and agile market conditions. The flexible adaptation of process model development makes it possible to meet current requirements. However, there is a need for research on the partial application of process maturity levels to support this risk-based approach.

3.4.1.2 ISO 22316:2017

The key influencing factors for corporate resilience are defined in ISO standard 22316:2017 (Security and resilience - Organizational resilience - Principles and attributes) (Röhe 2022). The potential successor standard ISO/AWI 22316 has been in *"Proposal"* status since the start of 2023 (Duchek 2019). It is currently being revised by an ISO technical committee as an approved project (ISO 2023-A). The standard was developed by an international panel of experts under the leadership of British risk manager James Crask, who currently works for the Nuclear Decommissioning Authority, an organization that is managing the nuclear phase-out in the UK. The panel included representatives from countries such as the UK, the USA, Australia, New Zealand, and Japan, all of which have considerable experience in dealing with natural disasters (Drath & Heller 2018; Yilmaz 2021).

Figure 3-7 below shows the structure of ISO 22316:2017 (ISO 2023-B):

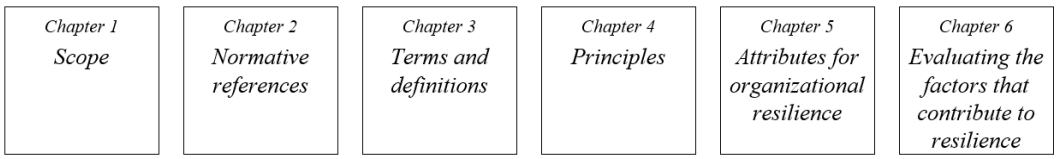

Figure 3-7: Table of Contents ISO 22316:2017
(own illustration based on ISO 2023-B)

Unlike many other standards, ISO 22316:2017 provides a detailed list of nine specific factors that contribute significantly to strengthening organizational resilience. It relates to the British standard BS 65000, which also focuses on organizational resilience, but takes a more reactive approach to interpreting this competence (British Standards Institution 2020). Here, a company's resilience is defined as its ability to anticipate, adapt to, and respond to unexpected and long-term events (Duchek 2019).

The development of the standard required the combined expertise of an interdisciplinary team that included specialists from the fields of risk management, change management, business continuity management and human resources management. Under the leadership of Crask, they devoted four years of intensive discussions to the goal of developing a uniform understanding of the core competence and certain basic principles. The following is a short overview of the fields of action identified to promote organizational resilience in accordance with ISO 22316:2017 (Bernard et al. 2022; Drath & Heller 2018; Duchek 2029; Ferdinand & Prem 2020; Gupta 2023; King et al. 2022; Röhe 2022; Teamhub 2023):

- ***Shared vision and clearly defined goals:*** *All hierarchical levels share a common vision as well as uniform goals and values that focus on the advantages of organizational resilience;*
- ***Comprehensive understanding of and influence on the environment:*** *The company has a deep insight into internal and external systems and has strategies in place to exert a targeted influence on them;*
- ***Effective and empowered leadership:*** *Company management maintains its effectiveness even in uncertain and changeable times and promotes a more proactive approach to overcoming challenges;*
- ***Promoting a resilience-promoting culture:*** *Resilience-promoting beliefs and values are firmly anchored in the organization, supported by a positive attitude and constructive behaviors;*
- ***Promoting the exchange of information and knowledge:*** *An open dialog and the exchange of knowledge between team members is encouraged, whereby learning from experience and mistakes is a high priority;*
- ***Ensuring the continued availability of resources:*** *The organization ensures that sufficient resources, including qualified employees, technologies, and information, are available to eliminate potential weaknesses and adapt quickly to changing conditions;*
- ***Coordination of business units:*** *Business units that contribute to resilience are actively identified, developed, and coordinated, creating a collaborative environment to pursue common strategic goals;*
- ***Promoting continuous improvement:*** *Results are regularly evaluated in order to learn from past experience and identify new opportunities;*
- ***Anticipatory management of change:*** *The organization is geared towards recognizing future changes at an individual stage and managing them strategically.*

Downstream RFs can be generated from these resilience principles (National Academy of Sciences 2010). These are formulated as organizational prerequisites that a resilient company should have (Bernard et al. 2022). It should be noted that Annex A of ISO standard 22316:2017 lists various relevant management disciplines for resilience, such as crisis management, communication management, business continuity management, environmental management, governance, financial management, supply chain management and information security (ISO 2023-B; Tjoa et al. 2024). Specific standards exist in some of these different disciplines. Standards that focus on such specific subject areas can be divided into a second group. These include, for example, information technology or supply chain security (Ferdinand & Prem 2020).

Conclusion: The ISO 22316:2017 standard provides a framework to support companies in designing their business activities in a future-proof manner. It describes the basic principles,

attributes, and measures for assessing RFs, also in connection with research gaps. It helps to better prepare companies for the challenges ahead by identifying factors that can strengthen a company's resilience and adaptability. According to Katz (2018), this also considers behavioral aspects that might have been neglected in the past. A central principle of this standard is to support companies in developing a culture of resilience. *"Culture"* requires sustainability in implementation - management systems may be able to make a fundamental contribution to this. This is achieved by building on existing risk management structures, promoting shared values, raising awareness of changing contexts and strengthening them through competent leadership. In summary, the standard is a concisely formulated guideline for companies that want to strengthen their immune system in a systematic and sustainable way.

The evolution of the successor standard remains of great interest (Grove 2024). ISO/AWI 22316 is expected to build on the principles and concepts used to date in ISO 22316:2017. The focus is expected to be on strengthening the organizational resilience of companies by providing guidelines, recommendations and best practices for the assessment and improvement of resilience factors in companies (Huber et al. 2023). Regarding the Venn diagram developed in section 3.3.4 (refer to Figure 3.5), this definition will therefore continue to represent only one area of corporate resilience (Fecher et al. 2021).

3.4.1.3 DIN SPEC 91461:2021

DIN SPEC 91461:2021, although not new, is rarely mentioned in the literature and complements the standards discussed in the two previous chapters (Fecher et al. 2021). This specification defines the basic framework for stress testing the resilience of, among other things, critical infrastructures and thus also management systems that are exposed to potential threats.

The term *"stress test"* is generally used to characterize the situation in which the performance of a system is subjected to real or assumed conditions. These conditions are usually combined in the use of a scenario designed to push the system, be it a technical system, an organization or society as a whole, to its limits. In a stress test, the system is subjected to an often-extreme load and checked to see whether it meets certain criteria. In extreme cases, the stress test aims to test the system's ability to survive these extreme conditions or the scenario.

In a narrower, technical context, the term is often used to check survivability under conditions that were not considered in the original design basis. New, changing conditions, emerging hazards, and threats as well as previously undetected harmful events and neglected risks are examples of situations in which it is of great importance to know whether the system or even the organization is up to the challenges (Beuth & Jovanović 2021).

While stress tests have been a common tool in the banking and insurance sector since the financial and banking crisis, they are largely unknown in other sectors such as trade, services and industry. In a business context, stress tests aim to determine the potential loss that a company could suffer in one or more predefined unfavorable scenarios triggered by crises, shocks or disruptions as described in chapter 1.1 (Gleissner et al. 2011). Stress tests are essentially scenario analyses in which extraordinary but nevertheless plausible shock events are analyzed with regard to their potential impact on the company, particularly with regard to its ability to survive (9001Simplified 2023; Sorge 2004).

Figure 3-8 below shows the content structure of DIN SPEC 91461:2021 (Beuth & Jovanović 2021):

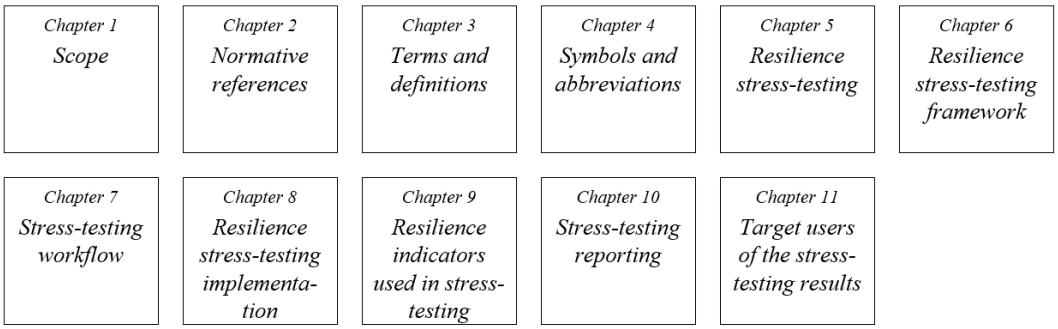

Figure 3-8: Table of Contents DIN SPEC 91461:2021
(own illustration based on Beuth & Jovanović 2021)

Up to this point, we have laid the methodological foundations for determining resilience. Now the focus shifts to the detailing of measures that were initially defined in abstract terms. The central questions here are:

- *How can the resilience of the companies under review actually be assessed?*
- *In what form do damage events actually occur?*

The primary goal of stress tests is to assess the resilience and consequently the resilience of companies in extreme situations, to strengthen stability and to broaden the perspective of traditional risk management (Huber et al. 2023; Hummel 2021). Stress tests are proving to be a valid tool, especially when testing complex, distributed system applications. Within the framework of the resilience concept, stress tests are ascribed far-reaching significance (Übermeister 2023). They depict comprehensive scenarios based on the risks determined in the risk-based resilience model (University of Minnesota 2016). With the help of a specified procedure, crisis scenarios are developed and their potential impact on the company is analyzed.

In the context of resilience, the main focus is on assessing a company's susceptibility to loss (Brooklyn 2023; Duchek 2019). The goal is to ensure, through careful analysis, that companies can survive in the long term, remain capable of acting even in times of economic crisis and compensate for negative effects as far as possible (Röhe 2022). Standard-specific instructions now enable management systems to bundle, guide and control specific objectives, activities, tools, and methods (Schäfer 2023-A).

Conclusion: The author considers DIN SPEC 91461:2021 to be a *"hidden champion"*, as it offers outstanding quality despite its low profile. It is an excellent addition to the standards listed and sets out a comprehensive framework for stress tests to check resilience and resilience measures and the standards applied in various areas (Duchek 2019). In the context with the research gaps, cross-phase activities and, accordingly, management systems are also taken into consideration (Übermeister 2023).

3.4.2 Management Models

In this paper, the term *"management system"* is defined as follows: A management system is a standardized instrument that maps the structure and processes of a company. It is based on the Deming quality management cycle (William E. Deming is an American pioneer in the field of quality management (Business Insider 2019)), which includes the planning of operational processes and activities, their implementation in accordance with the defined objectives and available resources, the monitoring of success and (if necessary) corrective action if the desired results are not achieved. This cyclical process can relate to a variety of aspects, including the quality of products or services, operational efficiency, environmental performance or health and safety (Mirtsch et al. 2019).

In order to understand and classify the structure and approaches of management models more precisely, Seghezzi (1996) draws a distinction between management concepts, such as total quality management or customer relationship management and management models or standards (refer to Chapters 3.4.1 ff.). In this view, management concepts represent a theoretical framework, while management models function as practical implementation aids. The concrete implementation of these concepts and models in a company ultimately takes place in the management system, which is aligned with the company's respective management concept and model.

These differentiations help to make the various aspects of corporate resilience easier to understand and promote in practice. A sound management system based on well thought-out concepts and tried-and-tested models can serve as a solid foundation for a company's resilience by helping to optimize both its strategic orientation and its operational processes.

3.4.2.1 TQM

Total Quality Management (TQM) is a comprehensive concept that aims to integrate quality as a constant goal in all areas of the company. TQM should therefore not be understood as an isolated management approach. It means that all processes are reviewed with the involvement of all employees (Total) to ensure that the products or services (Quality) meet the highest quality standards. TQM represents a holistic approach to corporate management that aims to continuously optimize processes and procedures.

The philosophy of TQM was coined in the 1940s by William E. Deming (refer to Chapter 3.4.2). Deming's findings were further developed in Japan and led to many Japanese companies successfully launching high-quality yet cost-effective products on the market. This quality management approach continued its successful course in the USA.

ISO 9001 (standard for quality management systems), the developed EFQM model (European Foundation for Quality Management) or the Japanese Six Sigma method are quality management systems based on the concept of TQM. They all pursue the goal of ensuring the highest quality from the customer's point of view and are based on the active participation of the entire workforce. TQM is tightly connected to lean management and kaizen in order to achieve maximum added value through the effective combination of different tools (Business Insider 2019; Eby 2023).

There are only limited direct descriptions in the literature in the context of business resilience. For this reason, the TQM model, which is divided into the following eight principles (Eby 2023; GBTEC 2023; Hendricks & Singhal 2010; KeyToData n. d.), is expanded to include these aspects:

- ***Customer orientation:*** *In view of corporate resilience, it is crucial to understand the current and future needs of customers and to pursue the goal of exceeding their expectations in order to adapt flexibly to market changes;*
- ***Managers****: Managers play an important role in setting common goals and aligning the organization to make it resilient. They should ensure that internal framework conditions are created to strengthen the resilience of both employees and the organization as a whole;*
- ***Employee participation:*** *Entrepreneurial resilience requires the active involvement of employees at all levels. Their skills are valuable resources for reacting to unexpected situations and making adjustments;*
- ***Process orientation:*** *The focus on efficient and agile processes enables the organization to adapt quickly to changing circumstances and increase its resilience;*
- ***System-oriented management****: Recognizing and controlling interlinked processes as an integrated system helps to increase corporate resilience in order to achieve the organization's goals;*
- ***Continuous improvement:*** *Continuous improvement of all aspects of the organization is crucial in order to be prepared for changes and crises;*
- ***Objective decision-making:*** *In the context of business resilience, decisions should be based on thorough data analysis to enable informed steps to overcome challenges;*
- ***Mutually beneficial relationships with suppliers:*** *A partnership-based relationship with suppliers can help to make the supply chain (end-to-end) more resilient and thus strengthen corporate resilience. Cooperation with suppliers should be based on mutual benefit in order to be able to respond to challenges in the long term.*

The TQM principles can be implemented in various ways. However, it is a demanding measure for companies that requires considerable commitment (GBTEC 2023). Long-term scientific studies, such as the EFQM Excellence Model, show that companies can outperform their competitors in terms of turnover, profit, productivity, and share value.

As already mentioned, there are hardly any correlations with TQM in the literature when it comes to corporate resilience. On the one hand, it appears that the disruptive change that has become apparent in recent years has resulted in a one-dimensional approach. On the other hand, TQM does not have a holistic character, as ecology, society and, in particular, people have become more of a focus alongside the quantitative values that are evaluated. Despite the proven successes up to the 1990s, TQM alone does not appear to be sufficiently tangible (Hendricks & Singhal 2010).

Conclusion: In summary, there is a lack of empirical research that examines the applicability of TQM in the context of corporate resilience. It appears that TQM is generally too static and cannot provide sufficient support without the corresponding extensions that are necessary for dynamic resilience. Key aspects have evolved significantly, and today's challenges require

adaptable concepts. It is therefore strongly recommended that TQM be expanded through holistic approaches and adapted to current requirements.

3.4.2.2 EFQM Model

The EFQM Model for Excellence is an approach for evaluating organizations, or rather management, in terms of sustainable excellence for all interested parties. Excellent results in terms of performance or customers are achieved, among other things, through leadership that raises the company's policies, strategies, resources, and processes to a high level. This provides management with relevant information on the relationships between cause and effect in the company (Krems 2009).

By 2019, the concept defined five fields in which so-called enablers are to be implemented and four fields in which key figures are to be collected. These in turn measure the progress in the organization towards the respective results achieved (Lay et al. 2009). The new EFQM Excellence Model 2020, on the other hand, asks three fundamental questions (Bruhn 2023):

- ***Why (Direction):*** *Why does the organization exist and for what purpose?*
- ***How (execution):*** *How does the organization intend to implement its strategy?*
- ***What (Results):*** *What the organization has achieved so far and what it wants to achieve in the future.*

The number of fields was also reduced to seven. A defined collection of key figures therefore only takes place in two fields instead of four (Mettier Wiederkehr 2020). In this respect, the collection of key figures has been relegated to the background for the time being. However, a comprehensive assessment is still possible on the basis of the RADAR logic, which is also used in the EFQM model. The RADAR logic serves as a dynamic evaluation tool that can be used in a company independently of the EFQM model (Bruhn 2023).

The RADAR logic includes the following assessments: Procedure, implementation, evaluation and improvement, relevance, and benefit as well as performance (Swiss Excellence Forum 2023). It is superimposed on the aforementioned elements of the EFQM Excellence Model (Bruhn 2023; Slawik 2019):

- ***Results:*** *How does the organization define the results it wants to achieve through its strategy?*
- ***Approach:*** *What procedures has the organization defined to achieve the desired results now and in the future?*
- ***Deploy:*** *How does the organization implement these procedures appropriately?*
- ***Assess and Refine:*** *How does the organization assess and improve the practices implemented in order to learn, improve and evolve.*

In the following Table 3-4, the EFQM model is considered in the context of corporate resilience and expanded to include newly developed resilience enablers in the context of this paper. This extension is based on the established EFQM model (Slawik 2019).

EFQM Main Criteria	EFQM Enabler	New developed (EFQM) Resilience Enablers
Approach - Deployment - Assessment & Refinement		
Direction	[1] Purpose, Vision & Strategy	- Innovative technologies, products, and services - Integrative hardware and software - Transparent access to products and services - Expansion into new business areas (e.g., artificial intelligence, e-commerce - Sustainable circular economy
Direction	[2] Organizational Culture & Leadership	- Freedom and responsibility - Development of innovative ideas - Openness and trust - Focus on excellence
Approach - Deployment - Assessment & Refinement		
Execution	[3] Engaging Stakeholders	- Customer feedback and ratings - Trend analysis - Partnerships with key suppliers - Identification of alternative sources of supply - Employee competencies - Investor relations communications - Cooperation with industry associations
Execution	[4] Creating Sustainable Value	- Environmentally friendly manufacturing and transport practices - Sustainable raw materials - Diversified and renewable energy sources - Design for environment - Social responsibility and employee engagement
Execution	[5] Driving Performance & Transformation	- Digital transformation strategies (e.g., cloud infrastructure) - Culture of innovation - Agile management practices and flexible organizational structures - Diversification of suppliers
Relevance & Usability - Performance		
Results	[6] Stakeholders Perceptions	- Customer perception - Employee perception - Investor perception - Social responsibility
Results	[7] Strategic & Operational Performance	- Reduce dependencies - Diversification - Automation of processes - Promote innovation - Flexible resource management - Monitoring performance indicators

Table 3-4: New Developed (EFQM) Resilience Enablers
(own illustration based on Slawik 2019)

The literature reveals a lack of resilience enablers in the context of corporate resilience within the EFQM model. Although various approaches exist, such as the EFQM Resilience Toolkit (INBIAN n. d.) or the EFQMplusR model (Gleich & Gleissner n. d.; Schüth & Peschl

2019), it is increasingly pointed out that simply adapting the resilience topic is sufficient. From the author's point of view, this view appears too superficial, as the topic of resilience is simply too complex to be integrated sustainably. In addition, the model is geared towards long-term and continuous change management. In this context, the question arises as to whether it is even capable of coping with abrupt shocks (Mooncamp 2022). Nevertheless, the EFQM model undoubtedly offers an open approach that provides an excellent basis for developing corresponding extensions. So far, however, there has been no comprehensive penetration or expansion of the model for excellence in this respect.

Conclusion: In summary and in the context of corporate resilience, the EFQM model lacks specific resilience enablers. Although various approaches exist, it is argued that a simple adaptation is not sufficient, as the issue of resilience appears too complex. The EFQM model is geared towards long-term change management and could therefore have difficulties coping with abrupt shocks. Nevertheless, as implemented, it offers an open basis for expansion.

3.4.2.3 St. Gallen Management Model

In order to explain the structure and approaches of management systems and the integration of corporate resilience in the company in more detail, the St. Gallen Management Model (SGMM) is also critically examined (Rüegg-Stürm 2016).

The model is an approach that serves to find answers to questions about the management, design, and organization of companies. This model focuses on the integration of different influences and the representation of their mutual relationships within an entrepreneurial network. If an overarching problem is divided into sub-questions and these sub-questions are in turn answered by separate investigations, there is a risk that no coherent, holistic solution to the overall problem will emerge. The model therefore offers itself as a kind of thought pattern in a complex world that enables management to adopt a consistent approach. In addition, the model distinguishes between normative, strategic, and operational dimensions, providing a comprehensive perspective on corporate management (Rüegg-Stürm 2016).

Figure 3-9 below shows the SGMM according to Rüegg-Stürm (2016), which resembles a racetrack:

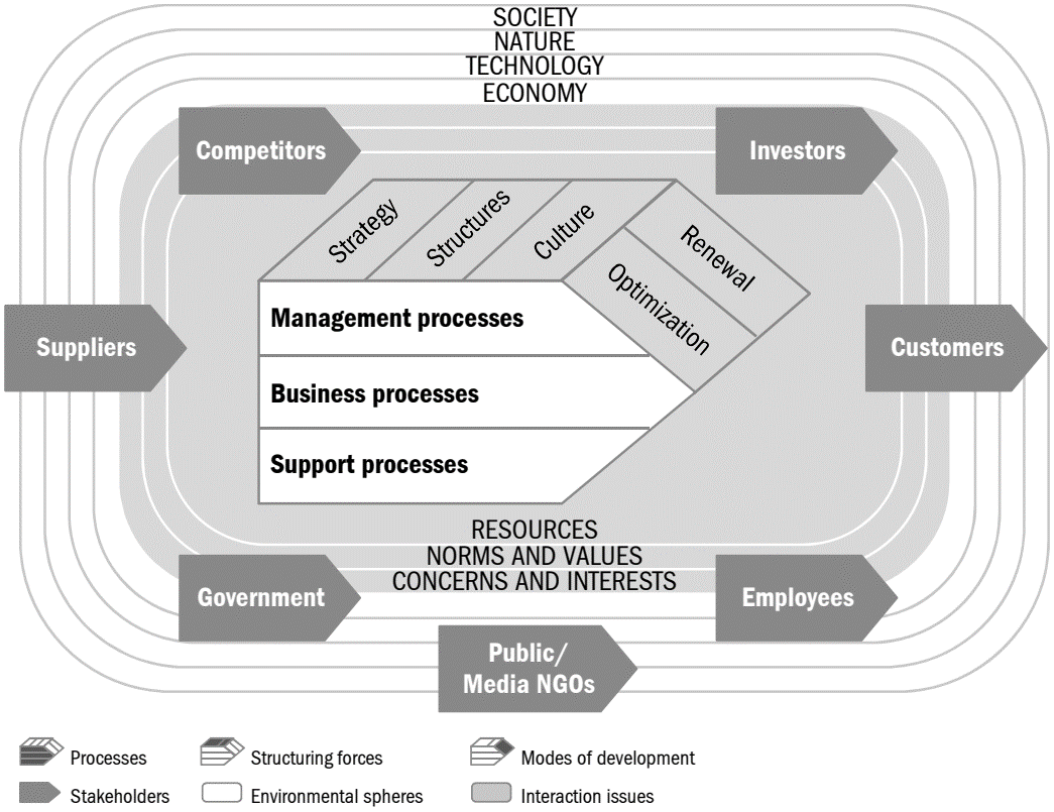

Figure 3-9: The St. Gallen Management Model (Rüegg-Stürm 2016)

According to Abegglen and Bleicher (2021), a distinction is made between a normative, a strategic and an operational dimension. The three levels are expanded and described below in the context of corporate resilience (Abegglen & Bleicher 2021):

- ***Normative level:*** *The focus here is on the company's general objectives, which are defined by guidelines and rules. The company's vision takes center stage and is the foundation for corporate policy and corporate culture. The main objective at this level is to create benefits for the company's relevant interested parties, whether internal or external. Taking into account the specific requirements of the company help to strengthen corporate resilience in particular;*
- ***Strategic management:*** *Based on the normative level, strategic management deploys resources to develop and maintain the company's potential for success in the context of resilience. Existing potential for success, the strategic success positions that have already been realized, are identified, and preserved. At the very same time, the development of new potential for success is targeted in order to ensure the company's future ability to overcome challenges and adapt to unforeseen events;*
- ***Operational management:*** *Operational management is responsible for implementing the guidelines from normative and strategic management, particularly with regard to increasing corporate resilience. The focus here is on*

implementation in the economic and social areas. This includes the analysis and optimization of performance processes, financial aspects, and information flows. In addition, the effectiveness of employee management is considered, as committed teams can make a decisive contribution to the resilience of a company.

These three levels of management are crucial to strengthening the company in the context of corporate resilience and making it more resistant to unforeseen challenges (Abegglen & Bleicher 2021).

According to Rüegg-Stürm (2016) and thus in the context of the SGMM, management is becoming increasingly complex and demanding. In a world that is becoming increasingly interconnected, effective management requires a variety of prerequisites. A full and comprehensive understanding of these prerequisites, both sound and far-sighted, is becoming increasingly important. Only on this basis can one's own management practice be shaped in order to successfully develop organizational value creation in line with the constantly growing environmental dynamics and taking into account resilient companies.

One critical comment is that the model does not take a comprehensive end-to-end view. The model focuses on a forward chain in the context of the supply chain. This means that the focus is on the sequence of activities or events that lead to the provision of products or services for the end consumer. A backward chain, which includes reactive corrective measures for all product groups, is not taken into account (Betzold et al. 2008). Irrespective of the consideration of corporate resilience, this represents a weakness of the model.

Conclusion: The model meets the relevant requirements at various levels in order to successfully support the integration of corporate resilience as a fundamental basis in companies. The only thing missing is the consideration of backward-looking corrective measures, which would enable a more comprehensive view.

3.4.2.4 Aachen Quality Management Concept

Another variant is the Aachen Quality Management Model (AQMM), which was developed at the Institute of Production Metrology and Quality Management in Aachen, Germany and the Fraunhofer Institute for Product Technology (Rehahn 2019). The authors of this model emphasize that existing concepts primarily aim to increase the match between customer requirements and product characteristics without explicitly considering the overall orientation of the company or its capabilities. Furthermore, due to their primary focus on value creation, these models lack appropriate mechanisms for feeding information back into neighboring processes and product groups. For this reason, the representation of information and communication relationships is often neglected and remains practically unoperationalized.

The components of the AQMM include management, resources, and services as well as the quality stream. In the area of management, the concept focuses on the efficient pursuit of goals and strategies, the design of organizational structures, the development of a management system and identity with values, with the emphasis on supporting the process organization.

The core of the model, which relates to company processes and workflows, is the quality stream. This comprises the Quality Forward Chain as well as the Quality Backward Chain as

structural elements. The first chain combines proactive and preventive measures for each product group, while the second organizes the reactive corrective actions for the product groups (unlike in the SGMM, for example, refer to Chapter 3.4.2.3). Defined control loops between these chains complement the model with further elements of continuous improvement. This enables comprehensive information feedback into all relevant processes and holistic mapping of product lifecycles from start to finish (Betzold et al. 2008; Huang et al. 2010; Rüegg-Stürm 2016; Schmitt 2011).

The third and final core element of the concept is the resources and services that reflect the capabilities required to achieve the objectives. The respective characteristics of the various company attributes are shown within the structural elements (Beaujean et al. 2008; Betzold et al. 2008; Rüegg-Stürm 2016; Schmitt 2011).

The structure of the aforementioned building blocks should always take into account the increase in customer satisfaction both externally and internally within the company as a key objective. In addition, the focus should also be on the continuous improvement of services, activities, and actions within the company according to Pfeifer and Schmitt (2014).

Figure 3-10 below shows the AQMM according to Pfeifer and Schmitt (2014):

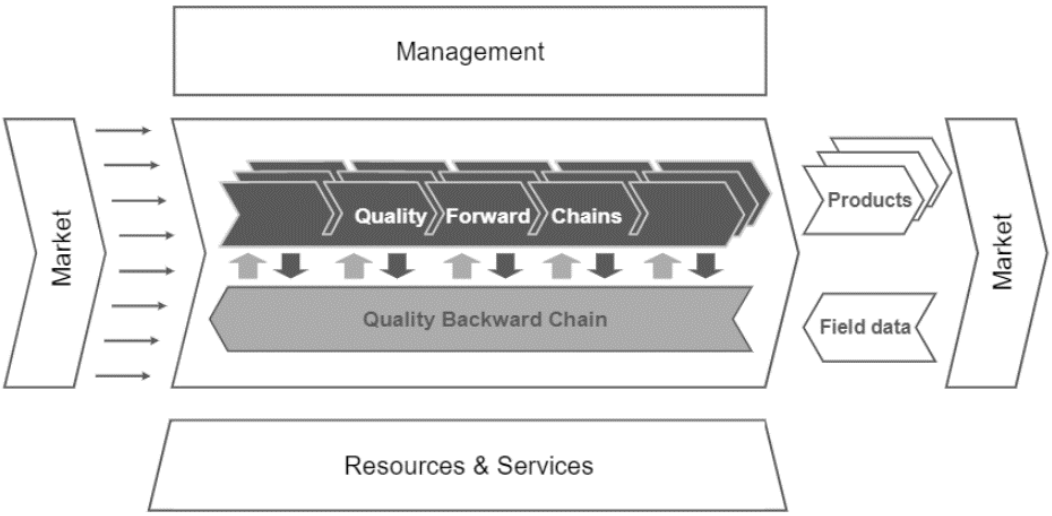

Figure 3-10: Aachen Quality Management Model (Pfeifer & Schmitt 2014)

Furthermore, the entrepreneurial task is to achieve an optimization between market requirements and company performance (Pfeifer & Schmitt 2014). In order to make this optimization more tangible and manageable, three additional perspectives (customer, management and operational perspective) are introduced in the AQMM and then specified in more detail in the context of corporate resilience.

The customer perspective plays a central role in aligning market requirements with the company's actual performance. The focus here is explicitly on the company's financial success and ability to act. The customer perspective, particularly with regard to product quality, supports the implementation of customer requirements in marketable products. In the AQMM, this

process, which represents the transformation of the company's input variables into output variables (from market to market), is represented by the quality stream. Continuous measurement and adjustment of this change ensures that the *"Customer Voice"* is optimally implemented, and that corporate resilience is strengthened (Pfeifer & Schmitt 2014).

The management perspective involves coordinating the company's direction and capabilities from a management perspective. Every company has a specific orientation that manifests itself in various aspects, such as corporate identity and strategy. The management perspective establishes the link between the company's orientation and its performance processes. This perspective is characterized by a top-down approach in order to define and adapt the company's orientation, taking into account the company's potential capabilities. The management perspective focuses on the definition of objectives and places special attention on the quality of the overall system. It therefore considers the proactive and responsible shaping of the framework conditions for the organization and focuses on the processes of the quality stream. As a result, the management perspective thus encompasses the normative (standards) and strategic direction of the organization and is responsible for the definition, development, and the integration of systematic and organizational competencies (Pfeifer & Schmitt 2014; Schmitt 2022).

The operational aspect focuses on implementing the objectives defined from the management viewpoint and optimizing the necessary processes. This includes adapting the company's capabilities to the company's direction. The perspective pursues a bottom-up approach and aims to align the required resources and specifications with the operational requirements that are derived from the management and customer perspective. A particular focus is placed on process quality. It ensures that services and resources are optimally provided to successfully implement the requirements of the quality stream (Pfeifer & Schmitt 2014).

Using the three perspectives (customer, management, and operations), the AQMM offers companies striving for corporate resilience ways in which qualitative thinking can be integrated into the various areas of the company. Only by considering all three perspectives can companies strengthen resilience by achieving the optimal balance between market demands and business performance while developing agile organizational structures within the given framework (Pfeifer & Schmitt 2014).

It is also important to note that every company is an important part of the global value chain. The *"market"* building blocks form the links of the quality streams between the individual entities, which together make up the entire value chain (Pfeifer & Schmitt 2014).

Conclusion: Similar to the SGMM, the model offers a way of integrating entrepreneurial resilience into companies. It places particular emphasis on taking into account the overall direction of the company and its capabilities. The model also includes a backward-looking approach. The different perspectives enable companies to find a balance between the demands of the market and their own performance. This makes a targeted contribution to strengthening corporate resilience. The AQMM also takes into account the networking between the various players in the global context of value chains.

3.4.3 Conclusion of the Discussion of Management Tools

A key component for the practical implementation of corporate resilience lies in the application of standards and norms as well as their concrete implementation in management

systems. While statutory regulations set out basic requirements for safety and environmental protection, standards such as those listed in sections 3.4.1.1 to 3.4.1.3 provide detailed technical specifications. These enable companies to meet these requirements effectively. In addition, standards help to reduce the burden of government regulations, among other things, and utilize the expertise of thousands of experts in Europe and around the world. As a result, standards and norms can be used as effective instruments for pursuing strategic goals, whether in international trade, research or even in building resilient corporate structures (Winterhalter 2023).

The application of integrated management systems (IMS) - the sum of various management systems (Kopia 20219; TÜV SÜD n. d.) - offers a great opportunity in the context of corporate resilience, as it focuses on sustainability - both ecological and social. Sustainability plays a decisive role in maintaining our economic strength and innovative capacity. But how are sustainability and innovation connected? Sustainability creates trust, trust promotes innovation, and innovation in turn enables sustainability. This cycle leads us from sustainable action to marketable innovations, which in turn enable a more sustainable future. Resilient structures form the bridge from sustainability to innovative capacity and thus ensure the competitiveness of the economy.

This is also confirmed by the Economist Impact study cited in chapter 3.4 (The Economist Group 2022). Since the start of the pandemic, sustainability has been one of the top five business priorities. Sustainability is defined in this study as follows Inclusion, social justice, and commitments to reduce carbon emissions are now at the top of the agenda, and organizations can no longer get away with simply publishing glossy mission statements. A proactive corporate approach is therefore essential (Winterhalter 2023).

The international standardization system plays a decisive role in creating comparability in the assessment of, among other things, the sustainability of products. This is of crucial importance in globalized markets. Integrated management models can serve as a basis for creating sustainable impacts (Winterhalter 2023).

Example
"The dandelion is impressively different from many other plants - but why? It continues to grow regardless of adverse soil conditions or how often it is pulled out as a weed. Through its umbrella seeds, it spreads seemingly effortlessly. The dandelion is thus a remarkable prime example of resilience - namely, the ability to respond robustly to disturbances or stresses and to recover successfully after setbacks. This concept is equally central to management systems and standards. The more resilient a company is, the better it can deal with unforeseen events and solve challenges as they arise. Therefore, management models and concepts but also management tools are crucial to achieve strong corporate resilience (Eulberg et al. 2023)."

Table 3-5: What does Corporate Resilience have in common with Dandelions? (Eulberg et al. 2023)

In the area of business resilience, general standards that define basic structures can be summarized. These include, in particular, ISO 22300, which explains terminology, and ISO 22316 (refer to Chapter 3.4.1.2), which deals with the principles of organizational resilience. Other standards from the ISO 223xx family deal with specific aspects of business continuity management and their implementation, among other things. At the same time, further international standards are being developed and are currently being prepared by ISO/TC 292. A comprehensive overview of currently valid ISO standards, standards in preparation and examples of national and institutional standards can be found in Appendix A (Ferdinand & Prem 2020; ISO 2023-C).

A key finding from the literature on management tools is the need to integrate resilience into the organizational structure and anchor it centrally. This recognizes the essential importance of a comprehensive perspective on resilience that covers all aspects of the organization's business. But this alone is not enough, as Dr. Stephen Flynn, Founding Director of the Global Resilience Institute at Northeastern University, points out (Flynn n. d.). He says: *"[...] what matters is how resilience is integrated into every business function and how you change the culture."* The key to successfully building business resilience lies in creating connections between the different business functions within the organization, which in turn requires the targeted use of resources. These findings are also supported by the Economist Impact study: The companies surveyed have focused the majority of their resilience-building efforts on ensuring smooth collaboration between different parts of the business (Flynn n. d.; The Economist Group 2022).

Figure 3-11 below shows the development and importance of cross-functional collaboration after and before the COVID-19 pandemic:

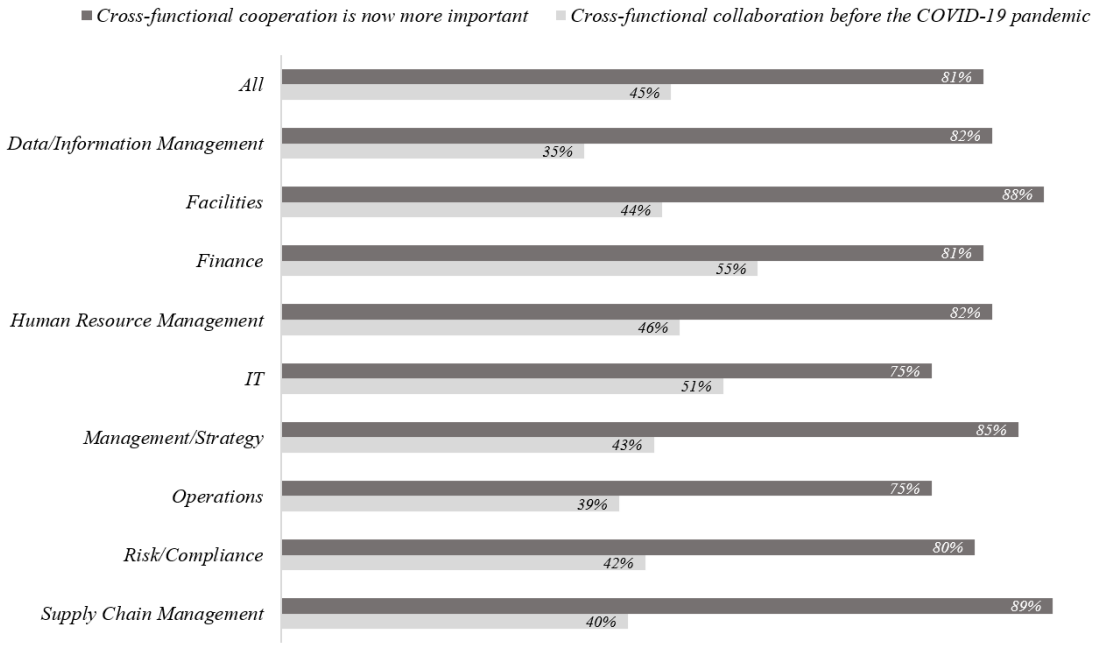

Figure 3-11: Cross-functional cooperation
(own illustration based on The Economist Group 2022)

Commenting on this new way of working, Scott Baldwin of Netflix suggests: *"The nature of decentralization requires you to reach out to others and become more cross-functionally oriented because you no longer live in a bubble with your functional team."* The emphasis on cross-functional collaboration is expected to increase further in the coming months and years (The Economist Group 2022). The author of this paper believes that management tools and a clearly defined, sustainable approach can support collaboration efforts. This represents another area that can gain importance in the mindset of organizations.

The allocation of resources is critical to these efforts, and, like many other systemic solutions, they need to be led by senior management. According to Margaret Millett of Uber, this means *"making sure that top management infuses this into the overall culture. [...] Management doesn't always stick to its word when it comes to implementation."* According to the aforementioned study, the Chief Executive Officer (CEO) or Board of Directors is responsible for building resilience in most cases, with the CEO being directly responsible for around a quarter of respondents (26 percent). Leadership from the top is most effective when the approach to building resilience is integrated throughout the organization down to the grassroots level. In this way, adequate resources and a collaborative approach go hand in hand (The Economist Group 2022).

According to the author of the paper, this applies to strictly hierarchically organized organizations; and not necessarily. A corporate culture cannot simply be changed with a few workshops and instructions, as it is deeply rooted. Moreover, old habits or what people regard as right or wrong behavior, as polite or impolite, as valuable or unattractive, cannot simply be changed. A culture that may have been formed over decades is stubborn and usually finds ways to perpetuate itself. It is said that a new strategy is implemented in around 100 days, a new structure in a year and a new culture in five or more years (Grätsch & Knebel 2018). Experience shows that a cultural change in a company down to the grassroots level takes around 1.5 to 2 years per management level.

Integral structures such as management tools not only strengthen the corporate culture, but also make a positive contribution to promoting cultural change towards corporate resilience. If the aspects of corporate culture that form the basis for any change are consistently taken into account, change in the company can progress more quickly. It is therefore necessary to make comprehensive and far-reaching changes in many areas of the company at the same time (Buchholz & Knorre 2023; Grätsch & Knebel 2018).

The standards and management models listed also take up these findings and support this holistic and creative approach in terms of an entrepreneurial view of resilience. Approaches such as the ISO 9000 ff. series of standards only meet these requirements to a very limited extent, as they provide only indirect (or no) guidance on the design of resilience management. The EFQM model has also been further developed by new (EFQM) resilience enablers (Schmitt et al. 2020).

In addition to the standards listed, the SGMM and the Aachen Quality Management Concept deliberately incorporate well-established and proven aspects as well as elements of existing management models. In particular, the external and internal influencing factors, the idea of continuous improvement and the requirements of a process-oriented approach of the ISO 9000 series are taken into account (Schmitt et al. 2020).

It can therefore be stated that standards are the starting point and that integrated management systems play a decisive role in promoting corporate resilience in companies. These systems already take specific requirements into account and expand on them. The scientific extensions of these models and concepts in the context of this thesis therefore address the deep anchoring of resilience in the corporate context. Management systems act as interpreters and translators of the corporate structure from top to bottom and have a significant influence on the corporate culture. Their processes and structures play a decisive role in maintaining and developing resilience, which contributes significantly to rooting the understanding of resilience in the company (The Economist Group 2022).

Companies still have a lot of work to do. Integration using proven standards and management models in the area of corporate resilience is still a rarity. The coordination of resilience efforts remains centralized in only a few companies and only in a few cases does it take place at a sufficiently high level in the organizational hierarchy. The financial and personnel aspects of sustainable resilience measures are also often inadequate. As Dr. Flynn aptly summarizes: *"The old method of risk management largely assumed that most days are fair weather days. Today, we live in a world where turbulence is the new normal."* It is the responsibility of management to develop a clear vision for building business resilience and to allocate appropriate resources to it. These efforts should include the creation of organizational structures that facilitate communication and coordination in strengthening resilience. Particular attention should be paid to adapting ways of working, improving governance, promoting sustainability, and increasing operational efficiency through (partly) existing standards and management models (The Economist Group 2022).

Both organizations and resilience experts, as well as academia, should focus on developing indicators and metrics that allow management to measure the impact of their resilience efforts and account for the results achieved. Building resilience in this way can have a tangible impact across the organization and not just be beneficial in times of disruption. Scott Baldwin of Netflix aptly sums up the benefits of this approach: *"You can prepare for bad things, and that preparation can produce good things."* (The Economist Group 2022).

Conclusion: According to the author, the implementation of corporate resilience requires the application of standards and their integration into management systems. On the one hand, these standards provide precise instructions and act as guidelines for implementation. On the other hand, they can also relieve companies of external pressure. Integrated management systems also emphasize the importance of sustainability and encourage innovation, which in turn helps to strengthen corporate resilience.

Furthermore, the application of international standards is essential for comparability in global markets. Being a resilient company requires deep integration and a cultural change that favors cross-functional collaboration. The allocation of sufficient resources and a targeted management level are important here.

Standards and models, such as the SGMM or the AQMM, facilitate and support the introduction of resilience in companies, shape the corporate culture and at the same time strengthen the understanding of resilience. Nevertheless, anchoring resilience in the corporate culture is not a matter of course. It requires clear objectives, suitable resources, and a revision of existing working methods. In addition, the development of indicators and metrics is crucial in order to evaluate the organizational impact and adequately prepare for future challenges in the long term.

3.5 Mathematical Models for Organizational Resilience

Understanding complex systems and dynamics, especially under conditions of high uncertainty, is a challenging task. These uncertainties often make it difficult to precisely analyze and predict system behavior. Therefore, robust mathematical models are essential to simplify such complex situations and make them more tangible. Mathematical models have played a crucial role during the COVID-19 pandemic in particular. Among other things, they were used to assess the impact of various policy measures and predict the spread. These models are not

only important for political decision-makers, who often have to act on the basis of these analyses but are equally relevant in a business context. The application of theories such as fuzzy set theory in such models enables better handling of the inherent uncertainties. By allowing for fuzziness and ambiguity in the models, a more realistic and flexible assessment of scenarios can be achieved. These techniques are therefore indispensable for transforming the complexity of the real world into mathematically manageable forms (Syga et al. 2022).

People spend a large part of their time solving problems, making decisions, or searching for documented information (Zimmermann 1993). A study by McKinsey (Abel et al. 2012; Ricoh n. d.) found that employees spend an average of up to 150 minutes a day searching for files and information.

Our decision-making processes are often accompanied by uncertainty. This happens for various reasons: Firstly, the initial situation may be so complex that a precise description is not possible. Secondly, there may be no clear idea of what we actually want. Thirdly, unknown factors, especially future events (including crises, shocks, or disruptions), may play a significant role. Our everyday language reflects these uncertainties. When we describe a problem in our usual language, we are in a sense creating a verbal model of the situation that reduces the complexity to a level that people can understand. Despite these sources of uncertainty, they do not prevent us from making decisions - in contrast to the classic IT approach to problem solving, where precision is of crucial importance (Nissen 2014; Zimmermann 1993).

Example
"To illustrate the principles of fuzzy logic, imagine that you want to help someone reverse into a parking space. You will then give instructions of the form "turn a little more to the left", "turn a little more back" or "turn harder", the driver will usually understand this and be able to react appropriately. Instructions such as "turn the steering wheel 1 degree, 4 minutes, 1 second to the right", "and now 13.5 millimetres to the rear", "and now 15 degrees to the right" would be neither understandable nor easy to carry out (Zimmermann 1993)."

Table 3-6: The Principles of Fuzzy Logic in Reverse Parking (Zimmermann 1993)

In 1973, the founder of fuzzy logic, mathematician Lotfi A. Zadeh from the University of California at Berkeley, explained in his *"Principle of Incompatibility"* that precision beyond a certain level is not useful: *"As the complexity of a system increases, our ability to make precise and significant statements about its behavior decreases. Beyond a certain threshold, precision and significance (relevance) become almost mutually exclusive properties.*" (Cisek 2021; Nissen 2014; Zimmermann 1993).

In 1964, Zadeh was planning to fly from New York to San Francisco. At John F. Kennedy International Airport, he inquired whether his flight was on time and received the following reply: *"Rest assured, your plane won't be too late."* Zadeh politely took his seat again and tried to define a category for *"not too late aircraft"* based on the departure board. The difficulties he encountered made him think about the problem for longer and a year later he wrote the first scientific paper on the theory of *"fuzzy sets"*. Since then, there have been numerous publications in this field of research. The theory can be understood as a generalization of both classical set theory and classical two-valued logic (Nissen 2014; Zimmermann 1993).

In contrast to traditional set theory, in that an element is either part of a certain set or not, the theory of fuzzy sets allows for a more differentiated degree of membership. The level

of membership is typically defined in the interval between 0 and 1 (binary statement). A degree of 1 means full membership and a degree of 0 means no membership. There is a continuous transition between these extreme values from *"being an element"* to *"not being an element"* (Nissen 2014; Zimmermann 1993).

The following definition is intended to serve as a mathematical representation of vaguely defined terms. Let's take the term *"comfortable room temperature"* as an example: If this is to be described or - which amounts to the same thing - the set of comfortable room temperatures is to be defined, only a clearly defined interval, for example from 20.0 to 25.0 degrees Celsius, could be specified in classical theory. A temperature of less than 20.0 degrees would therefore be classified as uncomfortable, which does not necessarily correspond to human perception. In the example of fuzzy sets, on the other hand, 19.9 degrees could be regarded as *"possibly no longer so pleasant"*, and this temperature could be assigned a degree of membership of 0.8 (assuming that the degree of membership decreases linearly with one degree of temperature difference) to the set of pleasant room temperatures. A fuzzy set is thus comprehensively described by the membership function, which indicates for each temperature the extent to which it is perceived as pleasant (Meyers 2009; Nissen 2014; Zimmermann 1993).

Essential elements of fuzzy logic are based on linguistic formulations and are referred to as linguistic variables. As shown in Figure 3-12 below, for example, instead of the binary statement *"dark"* (0) and *"bright"* (1) in a fuzzy set, different levels (bright; shady; gloomy; dark) of brightness are distinguished and described by a linguistic expression (terms) of a natural language. Since words are not as precise as numbers, they are represented by fuzzy sets. The levels, which are divided into intervals (0 to 1), are used to apply rules, such as switching the headlights on a vehicle on and off at a certain level (Begerow 2023; Nissen 2014; Zimmermann 1993).

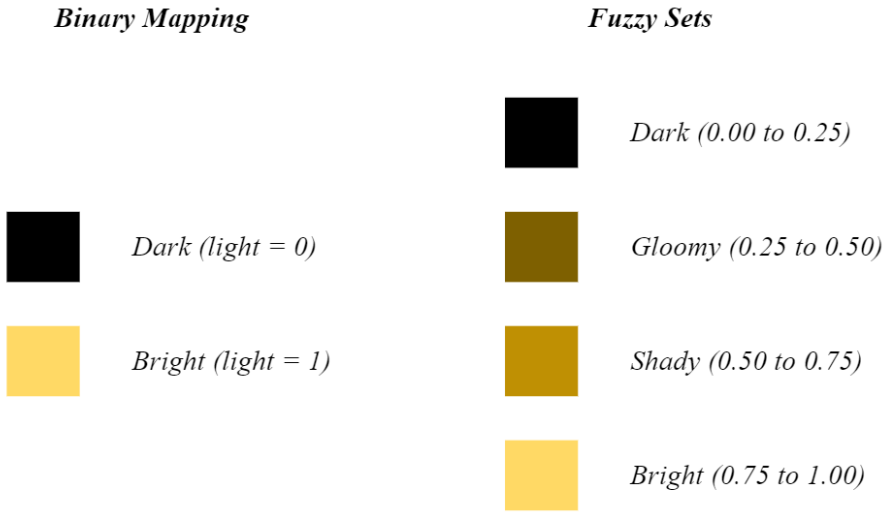

Figure 3-12: Fuzzy Sets and Membership Functions
(own illustration based on Begerow 2023)

Membership of an interval or level is determined by one or more membership functions. An input variable or a value cannot be strictly assigned to one or another specific set, but only belongs to a set in a specific part. Figure 3-13 below illustrates the transition of brightness during the course of the day. During the night, the proportion *"Dark"* is 1 and *"Bright"* is 0, while during the day the proportion changes. During the day, this proportion changes and takes on values such as *"Gloomy"* and *"Shady"* (Begerow 2023).

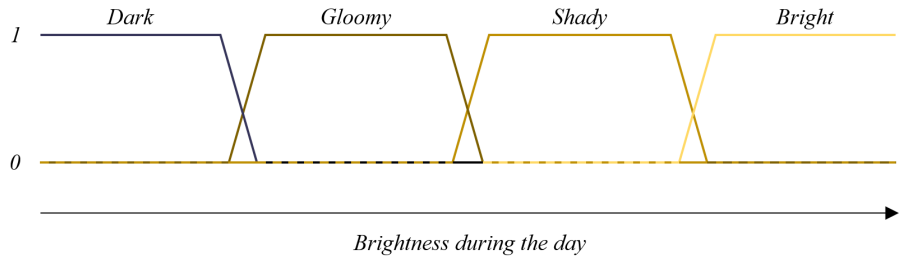

Figure 3-13: Affiliation Functions
(own illustration based on Begerow 2023)

Expert knowledge is used within the methodology. If you want to follow the approach of an expert system, the input data must first be converted into a linguistic form (fuzzification). After processing by the expert system, the resulting linguistic statements, which are in the form of membership functions of linguistic variables, are converted back into a numerical form (defuzzification). Algorithmic applications normally assume that a mathematical model or a mathematical method is available for a problem. Since most of these methods work with precisely determined values and many problems are therefore inadequately described, the theory of fuzzy sets is used to try to better adapt the model to the problems (Nissen 2014; Zimmermann 1993).

3.5.1 Basic Definitions in Fuzzy Set Theory

This section introduces the basic definitions and terms that are relevant for understanding the fuzzy model in this paper (Dubois et al. 1979):

Definition 1: Fuzzy set $\tilde{A}$ can be formally represented as follows:

$$\tilde{A} = \{x, \mu_{\tilde{A}}(x) | x \in X, 0 \leq \mu_{\tilde{A}}(x) \leq 1\}$$

where:

Fuzzy set $\tilde{A}$ is defined on the universe set $x \in R$. In general, set X can be either finite or infinite. $\mu_{\tilde{A}}(x)$ is a membership function of fuzzy set $\tilde{A}$. Each fuzzy set is completely and uniquely determined by its membership function.

Definition 2: A fuzzy number $\tilde{A}$ is a convex normalized fuzzy set $\tilde{A}$ of the real line R such that:

if exist $x_0 \in R$ such that $\mu_{\tilde{A}}(x_0) = 1$.

$\mu_{\tilde{A}}(x)$ is piecewise continuous.

Definition 3: Fuzzy number $\tilde{A}$ on R is to be a TFN if its membership function $\mu_{\tilde{A}}(x)$: $R \to [0,1]$ is equal to:

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x-l}{m-l} & x \in [l,m] \\ \dfrac{x-u}{m-u} & x \in [m,u] \\ 0 & otherwise \end{cases}$$

Where $l \le m \le u$, l and u stand for the lower and upper value of the support of X respectively, and m or the modal value. The triangular fuzzy number can be denoted as (l, m, u). The support of X is the set of elements $\{x \in R | l < x < u\}$. When $l = m = u$, it is a non-fuzzy number by convention.

Definition 4: The α-cut of the fuzzy number $\tilde{A}$ is defined as:

$$\tilde{A}^{\alpha} = \{x, \mu_{\tilde{A}}(x) | x \in X, 0 \le \mu_{\tilde{A}}(x) \le \alpha\}$$

where $\alpha \in [0,1]$.

The symbol $\tilde{A}^{\alpha}$ represents a non-empty bounded interval contained in X, which can be denoted by $\tilde{A}^{\alpha} = [l^{\alpha}, u^{\alpha}]$, l^{α} and u^{α} are the lower and upper bounds of the closed interval, respectively.

Definition 5: A linguistic variable is a variable whose values are expressed in linguistic terms (Zimmermann 1996; Zimmermann 2011).

Definition 6: The operations of fuzzy numbers are based on the theorem set by Dubois and Prade (1980). Let two triangular fuzzy numbers $\tilde{A} = (l_1, m_1, u_1)$ and $\tilde{B} = (l_2, m_2, u_2)$. Also, $\lambda = (\lambda, \lambda, \lambda)$ is a crisp number. Basic mathematical operations are:

$$\tilde{A} \oplus \tilde{B} = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$

$$\tilde{A} \ominus \tilde{B} = (l_1 - u_2, m_1 - m_2, u_1 - l_2)$$

$$\tilde{A} \otimes \tilde{B} = (l_1 \cdot l_2, m_1 \cdot m_2, u_1 \cdot u_2)$$

$$\tilde{A} \div \tilde{B} = \left(\frac{l_1}{u_2}, \frac{m_1}{m_2}, \frac{u_1}{l_2}\right)$$

$$\tilde{A}^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right)$$

$$\lambda + \tilde{A} = \tilde{A} + \lambda = (l_1 + \lambda, m_1 + \lambda, u_1 + \lambda)$$

$$\lambda \cdot \tilde{A} = \tilde{A} \cdot \lambda = (l_1 \cdot \lambda, m_1 \cdot \lambda, u_1 \cdot \lambda)$$

Definition 7: Defuzzification is the process by which a fuzzy number is transformed into a corresponding scalar value. The simple gravity method for the TFN $\tilde{A} = (l, m, u)$ yields the corresponding scalar A according to the formula (Zimmermann 1996; Zimmermann 2011):

$$A = \frac{(u - l) + (m - l)}{3} + l$$

Definition 8: The Euclidean distance between these two TFNs $\tilde{A} = (l_1, m_1, u_1)$ and $\tilde{B} = (l_2, m_2, u_2)$ is (Zimmermann 1996; Zimmermann 2011):

$$d = \sqrt{\frac{(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2}{3}}$$

3.5.2 Comparison of Fuzzy Numbers

The simple method of comparing fuzzy numbers and determining the degree of conviction that one fuzzy number is greater than or equal to another is described below (Baas & Kwakernaak 1977; Dubois & Prade 1979):

Definition 1: Let $\tilde{A} = (x; l_1, m_1, u_1)$ and $\tilde{B} = (y; l_2, m_2, u_2)$ be two fuzzy numbers with their supports defined on R.

Where l_1, l_2, u_1, u_2 are lower and upper bounds and m_1, m_2 are modal values of $\tilde{A}$ and $\tilde{B}$, respectively. Let $m_2 > m_1$ and $l_2 < l_1 < u_2$ and $l_1 < u_2 < u_1$, as shown in the following illustration:

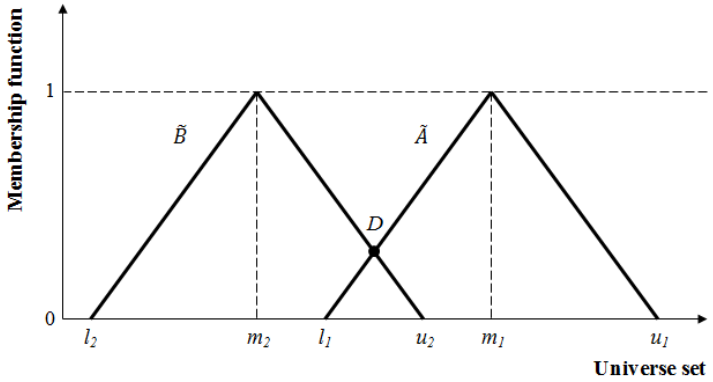

Figure 3-14: Fuzzy numbers $\tilde{A}$ and $\tilde{B}$
(own illustration based on Baas & Kwakernaak 1977)

Degree of belief that $\tilde{B}$ is greater than or equal to $\tilde{A}$ is denoted by $Bel\left(\tilde{B} \geq \tilde{A}\right)$ which is given using of the operation max and min (Baas & Kwakernaak 1977):

$$Bel\left(\tilde{B} \geq \tilde{A}\right) = \sup_{x \geq y} \min\left(\mu_{\tilde{A}}(x), \mu_{\tilde{B}}(y)\right)$$

From Figure 3-14 and Definition 1 it follows that:

$Bel\left(\tilde{A} \geq \tilde{B}\right) = 1$, because $\mu_{\tilde{A}}(m_1) = 1$ and $\mu_{\tilde{B}}(m_2) = 1$ and $m_1 > m_2$.

Definition 2: At the same time $Bel\left(\tilde{B} \geq \tilde{A}\right)$ is equal to the ordinate of point D, which belongs to both $\tilde{A}$ and $\tilde{B}$, i.e., it is the supremum of intersection $\tilde{A} \cap \tilde{B}$.

$$Bel\left(\tilde{B} \geq \tilde{A}\right) = ordinate\ of\ point\ D$$

When $\tilde{A}$ and $\tilde{B}$ are triangular fuzzy numbers, the ordinate of D is given by equation:

$$Bel\left(\tilde{B} \geq \tilde{A}\right) = \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}$$

Conclusion: Fuzzy logic makes it possible to take uncertainty into account by using fuzzy sets and linguistic variables. It allows for differentiated degrees of membership, which enables more accurate modeling of fuzzy terms. With regard to the research gaps, the use of the hybrid fuzzy model can thus also accurately determine the total value of the stress factors affecting each identified KPI.

The next sections build on this foundation by using heuristic methods and exact methods to optimize the results obtained by fuzzy logic. This allows practical solutions to be developed for complex problems in industrial and uncertain environments.

In addition to the previous text, the application of the Branch-and-Bound algorithm offers a new approach in this context. These algorithms, originally used in operations research and computer science, offer a systematic method for solving optimization problems. The optimization of RFs, with respect to budget and applicability constraints, makes this approach particularly valuable (Kerr 2016; Macuzić et al. 2016; Morrison et al. 2016; Tasic et al. 2020). In general, the problem is divided into small sub-problems (Branch), evaluated (Bound) and finally only the promising ones are pursued further (Aleksić et al. 2024; Bollwein & Westphal 2021; Tadic et al. 2024).

The method enables this final solution space to be searched efficiently and optimal to be determined (Aleksić et al. 2024; Lawler & Wood 1966; Tadic et al. 2024).

The application of this optimization method to organizational resilience is relatively new and therefore offers considerable research potential. Despite extensive research in the respective individual disciplines, there is a notable research gap at the interface between organizational resilience and exact optimization methods. Previous studies mostly focus on traditional approaches, such as risk management strategies and organizational learning processes, and often overlook the potential of advanced methods (Aleksić et al. 2024; Arsovski et al. 2015; Nozhati 2021; Tadic et al. 2024).

In the present work, the study relies on the fuzzy Delphi method to evaluate RFs. The Branch-and-Bound algorithms are still insufficiently researched in their application to improve organizational resilience as described (Coniglio et al. 2021). This research gap therefore offers a significant opportunity to use precise optimization methods and, above all, heuristic techniques to address the complex and dynamic requirements of organizational resilience (Aleksić et al. 2024; Hassani et al. 2013; Tadic et al. 2024).

Building on these findings, an innovative application of the Branch-and-Bound algorithm is presented in the following sections. This approach is intended to show how the resilience of organizations can be effectively improved through targeted resource allocation and optimization. This represents an extended, practicable and efficient way for companies to strengthen their adaptability in uncertain times (Aleksić et al. 2024; Tadic et al. 2024).

The ability of companies to develop resilience capacities to deal with unexpected events and recover from setbacks is crucial for ongoing success (Duchek 2019). Furthermore, a model for optimized improvement of RFs considering various constraints can be defined (Aleksić et al. 2024; Tadic et al. 2024).

The final results of the conducted research (Aleksić et al. 2024; Tadic et al. 2024) may differ only marginally from each other. With regard to calculation complexity, simplicity and comprehensibility, the selected approach according to Aleksić et al. (2024) is pursued in this dissertation.

"Correct understanding of a thing and misunderstanding of the same thing are not completely mutually exclusive."

Franz Kafka (1883 to 1924): Austrian writer.

4 RESEARCH METHODOLOGY

In addition to the literary discussion, an empirical analysis of the research methodology now follows. This chapter presents the approach used to answer the hypotheses in relation to research gaps both at the model level and, in part, at the holistic level (refer to Chapter 2.2). First, the research methodology is presented in general, with the following sections providing an overview of the empirical research conducted, which includes the selection of resilience indicators and their evaluation:

- *The presentation is based on the Fuzzy Delphi Technique, including the APQC's Process Classification Framework (Huber et al. 2023);*
- *Similarly, the method for aggregating indicators is described according to the guidelines of the Organization for Economic Cooperation and Development (OECD). This method generally describes a process in which various individual indicators are combined to form a composite indicator (OECD 2008-A);*
- *The indicators are then compared using Porter's Value Chain Analysis (VCA);*
- *Similar to the previous point, the standards are also aligned with the Global Reporting Initiative (GRI) to ensure consistency with this globally recognized guideline.*

The GRI helps organizations to report their environmental, social, and economic performance in a comparable manner (Gehmayr 2021). Finally, the methods are compared.

Introduction of the Fuzzy Delphi Technique

The Delphi method was developed by the RAND Corporation in the 1950s to create reliable forecasts and reduce uncertainties in the decision-making process (Mostafa et al. 2010). It is based on an iterative process in which DMs submit their opinions anonymously. Over several rounds, the DMs' views are summarized and reported back. The DMs can then adjust their opinions based on the feedback from the other participants. This process is repeated until consensus is reached, or opinions stabilize. In the course of this research, two rounds were defined in order to limit the time required by top management, especially as consensus was reached very early on (Salman & Tharwat 2020). The first round was accompanied, whereby the interviewer effect must be taken into account. In empirical research, this can lead to systematic distortions in the survey results and is due to the influence of the interviewer. This applies in particular to oral surveys. In order to minimize such possible distortions as far as possible, potentially influenceable factors were varied and already taken into account when

selecting the KPIs (Antwerpes 2016). The second round took place independently of this (Nemet 2023).

Example
"The Delphi effect was described by Eric S. Raymond in his book "The Cathedral and the Bazaar" and explains the phenomenon that the opinions of experts respectively DMs tend to converge or form consensus within the framework of a structured, multi-stage process - as used in the Delphi Technique. This effect results from iterative rounds in which DMs reconsider and adjust their views based on the aggregated results of the group, causing opinions to increasingly converge and eventually a consensus to emerge (Nemet 2023; Raymond 2001)."

Table 4-1: The Cathedral and the Bazaar (Nemet 2023; Raymond 2001)

Various variants of the Delphi method are mentioned in the literature, which can be used depending on the area of application, for example in strategic management. The most common of these are (Nemet 2023):

- ***Classic Delphi method:*** *The opinions of DMs are obtained in writing or electronically (e.g., by email) and processed iteratively in several rounds. Initially, a broad spectrum of opinions and assessments is collected. Over the course of several rounds, the DMs are encouraged to reconsider the results, adjust them if necessary and either form a consensus or stabilize their opinions. This method is used in the present research;*
- ***Policy Delphi:*** *This variant focuses on the identification, evaluation, and prioritization of strategies. Instead of a consensus, the focus is on recognizing differences of opinion and uncovering the pros and cons of various approaches. This method is intended to help develop a greater understanding of possible options for action and their effects;*
- ***Real-time Delphi:*** *Here, the opinions of DMs are obtained and discussed in real time, for example via video conferencing. This contemporary adaptation of the classic Delphi method enables real-time interaction between the DMs. Opinions can be exchanged immediately, and the iterative process accelerated, which can lead to both more efficient consensus building and faster decision-making.*

The classic Delphi method was selected for this research as it is best suited to the specific research objectives and methodological requirements. It is also suitable for a wide range of questions.

The following figure 4-1 shows both the general steps of the Delphi method and the steps added by the author. This was derived for the evaluation of sustainable KPIs (Nemet 2023):

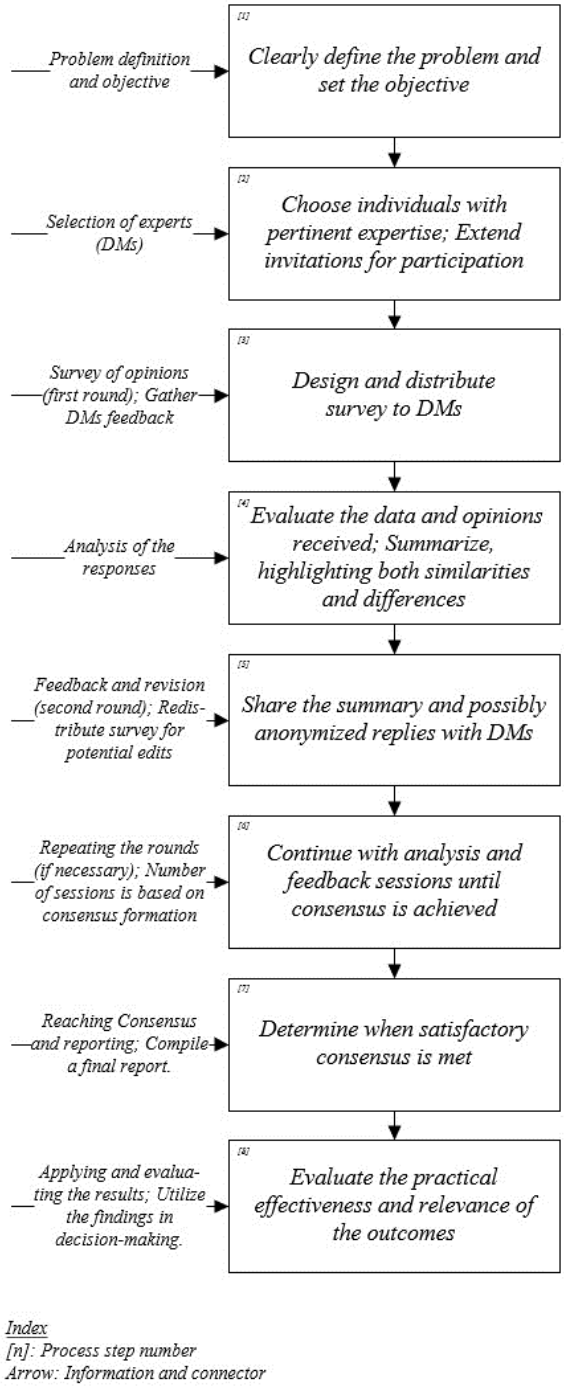

Figure 4-1: Assessment Procedure of Sustainable KPIs
(own illustration based on Nemet 2023)

By carefully selecting the DMs, both in terms of their different perspectives and their expertise, care was taken to ensure that a rapid consensus could be reached (analogous to Real-Time Delphi, for example). It is also relevant to emphasize that not only the number of respondents, but also the number of implementation rounds is important for reliable results.

Furthermore, it is of central importance to formulate clear and comprehensible questions in order to obtain precise answers from the DMs, which also increases their motivation (Nemet 2023). Finally, it is essential to share the results with all participants after the survey has been completed and to inform them about the next steps, as transparent communication is a key element for success.

Conclusion: The Delphi method is an iterative process for forming opinions with the aim of minimizing uncertainties in decisions (Amoushahi et al. 2022). Clear questions, a careful selection of diversified DMs, clear communication and the right number of iteration rounds are essential for the effective application of this method. This favors rapid consensus building and precise feedback from the DMs. However, according to Lenk et al. (2009), it should be emphasized that the result is ultimately a collection of subjective evaluations and should by no means be regarded as objective truth. Misinterpretations of this fact could lead to exaggerated expectations of the procedure. However, the structured procedure increases the probability that the group judgment, which is formed from the individual subjective opinions, comes closer to the actual facts.

[2] OECD Method

The OECD was founded in 1961 (OECD n. d.-B) and is an international organization that aims to improve policies for a better living environment. Its focus is on prosperity, equity, opportunity, and quality of life for all. Together with national governments, policy makers and members of the public, the organization develops international standards and evidence-based solutions to address a wide range of environmental, social, and economic challenges. With a wide range of data collection and analysis, the OECD provides a comprehensive knowledge platform on a variety of topics: From economic development and job creation to education. They promote the exchange of experiences and good practices, formulate policy recommendations and support international standard-setting (OEDC n. d.-C).

The OECD also describes a method for aggregating indicators. This generally represents a process in which various individual indicators are combined to form a composite indicator. Composite indicators are useful for presenting complex or multidimensional concepts, which usually defy direct measurement, in an easily understandable way. However, according to Fetzer and Benz (2004) and the OECD (2014-D), this can lead to challenges in terms of weighting, normalization, and aggregation of the individual indicators.

Below are some general steps as well as steps extended by the author (*Pathways to Crafting Sustainable Indicators*) based on the OECD Handbook that can be considered in the OECD methodology for composite indicators (SME Portal 2021; OECD 2014-D):

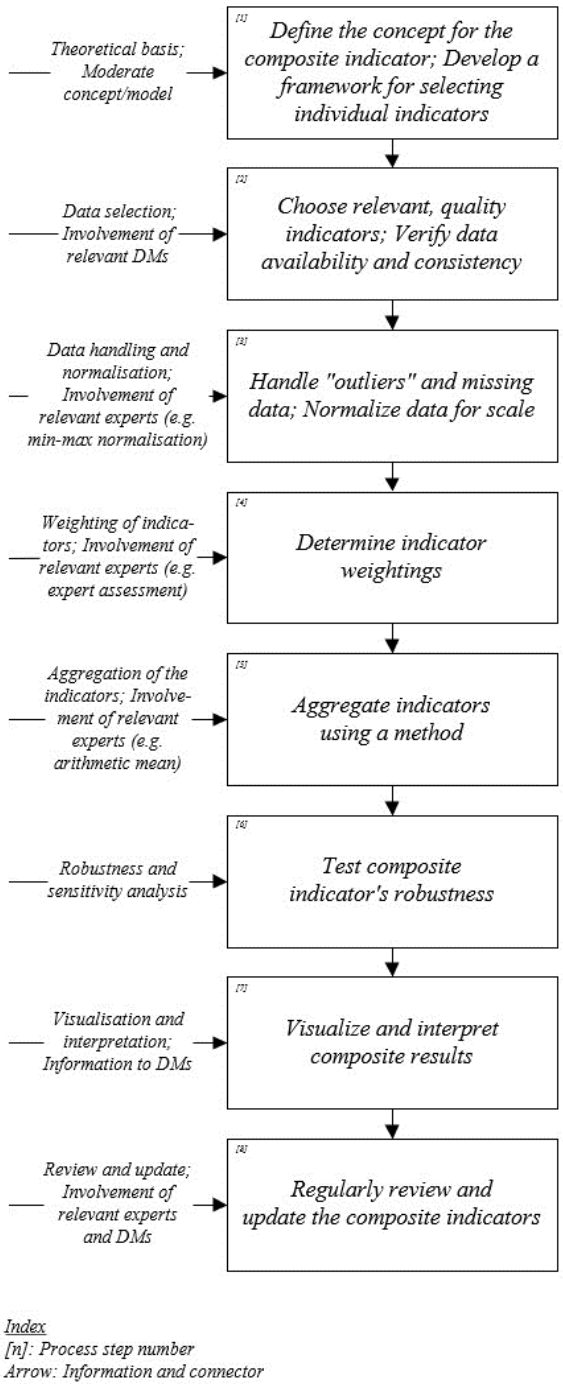

Figure 4-2: Eight Steps to Sustainable Indicators
(own illustration based on SME Portal 2021 and OECD 2014-D)

It should be noted that when developing a composite indicator, attention should always be paid to a transparent and comprehensible methodology. This is the only way to ensure the credibility and, above all, the acceptance of the results by all interested parties and, above all, DMs.

But how do you approach relevant KPIs? In particular, in the appropriate number to determine both an efficient and agile approach for companies.

From the author's point of view, there are two methodological alternatives that can be used individually or in combination, depending on the context. The combined approach is described as part of a systematic approach to corporate resilience. This is essential as the monitoring of KPIs is crucial for companies, but experience has shown that they tend to be defined imprecisely. If KPIs are not sufficiently specific or are formulated too generally, they are not measurable and consequently lose their value. In addition, tracking too many KPIs can cause a company to quickly lose focus on its primary goal. The recent pandemic has also highlighted that the majority of KPIs are heavily influenced by external factors. Although external factors undoubtedly have a significant impact on the conditions under which a company operates, they cannot be controlled. It is therefore crucial to ensure that your KPI set also includes indicators that can be measured independently of external factors. It is also essential to define clear responsibilities or *"owners"* for the KPIs who are responsible for achieving the defined targets. Finally, there is a partly contradictory observation regarding the measurement of identical KPIs to other companies for the purpose of benchmarking. Although it is tempting to track identical KPIs that are also tracked by the majority of companies in the industry. Nevertheless, it is crucial to determine KPIs that are specifically tailored to your own corporate strategy (Zhukova 2020).

In order to provide a final answer to the introductory question, the following section provides an insight into VCA according to Porter.

[3] Value Chain Analysis

The VCA was originally published in Michael E. Porter's book *"Competitive Advantage"* in 1985. The analysis enables a detailed consideration of the values of every aspect of a company along the supply chain (Kelwig 2022). The analysis model also acts as an extension of the business model and focuses primarily on optimizations (e.g., reducing production costs) and alignments (e.g., increasing sales) with the aim of generating value through all activities in the company. These are categorized into the primary and the supporting activities. Primary activities, which represent the supply chain from product manufacturing to sales and customer service, include inbound logistics, production, marketing and sales, outbound logistics and service. Although the supporting activities do not contribute directly to production or sales, they are still necessary to carry out the primary activities. These activities include infrastructure development, human resource management, technology development and procurement (Betzler & 2020; Heizer 2008; Sztuka 2023).

In the context of the creation of KPIs as well as the author's opinion, these can be derived directly from the activities described and taking into account the previous chapter. According to Dieffenbacher (2023) and Sztuka (2023), the individual activities can be further subdivided depending on their relevance to the company and the purpose of the analysis. For example, production/operations could be subdivided into assembly and packaging and marketing and sales into advertising, sales promotion or field service. Service could be subdivided into customer care and maintenance and repair, while technology development could be divided into product and process technology or work processes. A further systematization of this subdivision is possible by distinguishing between direct and indirect activities. Direct activities directly serve to create value for the customer (e.g., product design, final assembly, field service), while

indirect activities enable the continuous execution of direct activities (e.g., maintenance, sales administration).

Figure 4-3 below shows Porter's extended value chain model. As with the SGMM (refer to Chapter 3.4.2.3), this model does not include a backward chain. As already mentioned, this includes reactive corrective measures. In order to remedy this weakness in the context of corporate resilience, the model was expanded accordingly (grey coloring).

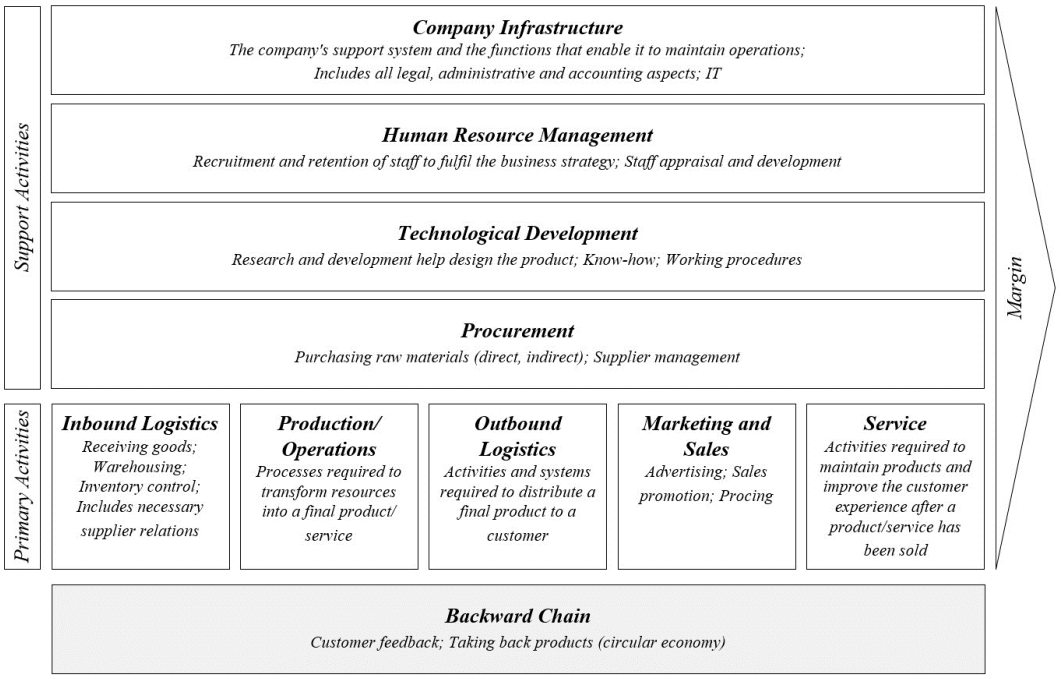

Figure 4-3: Porter's Value Chain Model including a Backward Chain
(own illustration based on Dieffenbacher 2023)

As already explained, the backward chain enables deeper control of the entire supply chain and offers companies significant advantages such as increased efficiency, reduced costs, and the opportunity to acquire intellectual property, which can optimize both product availability and profit margins (Cuofano 2023).

Within the context of this chapter, a comprehensive derivation of possible internal KPIs from the direct and indirect activities to possible KPIs from the literature is now possible. These help decision-makers to measure, monitor and optimize performance-critical corporate activities. For improved external reporting, it is advisable to take the GRI guidelines and indicators into account. Irrespective of this, it is always worthwhile comparing the KPIs internally within the company, as reporting is firmly established and is being continuously developed in cooperation with companies, investors, rating agencies, auditors, associations, trade unions, non-governmental organizations (NGOs) and academics (Malangré-Baldin 2015; Verhoeven 2022).

Conclusion: In the context of corporate resilience and using the OECD method, the VCA aims to examine and optimize a company's value creation along its supply chain in order to strengthen its ability to deal with uncertainties and crises. By precisely identifying KPIs from

the activities, the company's performance can be measured and improved. The integration of a backward chain into the extended value chain model, which enables reactive measures, completes the end-to-end view, and strengthens corporate resilience. This opens up the possibility of deriving specific corporate KPIs as well as RFs and establishing comparability with the GRI guidelines in order to make external reporting transparent and trustworthy for interested parties. Overall, the VCA contributes to the creation of a more resilient corporate structure that is able to react flexibly to changes and future crises.

[4] Global Reporting Initiative

The task of the GRI is to develop globally applicable guidelines for sustainability reports that can be used by large companies as well as small and medium-sized enterprises, other organizations such as cities and municipalities or governments and NGOs. The aim is to present the economic, ecological, social, and societal performance of the respective reporting party to a wide range of stakeholder groups in a standardized and comparable manner. Currently, more than 5,000 companies, associations, and organizations from over 70 countries worldwide use the guidelines of the GRI, which was founded in 1997. 83% (2015: 63%) of DAX[1] 40 companies now base their sustainability reports on these standards (Hillmer 2020; Malangré-Baldin 2015; Verhoeven 2022). They make it possible to compare companies within a sector, provided they publish the relevant data.

Any organization, regardless of its type, geographic location, size or reporting experience, can apply the GRI Standards. This allows them to report on their impacts on the environment, economy, and people, as well as their impacts on human rights. The reported information can be used by the organization for decision-making, for example in setting goals or evaluating and implementing its strategies using indicators. In addition, stakeholders can use the GRI Standards to understand which aspects organizations should report on. These stakeholders can also use the information provided by an organization to assess how they are or could be affected by the organization's activities (GRI 2023).

The GRI Standards are conceived as a system of interlinked guidelines and have been divided into three series since 2021: Universal Standards, Sector Standards and Thematic Standards (see Figure 4-4 below). The standards are applicable to all organizations that report in accordance with the GRI Standards. Depending on their industry affiliation, organizations use the industry standards and, depending on their core topics, the topic standards (GRI 2023).

[1] The DAX is the most important German share index.

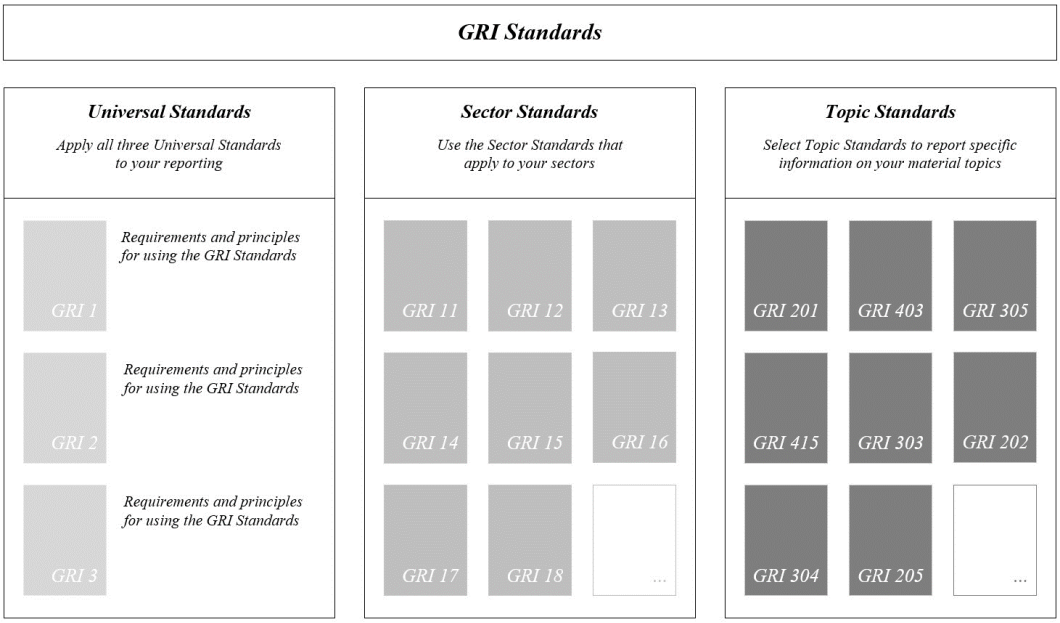

Figure 4-4: GRI standards
(own illustration based on GRI 2023)

When applying the GRI Standards, an organization typically starts with the Universal Standards, which introduce the purpose and system as well as key concepts for sustainability reporting. They also define the reporting requirements and principles that an organization has to meet in order to report in line with the GRI Standards. They also provide step-by-step guidance on how to identify material topics. In addition, the Standards are strategically aligned to provide a comprehensive profile of the organization and a context for understanding its impacts (GRI 2023).

The sector standards contain information for organizations regarding their anticipated material issues, which according to the author is formulated in a rather unspecific manner. However, a closer look at the standards and also later in the GRI Index reveals a clear specification of the topics. An organization uses the standards applicable to its sector both in defining its key topics and in determining the information to be reported on those topics (GRI 2023).

The topic standards contain disclosures that enable the organization to report on its impact on specific topics. These standards address a very wide range of topics. The organization applies the topic-based standards in accordance with the list of essential topics it has defined using elements of the universal standards (GRI 2023).

There is no further elaboration on these considerations. Nevertheless, the comparison of the resilience factors with the GRI Index is of great relevance in the further course of the methodology. This and the previous descriptions result in the following advantages: Companies now have the opportunity to develop or scrutinize indicators themselves using the methods and models described. Furthermore, existing indicators that may already be firmly established in the company can be finally compared with the GRI Index. As described at the beginning, this results in the possibility of a transparent comparison of companies within a sector.

The resilience factors determined later in section 4.1.2 are compared and assigned to the GRI Index, which comprises almost 120 indicators, below. As described above, this enables a transparent comparison of companies within a sector. This also contributes to the research gaps C (Heuristic optimization of corporate RFs) and D (Effectiveness of a dynamic approach to resilience management). The approach is an optimal development strategy, taking into account global comparability and applicability, and makes it possible to respond effectively to uncertainties.

Table 4-2 below shows the RFs that are important for production companies according to Macuzić (2016), as well as the indicators of the GRI Index (GRI 2023) that the author correlates with them:

RFs	GRI Standard	GRI Description	Disclosure	
Management commitment	GRI 2	General Disclosures	2-23	Policy commitments
			2-24	Embedding policy commitments
Reporting culture	GRI 2	General Disclosures	2-2	Entities included in the organization's sustainability reporting
			2-3	Reporting period, frequency, and contact point
			2-14	Role of the highest governance body in sustainability reporting
Learning	GRI 2	General Disclosures	2-17	Collective knowledge of the highest governance body
	GRI 404	Training and Education	404-1	Average hours of training per year per employee
			404-2	Programs for upgrading employee skills and transition assistance programs
			404-3	Percentage of employees receiving regular performance and career development reviews
Awareness	GRI 418	Customer Privacy	418-1	Substantiated complaints concerning breaches of customer privacy and losses of customer data
Preparedness	GRI 2	General Disclosures	2-12	Role of the highest governance body in overseeing the management of impacts
			2-13	Delegation of responsibility for managing impacts
			2-25	Processes to remediate negative impacts
	GRI 203	Indirect Economic Impacts	203-1	Infrastructure investments and services supported
			203-2	Significant indirect economic impacts
	GRI 306	Waste	306-1	Waste generation and significant waste-related impacts
			306-2	Management of significant waste-related impacts
	GRI 308	Supplier Environmental Assessment	308-2	Negative environmental impacts in the supply chain and actions taken
	GRI 403	Occupational Health and Safety	403-7	Prevention and mitigation of occupational health and safety impacts directly linked by business relationships

RFs	GRI Standard	GRI Description	Disclosure	
	GRI 413	Local Communities	413-1	Operations with local community engagement, impact assessments, and development programs
			413-2	Operations with significant actual and potential negative impacts on local communities
	GRI 414	Supplier Social Assessment	414-2	Negative social impacts in the supply chain and actions taken
			414-2	Negative social impacts in the supply chain and actions taken
	GRI 416	Customer Health and Safety	416-1	Assessment of the health and safety impacts of product and service categories
			416-2	Incidents of non-compliance concerning the health and safety impacts of products and services
Flexibility	GRI 201	Economic performance	201-2	Financial implications and other risks and opportunities due to climate change
			201-3	Defined benefit plan obligations and other retirement plans
Self-organization	GRI 2	General Disclosures	2-29	Approach to stakeholder engagement
Teamwork	GRI 405	Diversity and Equal Opportunity	405-1	Diversity of governance bodies and employees
Redundancy	GRI 2	General Disclosures	2-6	Activities, value chain and other business relationships
			2-9	Governance structure and composition
Fault-tolerance	GRI 402	Labor/Management Relations	402-1	Minimum notice periods regarding operational changes

Table 4-2: Assignment of RFs to indicators of the GRI Index (GRI 2023; Macuzić 2016)

The selection of applicable GRI indicators is neither exhaustive nor all-encompassing. This selection should be discussed and finalized together with the DMs in the corporate context, in relation to a problem or with regard to a strategy to be pursued, such as corporate resilience. It should also be noted that a direct comparison is not possible, as both the underlying RFs and the GRI indicators are similar in their description, but not identical. Experience shows that the chosen *"flight altitude"* of the assessment is decisive: The higher it is, the greater the degree of agreement. Conversely, at a lower *"flight altitude"*, the indicators are further apart and hardly comparable. Here it is necessary to weigh up which indicators should be considered comparable, and which should not. This should be a primary and conscious decision by top management so that there is no room for interpretation and uncertainty.

The derivation and implementation of RFs are of central importance for entrepreneurial resilience, and therefore ultimately also for entrepreneurial success. Figure 4-5 below illustrates the overall process developed as a model that shows the development path and structure of RFs (*Blueprint for RF Derivation and Assembly*). A comparable, step-by-step process has not yet been represented in the literature and represents an innovation in the definition. It therefore contributes to the above-mentioned research gaps C (Heuristic optimization of corporate RFs) and D (Effectiveness of a dynamic approach to resilience management).

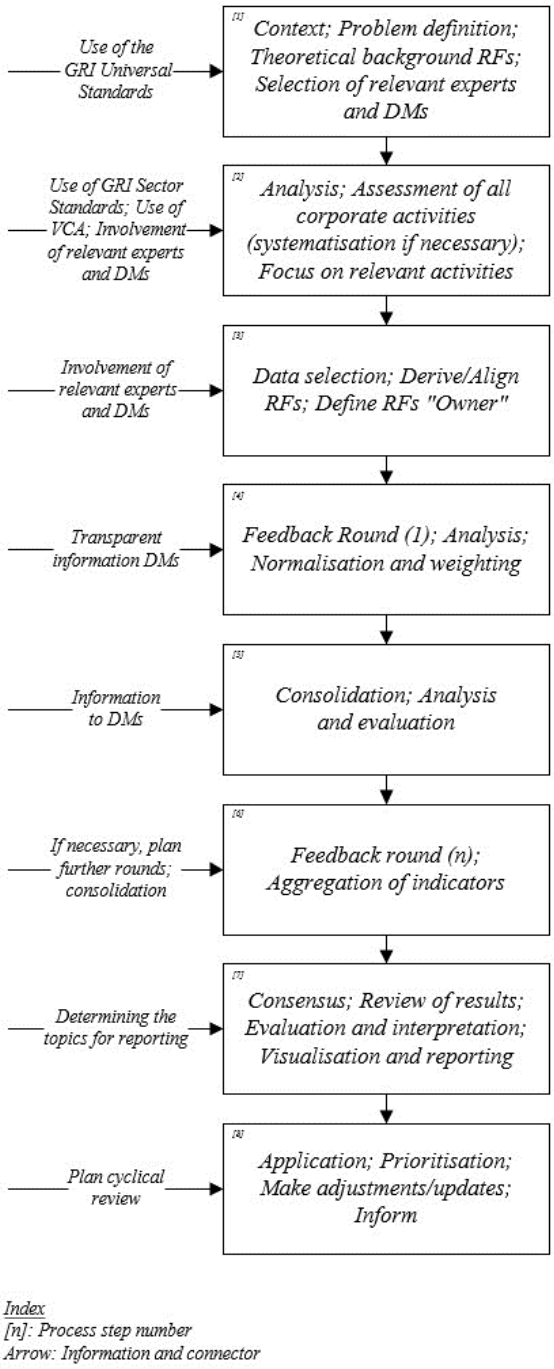

Figure 4-5: Model for the derivation and construction of RFs (own illustration)

Due to the sheer immense versatility of organizations, different methodological approaches, and strategies for selecting and applying RFs must be considered. It is not only in the context of the Fuzzy Delphi Technique that careful selection and involvement of the DMs, taking into account their perspectives and expertise, is crucial in order to facilitate rapid consensus building (Huber et al. 2023). Clearly formulated questions and transparent

communication of results are essential. The OECD method approach highlights the need for a transparent methodology in the development of composite indicators and calls for a specific, strategy-oriented selection of RFs. This can promote efficient and agile action within the company. The VCA focuses on the intensive monitoring of the entire supply chain, the derivation of internal RFs and external reporting in accordance with the GRI guidelines (Azapagic & Perdan 2010). It therefore acts as an upstream link between the individual elements and supports the DMs in identifying the *"right"* areas for developing the RFs in the context of the company-specific selection criteria. When applying the GRI indicators, a structured selection and adaptation to the corporate context and the specific problems should be made. A direct comparison with other organizations as part of a benchmark is possible but is not always necessarily expedient due to non-identical corporate circumstances. All approaches emphasize the importance of transparency, specific adaptation, and responsible handling of RFs in order to effectively support and manage corporate resilience and the strategic orientation of companies (GRI 2023).

Conclusion: The GRI standards are divided into universal, sector and topic standards and can be used by organizations of any size (GRI 2023). The integration of RFs into the GRI Index enables a transparent comparison of companies within an industry, for example. The relevant RFs should be selected strategically in order to strengthen corporate resilience. Different methodological approaches can be used, whereby transparency and adaptation to the corporate context are equally important from the author's point of view.

4.1 Detailed Methodology

This section introduces a two-stage fuzzy model, which forms the crux of this research, accompanied by a literature review (refer to Chapter 3.1). In the first stage, the level of RFs within the product delivery process of the analyzed company is determined using the proposed Fuzzy Delphi Technique. The second stage of the model calculates the weighted aggregated fuzzy value of RFs for each KPI and analyzes the relationship between RFs and KPIs using scatter plots. The outlined two-stage model is illustrated in Figure 4-8 (*Bridging RF Metrics with KPI Recovery via Fuzzy Logic*) (Huber et al. 2023). At the end, an optimization method is used to propose management techniques for organizational resilience enhancement.

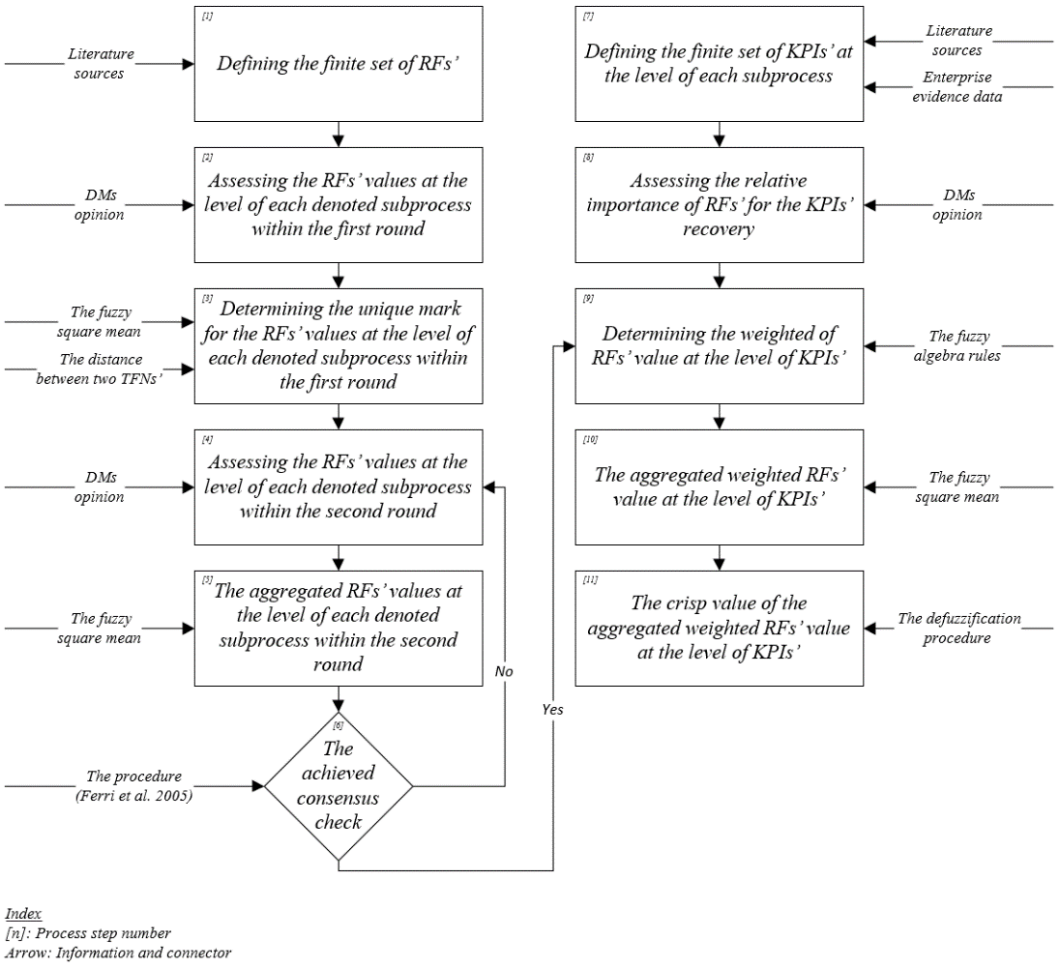

Figure 4-6: Proposed Fuzzy Model Connecting Aggregated Weighted RF Values with KPI Recovery Times (own illustration based on Ferri et al. 2005)

To conduct the proposed research within a corporate context, the following steps should be undertaken (Huber et al. 2023):

[1] Outline the primary processes and associated sub-processes (SP) of the company (refer to Chapter 4.1.1 and 4.1.2);

[2] Define a finite set of RFs (refer to Chapter 4.1.2);

[3] Establish the KPIs managed at the level of the identified sub-processes (refer to Chapter 4.1.2);

[4] Identify a group of experts possessing comprehensive knowledge and experience in enterprise resilience (refer to Chapter 4.1.2);

[5] Implement the proposed Delphi method to achieve a consensus among experts regarding the RF levels in the company under consideration (refer to Chapter 4.1.4);

[6] Compute the aggregated weighted RF values for each identified KPI (refer to Chapter 4.1.5);

[7] Evaluate the recovery time of the KPIs (refer to Chapter 4.1.5);

[8] Conduct a scatter plot analysis comparing RF values with KPI recovery times (refer to Chapter 5.3);

[9] Perform optimization analysis technique through heuristic algorithm or exact meth-od to propose management techniques for organizational resilience enhancement (refer to 5.4);

[10] Analyze the findings to pinpoint weaknesses and highlight areas for improvement (refer to Chapter 5.5).

The steps listed are detailed in sections 4.1.1 to 5.5 inclusive.

Conclusion: The two-stage fuzzy model presented here forms the core of the research. In the first stage, the degree of RFs in the product delivery process of the analyzed company is determined using the proposed Fuzzy Delphi Technique. In the second stage, the model calculates the weighted aggregated fuzzy value of RFs for each KPI and analyzes their relationships. There is a lack of research that empirically tests the procedure as well as the relationships in a business context (Huber et al. 2023).

4.1.1 Business Processes Analysis and Decomposition

[1] Outline the Primary Processes and Associated Sub-Processes (SP) of the Company (see also Chapter 4.1.2)

As already indicated in the previous chapters, the APQC Process Classification Framework (PCF) plays a central role in the identification and definition of processes. In the following, this framework is examined in more detail, particularly in the context of process selection.

The framework enables organizations to standardize their processes and identify optimization potential. The PCF provides an essential basis that supports companies in developing their own customized process definitions. By providing a standardized language, the PCF promotes the integration of different company models (APQC 2024-B; vom Brocke & Rosemann 2015).

The value of the PCF is particularly evident in enterprise architecture when connecting process and system models in order to clarify the interdependence between systems and processes. This makes it easier to understand and control the effects of changes across different models. In addition, the PCF enables objective benchmarking that can be carried out independently of industry-specific or company-specific characteristics (APQC 2024-B; Filho et al. 2020).

In globally operating and complexly structured organizations, such as the manufacturer mentioned in the case study, the effective organization of content plays a decisive role in facilitating employee access to the required information and collaboration. Here, the PCF provides a structured framework to organize content in a process-oriented way, which further increases efficiency and productivity within the organization (APQC 2024-B).

In order to effectively implement process improvements, it is essential to understand the relationships between processes and to be able to trace the flow of work through the organization (APQC 2024-C).

The PCF serves as a comprehensive catalog of process activities within an organization and acts as an inventory of what an organization does. However, it should be noted that the PCF does not describe the way in which an organization manages or executes its processes. Rather, it enables a systematic recording, grouping and subdivision of process activities. This allows organizations to create a detailed directory of their process activities. With its five-level hierarchical structure, the PCF allows organizations to design their process models with variable levels of detail. Ultimately, organizations can use the elements of the PCF to develop a detailed process map that provides a clear picture of internal operations (APQC 2024-D).

But why choose the PCF? There are several options available to organizations looking to implement a process framework, including Information Technology Infrastructure Library (ITIL), Supply Chain Operations Reference (SCOR), enhanced Telecommunications Operations Map (eTOM) or Value Reference Model (VRM). From the perspective of the author of this paper, however, the PCF stands out: It is more comprehensive, creates a standardized process language as described and offers a holistic system. These characteristics make the PCF an excellent starting point for process optimization (APQC 2024-E).

Furthermore, in a survey on the use of process frameworks in organizations, 70 percent of respondents state that they have chosen the cross-functional PCF for their process optimization initiatives, which positions it ahead of frameworks such as ITIL (25%), SCOR (15%), eTOM (4%) and VRM (3%) (Morgan 20219).

Choosing the *"right"* processes is essential for organizations to effectively meet their strategic goals and business needs. Lundquist (2023) emphasizes that companies should select their processes based on strategic goals. Given the dynamic market environments, it is advantageous to start from existing structures, as no company starts from scratch.

Furthermore, Schmidhauser (n. d.) and Davenport (1993) focus on strategically oriented processes, especially considering the limited resources in companies. Although these authors do not formulate a detailed method for process selection, they recognize the importance of strategic orientation (Hammer & Champy 1993). The literature offers methodological approaches to process prioritization, but these are described as time and resource intensive (Stickley & Winterbottom 1994). Other authors such as Becker et al. (2012) focus on the distinction between core and support processes, while Best and Weth (2009) focus directly on the identification of weaknesses (Schmidhauser n.d.). Strategic weighting is emphasized as a decisive criterion for process prioritization (Schmidhauser n. d.). To achieve strategic goals, relevant performance processes must be executed with maximum efficiency, which promotes long-term business resilience and sustainable competitive advantage.

An often overlooked but critical factor is the customer perspective. Customer satisfaction is a key performance indicator that provides insight into whether a company's processes are meeting expectations. Integrating customer feedback into process evaluation allows companies to both pursue strategic goals and increase customer satisfaction (Schmidhauser n.d.).

It is surprising that many authors neglect the customer's perspective. Only Schmelzer and Sesselmann (2006) indirectly consider the customer perspective by recommending the use of relative competitive strength as a prioritization criterion. A methodology that integrates both

the strategic importance and the need for action from the customer's perspective would ensure a targeted and efficient approach from the outset (Schmidhauser n.d.).

An essential element that must not be overlooked is the involvement and expertise of the company's DMs. Their in-depth insight into the process landscape is essential, as they are best placed to assess which processes are particularly relevant from their perspective. Based on this expert assessment and in line with the APQC PCF, the following selection of processes results (APQC 2015):

PCF ID	Hierarchy ID	Description according to APQC (2015)
Deliver Physical Products		
20022	4.0	Performing supply chain activities include planning supply chain, procuring materials and services, and managing logistics.
Planning for and aligning supply chain resources (p = 1)		
10215	4.1	Creating strategies for production and materials. Handle the demand for the products of the organization. Develop plans for handling materials. Develop and administer the schedule for master production. Plan for distribution requirements and its constraints by reviewing and assessing distribution policies and performance and by establishing quality standards and procedures.
Procuring materials and services (p = 2)		
10216	4.2	Creating a plan for procuring materials and services. Develop strategies for sourcing materials and services. Choose the most appropriate suppliers and develop contracts with them. Order the materials and services as per the requirements. Manage relationships with suppliers.
Producing, assembling, and testing products (p = 3)		
10217	4.3	Processing and delivering the finished goods manufactured by the organization. Schedule the production of products. Execute the product production activities. Perform tests to oversee and ensure quality of production. Maintain records of the production process. Track lots.
Managing logistics and warehousing (p = 4)		
10219	4.4	Administering and overseeing all activities related to logistics and warehousing. Outline and establish a strategy for the logistics function. Plan and administer the flow of inbound materials. Administer the operational activities of warehousing and outbound transportation. Manage reverse logistics including returns and exchanges.

Table 4-3: Process and sub-process selection based on APQC (2015)

The selected sub-processes represent the business environment described in chapter 2 almost in its entirety. They therefore describe the relevant core tasks of the company. In the context of corporate resilience, the process for planning and coordinating resources within the supply chain ($p = 1$) describes their strategic planning and coordination. The aim here is to manage any bottlenecks that may occur, but also to be able to react flexibly to changing demand conditions. The central purchasing and procurement of materials ($p = 2$) is a critical aspect of corporate resilience. Companies must be able to react quickly to changes in the availability of materials. The selection of suitable suppliers or even partners is crucial in order to ensure efficient ordering processes. The process of manufacturing or assembling products ($p = 3$) includes production as well as quality control of end products. In terms of corporate resilience, it

is also necessary to react to unexpected disruptions and at the same time ensure product quality in the long term. The last sub-process describes the management of logistics and warehousing $(\mathrm{p} = 4)$. These are also key areas in the context of corporate resilience. More than ever, companies must be able to react flexibly to changes - not only in demand - in transportation and warehousing. It is not only the company's current forward-looking orientation that plays a role here, but also the reversal or return and exchange of products, etc. (APQC 2015).

Taking into account the assessment of the DMs, these are therefore the strategic and relevant core processes of the company, which are used for further work.

4.1.2 Definition of the Input Variables

[2] Defining the Finite Set of Business Sub-Processes

The classification of the business process and its corresponding sub-processes adheres to the APQC framework as described in chapter 4.1.1 (APQC 2015). In this research, the focus is on the *"Deliver Physical Products"* process. The sub-processes of this process can be formally identified and represented using a set of indices: $\{1, .., p, .., P\}$. The finite number of sub-processes is designated as P, and $p, p = 1, .., P$ represents the index of the sub-process. Specifically, the sub-processes associated with *"Deliver Physical Products"* include (Huber et al. 2023):

- *Planning for and aligning supply chain resources* $(p = 1)$;
- *Procuring materials and services* $(p = 2)$;
- *Producing, assembling, and testing products* $(p = 3)$;
- *Managing logistics and warehousing* $(p = 4)$.

This framework provides a structured basis for the analysis of these sub-processes in the context of this research (Kreimeyer & Lindemann 2011).

Conclusion: The APQC framework provides a solid basis for analyzing the sub-processes in this research (Kreimeyer & Lindemann 2011). In particular, APQC's PCF serves as a taxonomy for business processes. Companies can use the PCF to establish a common terminology for naming, organizing, and representing their processes. It also proves to be a useful tool for viewing an organization in the form of horizontal processes and not vertical functions (APQC 2023). The PCF was developed as a flexible framework and global standard that can be adapted to the needs of any organization. Therefore, not all processes of a specific organization are listed in the PCF and not every process listed in the framework exists in all organizations. In addition, the PCF serves as a basis for benchmarking, allowing organizations to compare their performance with others (Varney 2023). It should be noted that no comparable, comprehensive approach incorporating these frameworks is yet known in the context of the research gaps. Therefore, it is necessary to conduct empirical work to identify and validate such frameworks in this specific context (Chlebna & Mattes 2020).

Formally, the list of proposed RFs is represented by a formal set: $\{1, .., j, .., J\}$. The total number of considered RFs is denoted as J. Each RF is indexed as $j, j = 1, .., J$. In this study, the

set of RFs is defined based to the referent literature. The RFs considered as significant for a production company encompass (Huber et al. 2023; Macuzić 2016):

- *Management commitment* $(j = 1)$;
- *Reporting culture* $(j = 2)$;
- *Learning* $(j = 3)$;
- *Awareness* $(j = 4)$;
- *Preparedness* $(j = 5)$;
- *Flexibility* $(j = 6)$;
- *Self-organization* $(j = 7)$;
- *Teamwork* $(j = 8)$;
- *Redundancy* $(j = 9)$;
- *Fault-tolerance* $(j = 10)$.

In this manner, we establish a clear framework for the identification and discussion of these crucial RFs in the context of the research.

Conclusion: In this study, the main RFs for an industrial company were defined based on the literature (Macuzić 2016). A model for deriving the RFs is also described in Chapter 4, [3] and [4]. Taking into account the research gaps, there is a lack of models and approaches that investigate the emergence of RFs in industrial companies. It is therefore necessary to carry out empirical work in order to identify these (Huber et al. 2023).

[3] Defining the Managed KPIs

There are no specific recommendations on which KPIs should be managed in different companies. Consequently, it is up to individual companies to select appropriate KPIs taking into account their size, business area and other relevant characteristics. In this research, KPIs are defined following the APQC framework to ensure broad applicability. At the same time, adjustments are made to suit the particular company and to ensure relevance and appropriateness (Huber et al. 2023).

The set of KPIs under consideration is represented by a set of indices: $\{1, .., i, .., I\}$. The total number of KPIs considered is referred to as I. The index of the individual KPIs is referred to as $i, i = 1, .., I$. In this research, the KPIs referenced by APQC (2015) are as follows (Huber et al. 2023):

- *Total cost of quality per $100,000 in revenue* $(i = 1)$;
- *Employee retention rate* $(i = 2)$;
- *Percentage of sales orders scheduled in response to customer requests* $(i = 3)$;
- *Total cost to perform the procurement process group per purchase order* $(i = 4)$;
- *Average lead time from procurement to payment in days* $(i = 5)$;
- *Percentage of unique suppliers that are active suppliers* $(i = 6)$;
- *Scrap and rework costs as a percentage of manufacturing costs* $(i = 7)$;
- *Total cost to produce per $1,000 revenue* $(i = 8)$;

- *Percentage of defective parts per million* $(i = 9)$*;*
- *Average lead time in calendar days from delivery request to successful delivery and disposal of returned goods* $(i = 10)$*;*
- *Perfect order performance* $(i = 11)$*;*
- *Percentage of on-time delivery by supplier* $(i = 12)$.

Conclusion: As already explained, there are no fixed recommendations for the selection of KPIs. Depending on their size, industry and other relevant factors, companies should either define their KPIs themselves or use established standard methods, taking into account the approaches discussed in Chapter 4. In this research, KPIs are defined according to the APQC framework presented and adapted accordingly to meet the specific requirements of each company. As mentioned in the previous conclusion, there is no comparable comprehensive approach to date that takes into account the model presented in the methodology. Therefore, it is necessary to conduct empirical work in this case as well.

[4] Defining the Set of DM Team

The assessment of the RF levels, denoted as $j, j = 1,..,J$, within each business process should be approached as a fuzzy group decision-making challenge. DMs need to have a strong understanding of these RF levels in order to effectively manage and continuously improve them.

In this research, a group of DMs is identified and represented using a specific set of indices as: $\{1,..,e,..,E\}$. The total number of DMs is denoted by E. The index of a DM is denoted as $e,., e = 1,..,E$ (Aleksić et al. 2017; Aleksić et al. 2022-B).

The DMS team is composed of key persons who occupy the highest positions in the company hierarchy. This composition provides a comprehensive overview of the company's activities and brings extensive experience to the decision-making process. In the organization studied, the DMs team is composed of the following individuals (Huber et al. 2023):

- *Chief Executive Officer* $(e = 1)$*;*
- *Operations Manager* $(e = 2)$*;*
- *Management System Manager* $(e = 3)$*;*
- *Global Supply Chain Manager* $(e = 4)$*;*
- *Human Resource Manager* $(e = 5)$*;*
- *Marketing Manager* $(e = 6)$*;*
- *Service and Sales Manager* $(e = 7)$*;*
- *Chief Information Officer* $(e = 8)$*;*
- *Research and Development Manager* $(e = 9)$.

It is important to emphasize that the DMs team is responsible for carrying out all the assessments and evaluations described in this research (Huber et al. 2023).

Conclusion: The selection of DMs is crucial and is usually based on the following assumption that the relevant people in the various divisions are aware of the core KPIs and the

associated business areas that are relevant to their respective divisions. It is essential that these individuals not only understand the KPIs, but also have the ability to derive meaningful insights from the data.

In this research, the focus was placed on the high-level process structure and the composition of the Group Management Committee (top management) in order to form a DM group that is small but diverse. The heterogeneity within the DM group helps to bring in different perspectives and ideas (Huber et al. 2023).

Although the decisions can have far-reaching consequences, it is nevertheless advisable to keep the group of DMs as small and effective as possible. The selection of DMs should include people who are directly responsible for the consequences of their decisions. The members of the decision-making group should also be aware of their role and responsibility, even if this did not need to be discussed again in this particular decision-making round (Ardebili & Padoano 2020; Laoyan 2023). However, it is advisable to address and communicate this transparently, especially in decentralized organizations where decisions can be made independently, and responsibilities are not always clearly defined. This promotes better understanding and more effective collaboration within the decision-making body.

4.1.3 Selection of Variables

In this research, two main sources of uncertainty are identified: The values of RFs at the level of sub-processes of the business process for the delivery product; and the relative importance of RFs for the recovery of the KPIs (Huber et al. 2023).

The assessment of RF values at each considered sub-process is carried out using five linguistic expressions, represented by type-one fuzzy numbers. These linguistic variables and their corresponding TFNs are as follows (Huber et al. 2023):

- *Very low value (B1) - (0, 1.5, 3);*
- *Low value (B2) - (1, 2.5, 4);*
- *Medium value (B3) - (3, 5, 7);*
- *High value (B4) - (6, 7.5, 9);*
- *Very high value (B5) - (7, 8.5, 10).*

These TFNs are used to quantitatively describe the level of RFs in the analyzed company within the range [0-10]. Specifically, a value of 0 indicates the lowest possible RF value, while a value of 10 signifies the highest possible RF value (Huber et al. 2023).

Furthermore, the assessment of the relative importance of the RFs for the recovery of the KPIs is described by the following seven linguistic expressions modelled by TFNs (Huber et al. 2023):

- *Extremely low importance (A1) - (0, 0, 2.5);*
- *Low importance (A2) - (0.5, 2, 3.5);*
- *Fairly low importance (A3) - (1.5, 3.5, 5.5);*
- *Medium importance (A4) - (3, 5, 7);*

- *Fairly high importance (A5) - (5, 6.5, 8);*
- *High importance (A6) - (6.5, 8, 9.5);*
- *Extremely high importance (A7) - (7.5, 10, 10).*

A value of 0 indicates that an RF has negligible relative importance for KPI recovery, while a value of 10 indicates that the RF holds utmost importance within the framework of KPI recovery (Huber et al. 2023).

These TFNs are defined along a real number line within the range [0-10]. A value of 0 indicates that an RF has negligible relative importance for KPI recovery, while a value of 10 indicates that the RF is of utmost importance in the context of KPI recovery (Huber et al. 2023).

4.1.4 Assessment of the Resilience Factors by Delphi Technique

[5] Implement the Proposed Delphi Method

The Delphi Technique stands out as a widely utilized qualitative method for group decision-making (Tellie 2016). At its core, it can be defined as a data collection and processing method executed through several rounds (Komatina et al. 2021).

When conducting the technique, one of the most important questions is how to determine the optimal group of DMs. There are no standardized recommendations for deciding the optimal number of DMs. Some researchers (Malone 2004; Somerville 2008) propose that a group of five to ten DMs is suitable for providing assessments. It may be suggested that, through the analysis of the research context, an optimal number of DMs may be determined (Huber et al. 2023).

In line with best practice, it is assumed that the DMs participating in the Delphi study have an accurate understanding of the identified problem or possess profound knowledge in the relevant area(s). At the same time, the experience level of the DMs may vary, and they may be at different levels of the company hierarchy. An important point in the implementation is that the anonymity of the DMs must be guaranteed during the implementation of the technique, so that individual biases and personal thoughts do not influence other participants. In this research, DMs were selected based on their significance to the company's operations, along with their knowledge and competence (Huber et al. 2023).

The Delphi method is conducted in several rounds. In the initial round, the DMs give their assessment of the problem being addressed. The assignment of the DMs' assessments to a single assessment can be done by applying different aggregation operators. The average value of the DMs' assessments is again communicated in writing to the DMs, who are to adjust their assessments in the second round according to this value. By applying the different procedures (von der Gracht 2012), it can be determined whether the DMs have reached consensus. If a consensus is reached, the average value derived from the second round's estimates is adopted as the decision. If not, the data collection and processing steps are repeated. It should be noted that the team of DMs makes individual assessments to determine the value of the RFs. This is because their expertise extends to several aspects of the business and all imponderables should be taken into account (Huber et al. 2023).

The questionnaire is modified in consideration of validated research (Aleksić et al. 2022-B) and is presented to each DM, complete with explanations of varying resilience levels within the business. The questionnaire includes guidelines with linguistic expressions, defining the level of organizational resilience for each RF as follows (Huber et al. 2023):

- *There are no blueprints or plans for the construction of organizational resilience, there is no awareness of organizational resilience - B1;*
- *There are drafts of activities for securing organizational resilience - B2;*
- *There are clear plans and activities for securing organizational resilience, and the competencies of all employees in the field of organizational resilience management are ensured - B3;*
- *Competencies of all employees in the field of organizational resilience management are ensured, and there is a partially developed awareness of organizational resilience - B4;*
- *All needed competences are ensured, and there is the absolute commitment of management and all employees regarding organizational resilience management - B5.*

The proposed Fuzzy Delphi Technique is realized in the following steps (1 to 6) (Huber et al. 2023):

Step 1: During the first round, each DM $e, e = 1, \dots, E$ assesses the level of RFs $j, j = 1, .., J$ at the level of each sub-process $p, p = 1, .., P$ by using one of the five predefined linguistic expressions, $\tilde{v}_{jp}^{1e} = \left(l_{jp}^{1e}, m_{jp}^{1e}, u_{jp}^{1e}\right)$.

Step 2: Let us determine the aggregated value of the DMs' assessment in the first round, $\tilde{b}_{jp}^{1}$ by applying the operator of the square mean:

$$\tilde{v}_{jp}^{1} = \left(\sqrt{\frac{1}{E} \cdot \sum_{e=1,..E} \left(l_{jp}^{1e}\right)^2}, \sqrt{\frac{1}{E} \cdot \sum_{e=1,..E} \left(m_{jp}^{1e}\right)^2}, \sqrt{\frac{1}{E} \cdot \sum_{e=1,..E} \left(u_{jp}^{1e}\right)^2} \right) \quad (1)$$

So that:

$$\tilde{v}_{jp}^{1} = \left(l_{jp}^{1}, m_{jp}^{1}, u_{jp}^{1}\right) \quad (2)$$

Step 3: Let us calculate the distance between $\tilde{v}_{jp}^{1}$ and TFNs that correspond to the predefined linguistic expressions $Bk, k = 1, .., 5$, $d\left(\tilde{v}_{jp}, Bk\right)$.

Step 4: To each RF $j, j = 1,..,J$ at the level of sub-process, $p = 1,..,P$, should be adjoined one of the predefined linguistic expressions $Bk, k = 1,..,K$ according to the expression.

$$\min_{k=1,..,K} d\left(\tilde{v}_{jp}, Bk\right) = B_{jp}^{*} \tag{3}$$

Step 5: During the second round, DMs adjust their assessment according to the average value of B_{jp}^{*}. Let the DMs' assessments in the second round be denoted as $\tilde{v}_{jp}^{2e}$.

Step 6: Let us check the correlation degree between the DMs assessment in the first, $\tilde{v}_{jp}^{1e}$, and the second round, $\tilde{v}_{jp}^{2e}$. If the degree of correlation is higher than or equal to 0.5, it can be considered that a consensus of DMs has been reached according to the developed procedure (Ferri et al. 2005). If there is no statistical dependency between DMs assessments in the first and second rounds, it is necessary to perform the second round of the assessment (Huber et al. 2023).

4.1.5 Analysis

[6] Compute the Aggregated Weighted RF Values for each Identified KPI

This section of the research outlines the steps to determine the relative importance of RFs in the recovery of KPIs within the business process titled *"Deliver Physical Products"*. The assessment of the RFs' relative importance for KPIs' recovery is approached as an independent problem, with the aim of achieving consensus in the assessment (Huber et al. 2023).

Decision Makers (DMs) have access to seven linguistic expressions. The guidelines, which feature linguistic expressions to define the importance of RFs for the recovery time of the addressed KPIs, are as follows (Huber et al. 2023):

- *The treated RF has extremely low importance for the treated KPI's recovery time - A1;*
- *The treated RF has low importance for the treated KPI's recovery time - A2;*
- *The treated RF has fairly low importance for the treated KPI's recovery time - A3;*
- *The treated RF has medium importance for the treated KPI's recovery time - A4;*
- *The treated RF has fairly high importance for the treated KPI's recovery time - A5;*
- *The treated RF has high importance for the treated KPI's recovery time - A6;*
- *The treated RF has extremely high importance for the treated KPI's recovery time - A7.*

[7] Evaluate the Recovery Time of the KPIs

Subsequently, the determination of the weighted aggregated RF value at the level of each designated KPI is accomplished by applying the fuzzy root mean square operator. The proposed procedure is implemented as follows, through steps 1 to 3 (Huber et al. 2023):

Step 1: The assessment of RFs $j, j = 1, .., J$ relative importance of RFs for the KPIs' $i, i = 1, .., I$ recovery time is denoted by TFN $\tilde{\varphi}_{ji}$.

Step 2: Let us calculate the weighted value of each RF $j, j = 1, .., J$ at the level of each denoted KPI:

$$\tilde{\theta}_{ji} = \tilde{v}_{jp} \cdot \tilde{\varphi}_{ji} \tag{4}$$

Step 3: Let us determine the weighted aggregated fuzzy value of RFs at the level of each KPI $i, i = 1, .., I$, $\tilde{\theta}_i$ by applying the operator of the fuzzy geometric mean.

4.2 Conclusion and Transfer

The KPIs for recovery time, denoted as $t_i$are obtained from company records. It is worth noting that this research does not consider KPI management, but rather tracks the sudden drop in KPI values. The timeframe required for the full recovery of the KPI values is designated as the recovery time and is expressed in months (Huber et al. 2023).

An assumption is introduced here: A linear correlation exists between the KPIs' recovery time and the weighted aggregated fuzzy value of RFs at the level of each KPI. This assumption is verified by determining the correlation coefficient between the mentioned variables (Huber et al. 2023).

The concluding steps of the research entail analyzing the relationship between the weighted aggregated RFs' value and the KPIs' recovery time. This should be executed as follows, through steps 1 to 2 (Huber et al. 2023):

Step 1: Let us determine the representative scalar TFN $\tilde{\theta}_i$, Δ_i by applying the simple gravity method.

Step 2: Let us determine the correlation coefficient between the KPIs' recovery time, t_i and the weighted aggregated value of RFs at the level of each considered KPI, Δ_i.

4.3 Enhancement of RFs through the Application of Heuristic Approaches or exact Methods

In this section, the Branch-and-Bound algorithm, as explained in chapter 3.5, is presented as a novel approach for enhancing RFs. The algorithm enables complex optimization problems to be solved efficiently and systematically. By applying it in the context of business resilience, this approach opens up completely new research perspectives by closing a gap between traditional management strategies and advanced optimization methods (Aleksić et al. 2024; Kerr 2016; Lawler & Wood 1966; Macuzić et al. 2016; Morrison et al. 2016; Tasic et al. 2020).

The following steps are now proposed to improve lowest ranked RFs:

[a] Identification of Management Techniques

The methods that can be used to improve the RFs are determined from the existing literature and by the DMs (Tague 2023). For each RF $j, j = 1,..,J$ mentioned, corresponding methods M_j and $m, m = 1,..,M_j$ that can be used to improve the RFs are identified and represented by an index (Aleksić et al. 2024).

[b] Assessment of the Suitability of the Management Techniques

To increase organizational resilience, each RF can be improved by implementing specific (one or more) management techniques (Appendix B) (Tague 2023). The management system manager selects from a defined collection $\{1,..,m,..,M_j\}$ those that may be best suited to strengthen the RFs in question (Aleksić et al. 2024).

The suitability of each method $m, m = 1,..,M_j$ for the improvement of a specific RF $j, j = 1,..,M$ is determined by a fuzzy group decision procedure. This procedure involves three DMs: The Chief Executive Officer ($e = 1$), the Operations Manager ($e = 2$) and the Management System Manager ($e = 3$). This group is formally specified by a set $\{1,..,e,..,E\}$. The total number of DMs is denoted as E and the index of DMs as $e, e = 1,.,E$. As it is known to be closer to the human way of thinking to express evaluations with linguistic terms instead of precise numbers (Aleksić et al. 2024).

It is well known that expressing evaluations in linguistic terms is closer to the human way of thinking than using conventional numerical scales. The theory of fuzzy sets offers a suitable tool for quantifying these linguistic expressions using fuzzy numbers (Dubois & Prade 1980; Zimmermann 2011). This allows precise handling of uncertainties and ambiguities. The most important features are the membership function, the granularity and the domain (Aleksić et al. 2024).

The use of TFNs is recommended in the literature due to their simplicity in modeling linguistic uncertainties and imprecision (Tadic et al. 2013). The background to this recommendation is that no complex mathematical calculations are required and at the same time the uncertainties of natural language are sufficiently captured. In addition, the granularity is usually determined based on the subjective assessment of the DMs, taking into account the size and complexity of the problem. Theoretical findings suggest that the selection of linguistic

expressions that a DM can use should be deliberately limited to a maximum of seven (Lootsma 1988; Nestic et al. 2019). This can, for example, avoid excessive demands and ensure the consistency of the evaluations (Aleksić et al. 2024; Tadic et al. 2024).

The predefined linguistic expressions and their corresponding TFNs cover a scale from *"Extremely low applicability"* to *"Extremely high applicability"*, reflecting the varying degrees of suitability of the techniques (Aleksić et al. 2024; Tadic et al. 2024):

- *Extremely low applicability - (1, 1, 2.5);*
- *Very low applicability - (1, 2, 3);*
- *Low applicability - (2, 3.5, 5);*
- *Medium applicability - (3.5, 5, 6.5);*
- *High applicability - (5, 6.5, 8);*
- *High applicability - (7, 8, 9);*
- *Extremely high applicability - (7.5, 9, 9).*

The scores of the TFNs are defined on a common measurement scale that makes it possible to quantitatively compare and classify the applicability of the techniques (Saaty 2013). A value of 1 indicates almost negligible applicability of the technique, while a value of 7 indicates the suitability of the technique with a high probability of improving RFs (Aleksić et al. 2024; Tadic et al. 2024).

To optimize the selection of techniques, the problem is formulated as a multidimensional Knapsack problem (combinatorics optimization problem), in which both the maximization of benefits (improvement of RFs) and compliance with budget and time constraints (implementation of the technique) are taken into account. This strategic approach enables organizations to improve sustainably by selecting the optimal techniques that have the greatest impact on increasing business resilience (Aleksić et al. 2024).

[c] Cost and Time Assessment

In addition to the basic assessment, the costs and time required to implement each management technique must be estimated for the implementation of the method. The estimates per management technique are based on empirical data and expert judgments of the DMs (Aleksić et al. 2024).

[d] Formulation of the Optimization Problem

In this step, the optimization problem is formulated in order to select the subset of management techniques that should improve corporate resilience. At the same time, the total cost and time required to implement the techniques should be minimized. The following steps (1-5) provide a detailed explanation of the proposed algorithm used to solve this problem (Aleksić et al. 2024).

Step 1: The fuzzy evaluation of the method suitability $m, m = 1, .., M_j$ for the improvement of RFs $j, j = 1, .., J$ is evaluated at the level of DMs $e, e = 1, .., E$. This evaluation is done by using predefined linguistic expressions and is modeled by TFNs x̃_jm^e (Aleksić et al. 2024).

$$\tilde{x}_{jm}^{e} = \left(a_{jm}^{e}, b_{jm}^{e}, c_{jm}^{e}\right) \tag{1}$$

Step 2: Determination of the overall suitability value of the method $m, m = 1, .., M_j$ for each RF $j, j = 1, \dots, J$ by applying a fuzzy operator for the geometric mean $\tilde{x}_{jm}$ (Aleksić et al. 2024).

$$\tilde{x}_{jm} = \left(\sqrt[E]{\prod_{e=1,..,E} a_{jm}^{e}}, \sqrt[E]{\prod_{e=1,..,E} b_{jm}^{e}}, \sqrt[E]{\prod_{e=1,..,E} c_{jm}^{e}}\right) = \left(a_{jm}, b_{jm}, c_{jm}\right) \tag{2}$$

Step 3: The representative scalar value $\tilde{x}_{jm}$, x_{jm} is determined by applying the center of gravity method (Aleksić et al. 2024; Wang & Luoh 2000).

$$x_{jm} = a_{jm} + \frac{c_{jm} - a_{jm} + b_{jm} - a_{jm}}{3} \tag{3}$$

Step 4: The cost assessment for each management technique $\gamma_m, m = 1, .., M$ is carried out by the management system manager. The person relies on experience, empirical data, and best practices to ensure a sound assessment of the cost of each technique (Aleksić et al. 2024).

Step 5: The optimization problem is formulated as a multidimensional Knapsack problem that considers both maximization and minimization constraints (Aleksić et al. 2024).

$$\max_{m=1,..,M} x_{jm} \tag{4}$$

Taking into account the budget limit $\mathcal{G}$:

$$\sum_{m=1,..,M} \gamma_m \leq \mathcal{G} \tag{5}$$

This budget represents the total budget available for improving RFs over the course of a financial year (Aleksić et al. 2024).

[e] Use of the Branch-and-Bound Algorithm

Through the methodology described in this section and the use of the Branch-and-Bound algorithm, this method offers a comprehensive approach to improving corporate resilience. It enables decisions to be made on the basis of quantified and systematically evaluated data. The Branch-and-Bound algorithm identifies the optimal solution (Aleksić et al. 2024).

" If you can't measure it, you can't improve it."

Peter F. Drucker (1909 to 2005): US-American economist and management thinker.

5 THE CASE STUDY IN A COMPLEX INDUSTRIAL COMPANY

In recent decades, resilience research has been conducted from various perspectives: Resistance and recovery, adaptation, and anticipation (Duchek 2019). Even though research interest has increased over the years, there is little consensus on what resilience means or how it is designed (Hepfer & Lawrence 2022). During a period of stable economic conditions, organizational performance indices do not show significant fluctuations. However, if serious disruptions occur, there can be a sudden drop in performance (Beuren et al. 2021). In practice, organizations need to manage performance such as quality, cost, productivity, innovation capability, time, etc. (Ishaq et al. 2014) in order to run their business successfully. As performance is a complex variable, it is measured and managed in practice using performance indicators (Závadský et al. 2019). Common sense suggests that more resilient organizations recover their performance faster than less resilient ones (Huber et al. 2023). It can be assumed that organizational resilience models are complex, which means that their assessment cannot be performed directly; assessment models based on the judgments of DMs could be applied. This assumption is important as many management problems require this assessment approach, which involves a degree of uncertainty (Huber et al. 2023).

The motivation for this research arises from the various uncertainties of the business context mentioned above (see chapter 2). Companies can be affected by various factors such as competition, market changes, political instability and natural disasters. The COVID-19 pandemic has shown how quickly an uncertain situation can develop and how companies must react to it (Huber et al. 2023).

Uncertainties for companies have been omnipresent, and not just since pandemics, unstable geopolitical situations, or endangered supply chains. Corporate resilience is therefore seen as an important ability for companies to deal with these very changes and crises (Fatoki 2018). In a rapidly changing world, it is therefore crucial that companies are resilient, as this is a prerequisite for their success. Therefore, both uncertainty and resilience are closely related concepts that are of great importance to organizations. Since organizational resilience models, like business processes, are complex in nature, their assessment cannot be performed directly. This means that they require assessment models based on the judgment of decision makers. This feature is important because for a large number of management problems it is not possible to measure the variables of interest directly. This is because these variables are subject to a certain degree of uncertainty. At the same time, it is closer to human thinking to use linguistic variables for evaluation. Various mathematical theories support the quantitative description of linguistic expressions (Zimmermann 2011). Many mathematical theories support the quantitative modeling of linguistic expressions. The theory of fuzzy sets (Dubois & Prade 1980; Zimmermann 2011) is used in many research areas to describe uncertainty quantitatively (Huber et al. 2023).

The Fuzzy Delphi Technique is used to assess the organizational resilience of the company. Decision-making is based on a consensus of expert opinions and uncertain information on a specific topic or problem. The overall objective of this research is to analyze the dependency between the factors of organizational resilience and the recovery times of the KPIs. In order to achieve the defined research objective, both the organizational resilience and the recovery time of KPIs should be assessed in the treated company (Huber et al. 2023).

The company under review has a decentralized organizational structure. All business units are mapped in a matrix organization that operates autonomously in the global supply chain of precision industrial components. Nevertheless, all organizational units should interact closely with each other without restricting their independence, flexibility, and agility in the market. In order to master the aforementioned challenges, it is essential for almost all organizational units and employees - regardless of the respective company size, characteristics, form and maturity - to maintain a management system. The studied company has a well-structured business process in accordance with ISO 9001:2015, ISO 14001:2015, ISO 17025:2018, ISO 80079-34:2020 and ISO 27001:2022 standards, so it is possible to propose a business process framework similar to APQC (Huber et al. 2023).

The DMs were included in the first round and also participated in the second round of the Fuzzy Delphi Technique after the calculations presented in section 3.5 (Huber et al. 2023).

5.1 Application of Business Processes Analysis and Decomposition

The first step is to analyze and decompose the production process in the company to be analyzed on the basis of the proposed sub-processes in accordance with section 4.1.1. The decomposition of the process in the context of the APQC PCF refers to the systematic division of business processes into smaller, manageable elements. This allows a deeper understanding of the processes within the company and helps to identify potential for improvement (APQC 2015).

As already described in Chapters 2 and 4.1.1, the selected sub-processes represent the business environment almost in its entirety. Since the company is a production company, as described above, the company's internal process: Manufacturing Processing will now be examined in more detail based on this.

The four sub-processes (p = 1; p = 2; p = 3; p = 4) of the *"Deliver Physical Products"* process group listed in section 4.1.2, which are referred to as *"Source"* in the following figure, are followed by the resulting *"Input"* in the production process mentioned, which in turn is subdivided into the following steps and labeled as *"Activity"*:

- *Material staging for production;*
- *Execute operation according to instructions;*
- *Inspection operation (if required);*
- *Confirm production order;*
- *Move goods to storage location.*

The resulting *"Output"* is sent via process interfaces to further process areas, which are defined as *"Destinations"*. Figure 5.1 below shows this in detail:

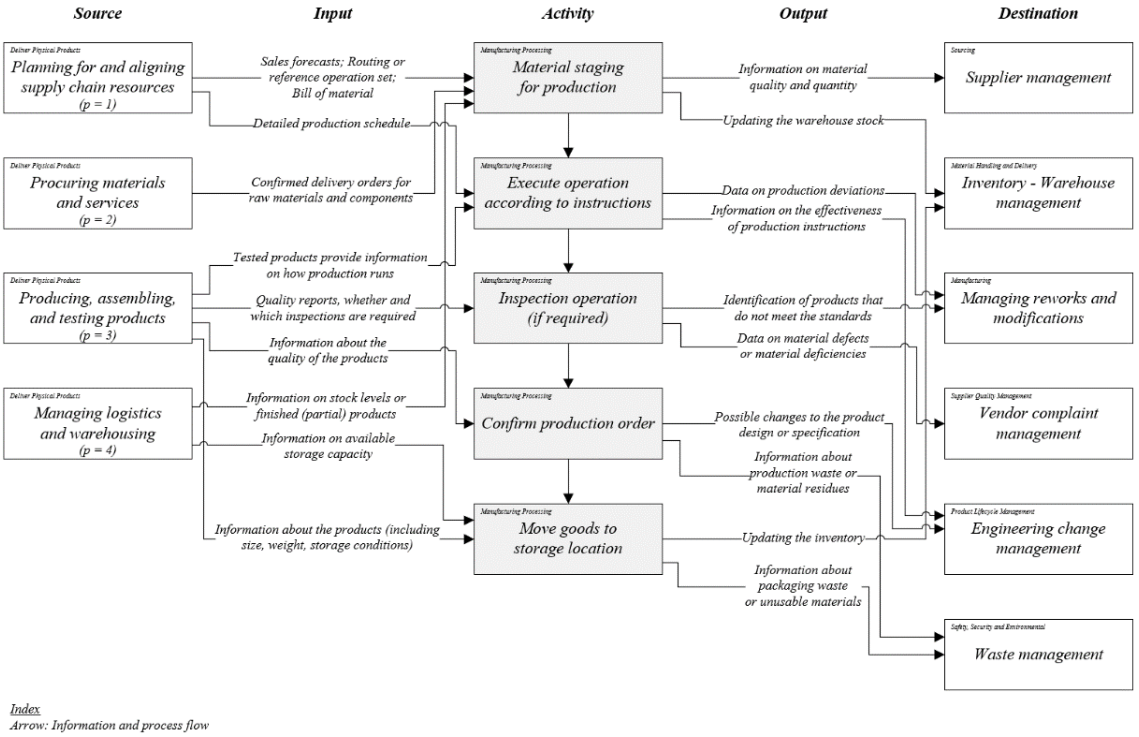

Figure 5-1: Analyzed and decomposed production process based on the APQC PCF
(own illustration based on APQC 2015)

The input processes (Source) in the production environment lay the foundation for an efficient production process by initiating the release of production orders in the system and triggering the subsequent manufacturing processing process. A key aspect of this phase is checking production capacities and the material situation in order to proactively address and solve any problems. Material planning plays a central role and is driven by system requirements and the implementation of orders, ensuring precise material requirements planning (APQC 2015).

Furthermore, transactional processes for material movements include maintaining inventory accounting and specific processes for certain items, including additional levels of control for traceability and environmental considerations. These transactions, which involve the movement, storage, or issue of material, are carefully recorded to feed into the accounting systems and ensure their integrity for accurate inventory management. In addition, inventory counts allow for verification and adjustment of inventory accuracy levels. All of the company's sites are integrated into the site control process, enabling consistent and comprehensive recording of relevant data (APQC 2015).

Within process management, process responsibles take on decisive roles. The Process Owner, as the person with overall responsibility for a process area, and the Process Leader Unit,

responsible for specific sub-processes within an organizational unit, are key figures in the management and optimization of business processes.

The Process Owner is primarily responsible for defining and establishing the performance of the processes as well as relevant key figures. Another important task is to review the process documentation with regard to its suitability and to plan and allocate both human and financial resources appropriately. Compliance with conformity standards for products, services and processes is also part of his responsibilities. In addition, the Process Owner initiates and monitors the continuous improvement of processes and ensures that they are applied correctly. He leads and informs the Process Leader Unit about process content, prepares annual reports on the process status, and provides the team with the necessary tools and methods for process management.

The core tasks of the Process Leader Unit include defining the specific target specifications for its unit, measuring, and evaluating the actual situation using key figures and promoting continuous improvement. He checks the process documentation for suitability and conformity and evaluates the required human and financial resources. In addition, the Process Leader Unit sets specific targets for the process development of its unit and monitors compliance with and application of the processes. In the event of deviations, he initiates suitable measures for improvement. He contributes to the technical training of process users, ensures that the process documentation within his unit is up to date and participates in process audits.

The process input (Input) to the production process resulting from the sub-processes is described as follows:

- ***Sales forecasts: Routing or reference operation set; Bill of material:*** *Sales forecasts, routings and BOMs guide the production planning process by predicting demand and identifying the necessary steps and materials for production;*
- ***Detailed production schedule:*** *A detailed production plan determines the timing and sequencing of manufacturing activities to ensure that production matches demand and resource availability;*
- ***Confirmed delivery orders for raw materials and components:*** *Confirmed delivery orders for raw materials and components provide a schedule of when raw materials will be available for production, making inventory management easier;*
- ***Tested products provide information on how production runs:*** *Tested products provide information on the efficiency and effectiveness of the production process and highlight areas for improvement;*
- ***Quality reports, whether and which inspections are required:*** *Quality reports show the need for inspections and ensure that products meet the specified standards before they reach the next stage of production or the customer;*
- ***Information about the quality of the products:*** *This information provides an indication of the extent to which the final product meets quality standards and serves as a guide for quality control and improvement measures;*
- ***Information on stock levels or finished (partial) products:*** *Data on stock levels or finished (partial) products enables effective inventory management and is used for production planning to meet demand without holding excessive stock levels;*
- ***Information on available storage capacity:*** *Knowing the available storage capacity helps to plan efficient storage of finished products to make the best use of space and optimize logistics;*

- ***Information about the products (including size, weight, storage conditions):*** *Information such as the size, weight and storage conditions of the products is crucial for planning the logistics, storage and distribution phases so that the products can be stored under optimal conditions until delivery.*

Based on the previously outlined inputs for the production process (Activity), this can be implemented in five steps, as already explained in the introduction. These steps ensure specific process performance: The execution and completion of production and testing according to the production orders and the transfer of the manufactured material to shipping or stock. The process also ensures that the production order is logically confirmed, and the products are available.

The following process output (Output) can now be derived based on the production process:

- ***Information on material quality and quantity:*** *The production process provides detailed information on the quality and quantity of the materials used, which is essential for quality control and further planning;*
- ***Updating the warehouse stock:*** *Warehouse stocks are updated based on the latest production results to ensure an accurate overview of available materials and products;*
- ***Data on production deviations:*** *Data on deviations in the production process is collected to provide information on efficiency and potential problem areas;*
- ***Information on the effectiveness of production instructions:*** *The process generates insights into the effectiveness of production instructions and their influence on the production process;*
- ***Identification of products that do not meet the standards:*** *Products that do not meet the specified quality standards are identified, which is crucial for quality control and rework;*
- ***Data on material defects or material deficiencies:*** *Data on material defects or material deficiencies is provided, which is important for evaluating supplier quality and adjusting material procurement;*
- ***Possible changes to the product design or specification:*** *The production process may suggest changes to the product design or specification to improve product quality or manufacturability;*
- ***Information about production waste or material residues:*** *Information about production waste or material residues is collected to minimize environmental impact and increase efficiency;*
- ***Updating the inventory:*** *Inventory management is updated to ensure accurate stock management and optimal material availability;*
- ***Information about packaging waste or unusable materials:*** *Details of packaging waste or unusable materials relevant to the company's waste management and sustainability efforts are provided.*

The downstream processes (Destinations) vary greatly and thus illustrate both the complexity and the diversity of the influence of the production process, including the sub-processes, on the entire supply chain. The descriptions of these processes are specified as follows:

- ***Supplier management:*** *In the context of supplier management, there is a set of follow-up processes, including contract management, supplier audits and material transfer management. Here, information originating directly from the production process is forwarded to suppliers, which enables effective communication and coordination;*
- ***Warehouse and inventory management:*** *This process includes handling material movements, maintaining inventory accountability and specific processes for certain items, including additional levels of control regarding traceability and environmental concerns. All material movements are recorded for inclusion in the accounting records. These transactions have all the necessary controls in place to ensure the integrity of the transactions and the accuracy of the inventory. It is also possible to check and adjust the accuracy through stock counts. All locations within the company are involved in the stock location control process to maintain relevant records;*
- ***Management of rework and modifications:*** *This process defines the procedure for managing rework and modifications. To clarify the scope of the rework and modification process, a distinction must be made between the terms "rework" and "modification". Rework refers to the reworking of non-conforming items to ensure they fully comply with the specifications. Modifications, on the other hand, are changes to the functionality of a product in order to meet new requirements and are only carried out after specific authorization on the basis of documented specifications;*
- ***Supplier complaint management:*** *The supplier complaint management process regulates the procedure from the receipt of a quality report regarding a supplier problem to the conclusion of the report. The buyer drives this process and carries out the tasks from start to finish, unless an escalation is required, in which case the Supply Chain Engineer/Quality department takes the lead and often resolves the issue together with stakeholders from different functions;*
- ***Engineering change management:*** *Engineering Change Management (ECM) is a structured and formalized process for handling customer and regulatory inquiries regarding product performance and solution approaches. It promotes continuous value creation for customer processes and includes the coordinated management and standardized tracking of changes with the aim of processing changes efficiently and effectively and ensuring their traceability;*
- ***Waste management:*** *Waste is correctly sorted into main fractions and disposed of properly to meet environmental standards and promote sustainability.*

Graphics are added to all the process descriptions presented, which include so-called swimlane diagrams. These illustrate the responsibilities of various roles and the individual activities over a period of time. In addition, the process diagrams can include relevant follow-up documents (e.g., work instructions, templates and checklists, guidelines, operating policies), which describe specific process activities in more detail and thus enable a more precise description. In addition, process chain characteristics are provided, which include general as well as more detailed information on the process, the associated process KPIs, the designated Process Owners and process inputs and outputs. Furthermore, ISO-compliant documentation and process control data (e.g., creator, reviewer, approver, release date, document ID, document type, review

interval) is maintained, which guarantees the uniqueness and reliability of the documented information within the corporate framework. Together, this comprehensive information forms the basis of the business process.

The resilience assessment model is then applied, based on the description of the production process outlined above, to assess the resilience and effectiveness of the processes.

5.2 Application of the Resilience Assessment Model

The defined DMs team has received an email, which includes the pertinent data necessary for evaluating RF value levels, as detailed in Section 3.3.3. The input data for the Fuzzy Delphi Technique are evaluated values at the level of the business process of physical product delivery. This data is presented in Appendix C for the initial round one and in Appendix D for the subsequent round (Huber et al. 2023).

The proposed Fuzzy Delphi Technique is illustrated by the example of determining the value RF $j = 1$ at the level of sub-process alignment of supply chain resources ($p = 1$) (Huber et al. 2023).

In the initial round, the DMs evaluated the values of the addressed RF in the following way:

B5; B4; B4; B4; B4; B4; B4; B4; B3; B2.

The aggregated value of the DMs' assessment in the initial round, denoted as $\tilde{v}_{11}^{1}$ is derived by applying the fuzzy square mean operator (Huber et al. 2023):

$$\tilde{v}_{11}^{1} = \left(\sqrt{\frac{7^2 + 6^2 + 6^2 + 6^2 + 6^2 + 6^2 + 6^2 + 3^2 + 1^2}{9}}, \sqrt{\frac{8.5^2 + 7.5^2 + 7.5^2 + 7.5^2 + 7.5^2 + 7.5^2 + 7.5^2 + 5^2 + 2.5^2}{9}}, \sqrt{\frac{10^2 + 9^2 + 9^2 + 9^2 + 9^2 + 9^2 + 9^2 + 7^2 + 4^2}{9}} \right) = (5.53,7,8.50)$$

Let us determine the distance of TFN $\tilde{v}_{11}$ from B1 (Huber et al. 2023):

$$d(\tilde{v}_{11}^{1}, B1) = \sqrt{\frac{1}{3} \cdot ((5.53-0)^2 + (7-1.5)^2 + (8.50-3)^2)} = 5.411$$

Similarly, the distance of TFN $\tilde{v}_{11}$ from the remaining predefined linguistic expressions is calculated as follows (Huber et al. 2023):

$$d(\tilde{v}_{11}^{1}, B2) = 4.510$$
$$d(\tilde{v}_{11}^{1}, B3) = 2.054$$
$$d(\tilde{v}_{11}^{1}, B4) = 0.490$$
$$d(\tilde{v}_{11}^{1}, B5) = 4.219$$

Let us identify a linguistic expression that can describe the aggregated value of the DMs' assessment in the initial round, according to the following expression (Huber et al. 2023):

$$min(5.411;\ 4.510; 2.054; 0.490;\ 4.219) = 0.490 \rightarrow B4$$

In the second round, the DMs provided assessments of B4; B3; B3; B2; B3; B3; B3; B2; and B2 (Huber et al. 2023).

The aggregated value from the DMs' assessments in the second round is determined using the fuzzy square mean operator (Huber et al. 2023).

$$\tilde{v}_{11}^{2} = (3.06, 4.71, 6.45)$$

The consistency of the DMs' assessment is verified according to the developed procedure (Ferri et al. 2005).

Through additional calculations, the value of the correlation coefficient can be determined. The value of the correlation coefficient between the assessment of the value RF in the first and second rounds is 0.8. $j = 1$ in the first and second rounds is 0.8. The obtained value of the correlation coefficient shows that there is a strong positive relationship between the estimates of DMs in the first and second rounds, so that the value of RF $j = 1$ obtained in the second round can be considered as the final value (Huber et al. 2023).

Similarly, the aggregated values of the RFs were determined at the level of the individual sub-processes of the considered business process and presented in Appendix D (Huber et al. 2023).

Based on the obtained values of the correlation coefficients, it can be concluded that the values of the RFs obtained in the second round can be accepted as the final values of the RFs at the level of each sub-process (Huber et al. 2023).

Conclusion: The decision-making rounds with the DMs were successfully completed within just a few weeks and therefore in a timely manner. In addition to the necessary

preparation, one of the biggest challenges was finding suitable dates, as the DM group consists exclusively of members of top management and their availability is limited. The short intervals between the meetings proved to be extremely beneficial, as they ensure that relevant information and possible connections are not lost. This helps to maintain the knowledge originally conveyed and the dynamics of the decision-making process. It is also important to note that decisions generally do not improve if they are postponed. Timely execution of decision rounds is also an important aspect of business resilience. In a constantly changing business world, the ability to make decisions quickly and effectively is crucial to the company's success (Huber et al. 2023).

5.3 Implementation of the Method

The assessment of the relative importance of RFs for the recovery of KPIs' is conducted for each designated KPI at the level of each addressed sub-process (refer to Table 5-2). This activity was carried out by the DMs during a panel discussion, which took place after the second round of the Fuzzy Delphi Technique. The assessment adhered to the guidelines outlined in Chapter 3.3.4. The panel discussion was held at the company headquarters and involved all DMs who participated in previous activities (Huber et al. 2023).

RFs	$i = 1$	$i = 2$	$i = 3$	$i = 4$	$i = 5$	$i = 6$	$i = 7$	$i = 8$	$i = 9$	$i = 10$	$i = 11$	$i = 12$
$j = 1$	A3	A7	A5	A6	A5	A7	A3	A7	A4	A5	A7	A7
$j = 2$	A5	A2	A6	A7	A5	A3	A3	A6	A4	A6	A6	A7
$j = 3$	A5	A6	A5	A5	A2	A2	A6	A5	A4	A4	A6	A5
$j = 4$	A6	A6	A6	A5	A7	A6	A6	A6	A5	A4	A5	A6
$j = 5$	A5	A6	A5	A5	A5	A3	A5	A4	A6	A6	A6	A6
$j = 6$	A4	A2	A4	A6	A6	A3	A4	A5	A2	A4	A4	A5
$j = 7$	A2	A4	A4	A4	A3	A3	A4	A3	A3	A3	A4	A4
$j = 8$	A3	A7	A4	A4	A3	A4	A4	A3	A3	A4	A5	A4
$j = 9$	A5	A2	A2	A3	A2	A1	A6	A5	A5	A5	A4	A3
$j = 10$	A7	A2	A3	A3	A3	A5	A5	A4	A5	A4	A4	A5

Table 5-1: The Importance of RFs for KPIs' Recovery in each Treated Sub-process (Huber et al. 2023)

Let us determine the aggregate weighted value of RF (j = 1) at the level of KPI ($i = 1$), denoted as $\tilde{z}_{11}$ (Huber et al. 2023):

$$\tilde{z}_{11} = \tilde{v}_{11} \cdot A3 = (3.06,4.71,6.45) \cdot (1.5, 3.5, 5.5) = (4.59,16.49,35.48)$$

The other aggregated weighted values of RFs are calculated similarly to the methods presented in Appendix E (Huber et al. 2023).

The recovery time is taken from the company records, as explained in chapter 3.4. The representative scalars of resilience at the KPI level, as well as the recovery time of each KPI, are provided in Table 5-3 (Huber et al. 2023).

KPIs	z_i	t_i $(in\ months)$
$i = 1$	31.10	10
$i = 2$	36.76	7
$i = 3$	32.42	5
$i = 4$	37.07	7
$i = 5$	31.50	4
$i = 6$	32.41	6
$i = 7$	27.61	10
$i = 8$	27.81	6
$i = 9$	23.92	7
$i = 10$	22.84	9
$i = 11$	27.09	7
$i = 12$	25.61	8

Table 5-2: Total Aggregated Weighted Crisp RFs and KPIs' Recovery Time (Huber et al. 2023)

The input data for the correlation analysis consists of the representative scalars of the aggregated weighted total RF values and the recovery time expressed in months. The obtained value of the correlation coefficient is presented as follows (Huber et al. 2023):

	The weighted aggregated RFs' value at the level of each KPI	The recovery time of each KPI
The weighted aggregated RFs' value at the level of each KPI	1	
The recovery time of each KPI	-0.73857	1

Table 5-3: Impact of Aggregated Weighted RFs on KPIs' Recovery Time (Huber et al. 2023)

Based on the acquired value of the correlation coefficient, a statistically significant influence of RF values on the recovery time of KPIs can be concluded. A negative coefficient value indicates that an increase in RF values corresponds to a decrease in recovery time (Huber et al. 2023).

Conclusion: Regarding the research gaps A (Hybrid Fuzzy Models for KPI Optimization) and B (RFs and KPI recovery time: A negative correlation), the results presented provide valuable insights. As can be seen in Table 5-4, the correlation analysis between the aggregated weighted RF values and KPI recovery times shows a significant negative correlation coefficient of -0.73857, indicating that higher RF values are associated with shorter KPI recovery times. Overall, this analysis thus demonstrates a statistically significant influence of RF values on KPI recovery times, with higher RF values leading to shorter recovery times (Huber et al. 2023).

[8] Conduct a Scatter Plot Analysis

A scatter plot is used to illustrate the data for the previous statement that an increase in RF values is accompanied by a shorter recovery time. This also serves as validation. A scatter plot is an effective tool for visualizing correlations by graphically representing the relation between two variables and thus illustrating any correlations. A holistic view of the data also allows possible patterns to be recognized. A linear trend line is inserted for better interpretation of the

scatter plot. To interpret the scatter plot, the following three steps are followed (Minitab 2023; Yi 2021):

[a] Establish and evaluate the model relationship;
[b] Identify group-related patterns;
[c] Identify further patterns.

[a] Establish and Evaluate the Model Relationship

The scatter plot in Figure 5-2 illustrates a negative correlation. The abscissa (x-axis) shows the KPIs for the recovery time in months, while the ordinate (y-axis) shows the overall rating of the weighted RFs (Arnadottir 1996; Huber et al. 2023; Jiang et al. 2019). It is clear from the scatter plot that the overall score of the weighted RFs decreases the longer the KPI for recovery time lasts. This means that KPIs with longer recovery times (on the left side of the figure) have higher overall weighted RF scores than those with shorter recovery times. These results are consistent, as an increase in RF values appears to be accompanied by a reduction in recovery time.

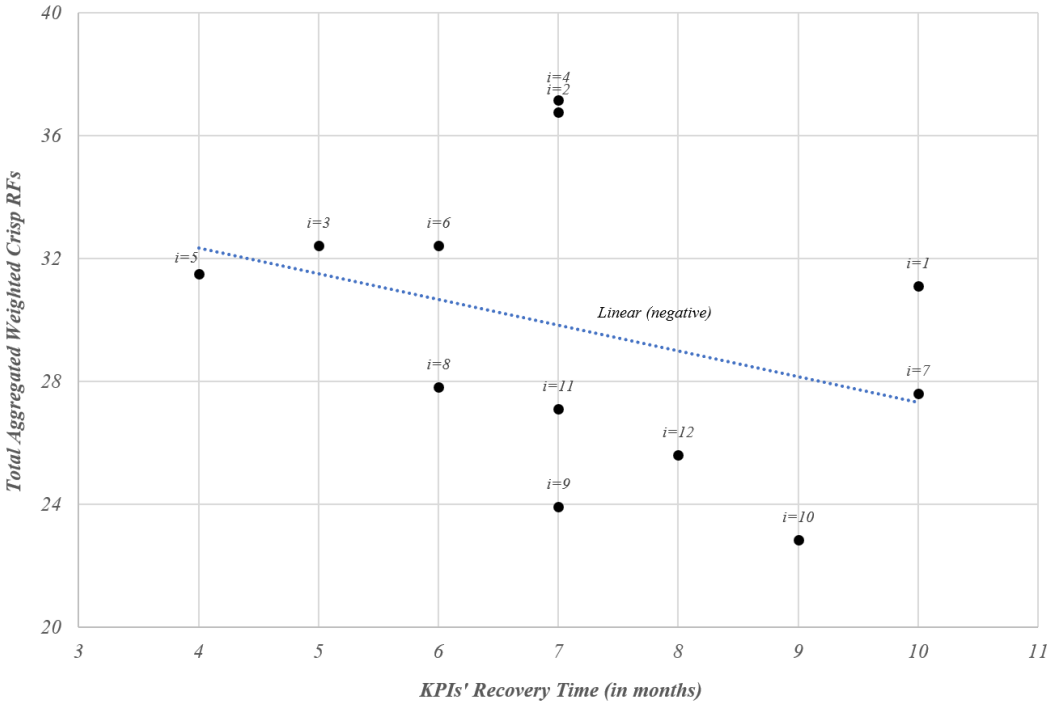

Figure 5-2: Scatter plot shows a negative correlation between the KPI's Recovery Time and the Total Aggregated Weighted Crisp RFs (Huber et al. 2023)

Given the high variance, it is possible to examine the strength of the relationship between the abscissa and the ordinate through a simple linear regression analysis (using Microsoft Excel) using the values in Table 5-3. This analysis aims to explain the strength and direction of the relationship between the two variables (Huber et al. 2023).

The quality of the calculated regression is assessed using the measure of determination. This indicates what percentage of the variance of the suspended variable is explained. In this case, the coefficient of determination is 0.189, which explains around 19 percent of the variance of the variable (Walther 2022). However, a higher value in this context is desirable. As the sample size increases, or as in this case the variance, there tends to be a greater probability that different values for the dependent variable will occur for the same independent variable. This can lead to a reduction in the coefficient of determination. Nevertheless, it can be concluded that the regression model makes a statistically significant contribution to the explanation (Huber et al. 2023). Even analyses with a low coefficient of determination can provide valuable information. Individual independent variables can be statistically significant. This means that variables can be identified that can cause a change in the dependent variable (Sonneck 2020). In the context of the work, these are correlations between the DMs, RFs or KPIs.

[b] Identify Group-related Patterns

The scatter plot can reveal group-related patterns that can be summarized and analyzed as part of further interpretation. For example, differences in the x-y relationships are searched for, whereby group-related patterns, such as different slopes, positions, or clusters, can be identified (Minitab 2023; Yi 2021). Figure 5-2 shows four groups with different characteristics (Huber et al. 2023):

- ***Group 1 (i = 3; i = 5; i = 6):*** *The y-values are almost identical and show a close relationship to the KPI recovery times;*
- ***Group 2 (i = 2; i = 4):*** *Here the values do not appear to differ significantly;*
- ***Group 3 (i = 8; i = 9; i = 10; i = 11; i = 12):*** *This group has the lowest total aggregated weighted RFs and shows a steeper slope overall;*
- ***Group 4 (i = 1; i = 7):*** *Compared to the other groups, the values in this group have consistently higher x-values and therefore the longest recovery times.*

It is therefore also possible to form additional groups and interpret them accordingly. For example, contrasting values, such as the lowest ($i = 5$) compared to the longest ($i = 1$) KPI recovery time, with almost identical Total Aggregated Weighted Crisp RFs, or entire groups of data sets ($i = 4$; $i = 2$; $i = 11$; $i = 9$) with the same KPI recovery times but different Total Aggregated Weighted Crisp RFs, could be compared for further analyses (Huber et al. 2023). A meaningful grouping can help to characterize the data more accurately. However, it is essential to note that there may not be a compelling group-related pattern (Minitab 2023). This requires further analysis for clarification.

[c] Identify Further Patterns

The final step is to identify outliers that indicate unusual conditions in the data. This means that data points that may be far away from the other data points (e.g., $i = 2$; $i = 4$) can have a significant influence on the results. Time-dependent trends may indicate changing data conditions. In this context, it is crucial to identify the causes of outliers and correct data entry or measurement errors if necessary. It may also be necessary to eliminate data points that are due to unusual, one-off events (exceptional conditions). In addition, it is also capable of

recording time-dependent correlations in order to be able to analyze chronologically recorded data with regard to trends. The analysis can then be performed again (Minitab 2023; Yi 2021). From the author's point of view, these steps must be carried out at regular intervals anyway in order to obtain comparative data and carry out analyses. It should be noted that the focus is not only on past values. Rather, the analyses should be future-oriented in order to be able to act actively and thus proactively shape the future instead of having to react to unexpected events under pressure (Huber et al. 2023).

Conclusion: To verify the previous assumption that higher RF values correlate with shorter KPI recovery times, a scatter plot analysis is performed. This confirms the negative correlation and provides insights into the data patterns. This forms the basis for further analysis and fields of research.

5.4 Enhancement of RFs through the Application of Heuristic Approaches or exact Methods

[9] Performing Optimization Analyses using Heuristic Algorithms or exact Methods

Building on Chapter 4.2 and the case study described in the previous Chapter 5, the proposed Branch-and-Bound algorithm is now applied to optimize the lowest ranked RFs at the level of identified four sub processes. Those are: Awareness (j=4), Self-organization (j=7) and Redundancy (j=9). For the purposes of executing the algorithm, their indices are referred to as Awareness (j=1), Self-organization (j=2) and Redundancy (j=3).

As part of the case study, the representative DMs according to the research guidelines (refer to Chapter 4.2) evaluated the suitability of various management techniques (Appendix B) for improving the RFs. The Management System Manager provided an assessment of the cost and time required for each management technique (refer to Appendix B). The specific method $m = 9$ for RF $(j = 1)$ was evaluated as an example by the algorithm (refer to Chapter 4.2, steps 1-3), with the DMs rating the suitability as follows (Aleksić et al. 2024):

$$\mathrm{L3}, \mathrm{L5}, \mathrm{L4}$$

The aggregated value was calculated by applying the fuzzy cubic mean (Aleksić et al. 2024):

$$\tilde{x}_{19} = \left(\sqrt[3]{\frac{1}{3} \cdot (2^3 + 5^3 + 3.5^3)}, \sqrt[3]{\frac{1}{3} \cdot \sum_{e=1,..,E} (3.5^3 + 6.5^3 + 5^3)}, \sqrt[3]{\frac{1}{3} \cdot (5^3 + 8^3 + 6.5^3)} \right) = (3.88, 5.28, 6.72)$$

The representative scalar TFN $\tilde{x}_{19}$ was obtained by applying the centroid defuzzification method (Aleksić et al. 2024):

$$x_{19} = 3.88 + \frac{6.72 - 3.88 + 5.28 - 3.88}{3} = 5.30$$

Similar calculations provide the unique values for the suitability of the method whose execution should improve the identified RFs (Aleksić et al. 2024).

By applying a suitable software solution that integrates the Branch-and-Bound algorithm, we obtain the optimal set of techniques required to improve the RFs in the organization (OR-Tools 2024). This optimal solution was found in the 23rd iteration within 0.041872 seconds (Aleksić et al. 2024).

The management techniques that need to be applied to improve the three RFs are listed in Table 5-1 below (Aleksić et al. 2024):

The treated RFs	The optimal set of management techniques
RF ($j = 1$)	$m = 2; m = 6;$ $m = 20; m = 21;$ $m = 23; m = 24.$
RF ($j = 2$)	$m = 3; m = 5; m = 6; m = 9;$ $m = 14; m = 16; m = 2;$ $m = 6; m = 20; m = 21; m = 24.$
RF ($j = 3$)	$m = 3; m = 6;$ $m = 9; m = 20;$ $m = 21; m = 23.$

Table 5-4: The Optimal Set of Management Techniques
(own illustration based on Aleksić et al. 2024)

It can be seen that certain management techniques that are applicable to all RFs, such as generic flowcharts, brainstorming and brainwriting, should be prioritized for implementation. Other methods that could improve at least two RFs include the balanced scorecard, generic checklists, mind map, 5W2H and importance-performance analysis. Finally, relationship diagrams and/or generic tables could be defined (Aleksić et al. 2024).

These management techniques are fundamental for increasing business resilience by strengthening the listed key areas such as flexibility, awareness, and adaptability (Aleksić et al. 2024).

The empirical validation through the case study confirms the effectiveness of the proposed approach, which enables informed decision-making based on optimized resource allocation. The use of Branch-and-Bound heuristics to optimize corporate RFs provided concrete insights into the effectiveness of this approach. The results revealed a clear sequence of management techniques that should be used to efficiently improve RFs (Aleksić et al. 2024).

Furthermore, the results offer both theoretical and practical implications for companies aiming to strengthen their corporate resilience. Companies are recommended to first assess the values of their RFs and, in particular, to prioritize those RFs with the lowest values for improvement. The identified and evaluated techniques used in this study should serve as a basis for further calculations (Aleksić et al. 2024).

Conclusion: For the future, we recommend conducting further case studies in similar organizational contexts in order to perform appropriate statistical tests. This would allow for more robust conclusions and could lead to refinement of the methods used. In addition, the application of heuristic and meta-heuristic algorithms should be considered to develop and evaluate a wider range of solutions for improving RFs (Aleksić et al. 2024; Tadic et al. 2024).

Future research could also investigate how flexible these management techniques are to adapt to changing market conditions and technologies and whether they are sustainable in the long term (Aleksić et al. 2024; Tadic et al. 2024).

By considering time and cost constraints, it was also ensured that the identified management techniques are not only theoretically effective, but also practicable in a real business context. These considerations are crucial for the implementation of decisions that are consistent with both resource constraints and the strategic goals of a company (Aleksić et al. 2024; Tadic et al. 2024).

5.5 Conclusion of the Case Study

[10] Analyze the Findings

After applying the proposed Fuzzy Delphi Technique, the value of the RFs is determined at the level of the individual sub-processes. In the next step, the relative importance of the RFs for the recovery of the individual KPIs is derived by direct evaluation. The weighted value of the RFs is determined by multiplying the previously defined variables. The weighted aggregated fuzzy value of each RF is obtained by applying the aggregation operator to the fuzzy root mean square. The representative scalar of the weighted aggregated fuzzy value of each RF is determined by applying the simple gravity method (Huber et al. 2023).

The result of the study is an analysis of the relationship between the weighted aggregated value of each RF and the recovery time of each KPI. The calculations presented and the correlation analysis show that the assumption of a negative correlation is confirmed. There is a negative statistical dependency between the RFs and the time required to restore the KPIs (Huber et al. 2023).

Comparing the results with the research already presented, the following can be observed: The areas in which resilience aggregation is conducted can be exemplified by military service (Hodicky et al. 2020), the measurement of social resilience (Copeland et al. 2020) and the quantification of operational supply chain resilience (Munoz & Dunbar 2015). Each of the aforementioned studies considers its own set of resilience indicators/factors, which leads to the conclusion that there is no standardized list of RFs. In the aforementioned papers, the resilience indicators/factors are presented with unique values, in contrast to the research proposed here, which uses linguistic variables. This suggests that there are different approaches to aggregating resilience indicators/factors. The aggregated value can be accurately determined by applying

MADM techniques, such as the analytic hierarchy process (Hodicky et al. 2020), or by applying simple aggregation operators (Copeland et al. 2020; Munoz & Dunbar 2015). In the study presented here, the aggregated value is determined by applying the Fuzzy Delphi Technique and the fuzzy square mean operator (Huber et al. 2023).

Improving the overall resilience of companies and their DMs requires a holistic approach that takes various aspects into account. Based on the case study conducted, the author, together with the DMs that provided the input data for the case study, derives the following general recommendations for increasing organizational resilience (Huber et al. 2023):

- ***Establish strong risk management practices:*** *Companies should implement a comprehensive risk management system that identifies potential risks, evaluates them, and takes appropriate measures to address them. Such an approach makes it possible to respond to potential threats at an early stage and minimize damage;*
- ***Diversification of business activities:*** *Companies should reduce their dependence on individual products, markets, or suppliers. A broader base enables them to respond better to changes in the market and cushion potential risks more effectively;*
- ***Promote flexibility and adaptability:*** *Companies should develop a corporate culture that promotes flexibility and adaptability. This includes fostering a spirit of innovation, a willingness to change, and the development of agile structures and processes;*
- ***Empowering leaders:*** *Decision-makers should have a high level of resilience Companies should support their leaders by providing them with the necessary resources, training, and coaching to deal with challenging situations;*
- ***Continuous training and learning:*** *Companies should ensure that their employees are continuously trained to keep up with changing demands and challenges. This includes both technical and generic competencies, such as problem-solving skills, communication, and teamwork;*
- ***Build a strong network:*** *Companies should build and maintain relationships with relevant stakeholders, including customers, suppliers, partners, and regulators. A strong network can be invaluable in times of crisis to gain support and find solutions together;*
- ***Leverage technology and digital transformation:*** *Companies should take advantage of modern technologies to make their processes more efficient and improve their resilience. This can include the use of data analytics, artificial intelligence, and other technologies to identify risks early and make informed decisions.*

These recommendations serve as a starting point for improving the resilience of companies and their DMs. Companies need to address their challenges and needs and develop adapted solutions accordingly. Another approach that can be combined with the proposed measures is to rank the proposed RF to identify the last ranked ones. This allows DMs to propose more concrete measures to improve them and maintain the values of the top-ranked ones (Huber et al. 2023).

The primary contribution of the research can be briefly summarized as follows: There are only a limited number of papers that address the problem in a similar way and define relationships between RFs and KPIs. All existing uncertainties in the model are described by linguistic variables modelled by Fuzzy Sets Theory. The fuzzy values of the RFs at the level of

delivery of the physical product sub-processes are determined using the extended Fuzzy Delphi Technique. The weighted aggregate fuzzy value of resilience at the KPI level is precisely determined by applying fuzzy algebra rules (Huber et al. 2023).

The primary constraint of the research pertains to the selection of the DM team, comprised of top management representatives. This selection takes into account their knowledge, skills and experience related to overall business operations, strategy and the organizational state and functioning (Huber et al. 2023).

On the other hand, the proposed model can be considered flexible as it allows for changes in the number of KPIs and RFs. Furthermore, the number of DMs can be adjusted according to the specific nature of the organization under consideration (Huber et al. 2023).

Future research should cover the extension of the Delphi method, the use of alternative methods for consensus verification, the development of new methods and the comparison of the resulting findings. In terms of benchmarking resilience management, it can be assumed that this model should be applied to different business processes and additional industrial or economic sectors. In addition, it would be beneficial to test the proposed model with different types of fuzzy numbers to assess their suitability to account for existing uncertainties (Huber et al. 2023).

"Leadership is now the ability to step outside the culture that created the leader and to start evolutionary change processes that are more adaptive."

Edgar H. Schein (1928 to 2023): US-American social scientist.

6 DISCUSSION AND IMPLICATION

This chapter serves to interpret the research findings and place them in a broader context. It also creates space for critical self-reflection in order to emphasize the importance of this work both for the scientific environment and for practical application.

The main objective of this thesis is to develop a model for assessing business resilience at the business process level. This model takes into account the interactions between the KPIs of a process and the RFs using the Fuzzy Delphi Technique. To achieve this scientific goal, the following sub-goals are pursued (Huber et al. 2023):

- *Identification and selection of a suitable resilience model for complex production organizations and precise evaluation of RFs at the level of each identified sub-process;*
- *Definition and selection of KPIs at sub-process level that are relevant in a process-oriented environment for the manufacture of physical products. This also includes defining the required recovery time for each identified KPI after a disruption;*
- *Determination of the aggregated RF value at the level of the individual KPIs;*
- *Perform a scatter plot analysis of the aggregated RF value at KPI level and calculate the recovery time for each KPI using regression and correlation analysis;*
- *Conception of an optimization model for the selection of strategies to improve resilience factors.*

The model was validated using the case study carried out in Chapter 5 in a complex industrial company. As a consequence, the model finally developed in Figure 4-8 could be successfully implemented with real data as well as the selected business areas.

In the following chapters, the model is extended and supplemented by the previous models and methods in order to develop a new comprehensive and practice-oriented ***"Resilience Management Model Framework (RMMF) of Corporate Resilience"***® as a guideline which may be used by industrial companies.

6.1 Summary of the Results and Proposed Approach to Organizational Resilience

This section summarizes the key findings of the previous chapters. This includes a concise presentation of the key findings and their relevance to the overall subject of organizational resilience in complex industrial enterprises in uncertain environments.

To begin with, the aforementioned RMMF of entrepreneurial resilience will be described. The author of the paper aims to develop an easily understandable and accessible framework for business resilience. This framework should adequately take into account the complex reality of companies without adding unnecessary complexity (Drath & Heller 2018).

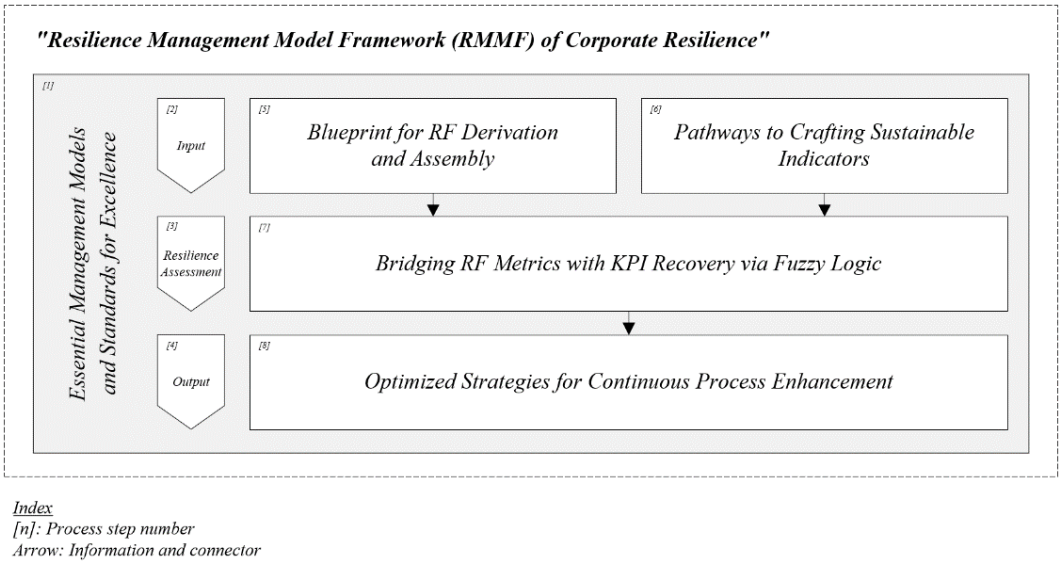

Figure 6-1: The Resilience Management Model Framework (RMMF) of Corporate Resilience (own illustration)

The result of this work is presented in Figure 6-1 as the *"Resilience Management Model Framework of Corporate Resilience"*. It is a structured model consisting of various interlinked process steps and dimensions.

The RMMF of corporate resilience integrates various approaches in this way. The management systems combine tools, activities, methods, and tools both out of a desire for corporate excellence and to firmly anchor them. Their aim is to manage and control the company in relation to specific objectives, such as strengthening corporate resilience (ISO 2015). Management systems therefore promote corporate resilience by providing a structured framework. This helps to prepare for potential disruptions, respond to them appropriately and effectively recover from them sustainably while continuing to pursue business objectives (Koslowski 2014). The result is a resilient, partly flexible safety net that both cushions the impact in the event of disruptions and reduces the metaphorical *"drop height"* - in terms of the potential maturity and resilience of the management system.

International as well as industry- and sector-specific standards complement the management systems by providing guidelines for the implementation of objectives (Schäfer 2023-B). The integration of standards into the management systems contributes to the establishment of consistent and cross-sector processes and procedures. There is a particular focus on the continuous development of management systems to ensure that they are in line with the latest technology, best practice, and industry standards. Standards and management systems work hand in hand with the aim of achieving corporate goals and promoting continuous improvement.

The input factors are primarily concerned with the development of RFs and KPIs. The guidelines for RFs are central to the creation of this framework, whereby an individual approach depending on the type of the company is essential. Various approaches, such as the OECD method and VCA, emphasize the need for transparency and RFs adapted to the context. It is important to consider the specifics of each company when selecting indicators and to define clear, measurable KPIs.

The use of fuzzy logic makes it possible to use fuzzy sets and linguistic variables to take uncertainties into account. Through differentiated degrees of membership, it allows a more precise representation of fuzzy terms. A hybrid fuzzy model can therefore be used to determine precise values for each identified KPI.

In the final step, proven and logical methods are used to optimize the strategies for continuous process improvement. Some of these methods are considered optional, as they should always be considered in an operational context. However, it is advisable to review and apply the methods in terms of their applicability.

In the following, the research results on the problem (refer to Chapter 2) are summarized and presented in detail in relation to the four dimensions:

[a] Essential Management Models and Standards for Excellence Dimension
[b] Blueprint for RF Derivation and Assembly and Pathways to Crafting Sustainable Indicators (Input) Dimension
[c] Bridging RF Metrics with KPI Recovery via Fuzzy Logic (Resilience Assessment) Dimension
[d] Optimized Strategies for Continuous Process Enhancement (Output) Dimension

[a] Essential Management Models and Standards for Excellence Dimension

The first dimension [1] (in gray) represents the essential management models and standards for excellence, which represent the elaborated models and standards. Integrated management systems act as a guide and emphasize the importance of sustainability and innovation, which contribute to strengthening corporate resilience. The application of international standards is essential for global market comparability. Furthermore, a profound cultural change promotes cooperation, which is of central importance for resilience. This model supports resilience initiatives and the holistic approach through the various phases of the Deming Quality Management Cycle.

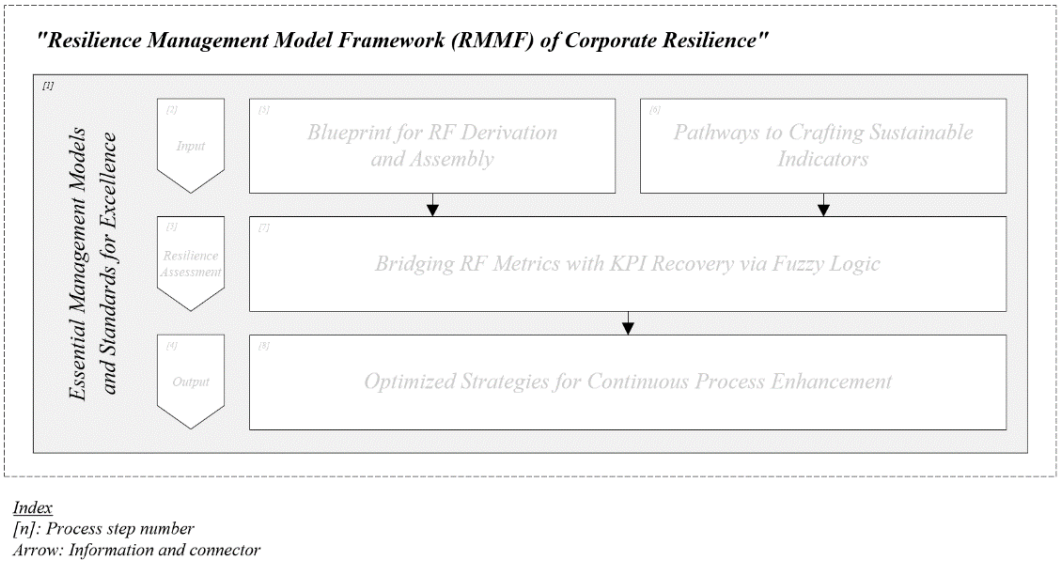

Figure 6-2: RMMF: The Essential Management Models and Standards for Excellence Dimension (own illustration)

Both standards and norms play an essential role in strengthening and improving corporate resilience. Compliance with voluntarily imposed standards ensures that a company's management systems remain up to date. However, relying on standards alone is not enough. While ISO certification is a first step, further measures are required to build a sustainable system.

Example
"The traditional business model of large companies like Coca-Cola or McDonald's is facing growing normative challenges. For decades, fast-food chains and soda manufacturers could rely on their track record, on constant demand and global cult status. But with a growing awareness of health and sustainability, many consumers now prefer regional apple spritzers or hand-crafted burgers. Attempts by industry leaders to respond with products like veggie burgers and Coke Zero often come across as hasty attempts at adaptation rather than forward-looking innovation. EU marketing standards are designed to ensure product quality, protect consumers, and ensure consistent standardization across the EU. These standards also promote trade by being consistent with international standards that have been in place since the 1950s (Rühl 2020; Schmeitzner 2023)."

Table 6-1: Standards: Example of traditional big players such as Coca-Cola or McDonalds (Rühl 2020; Schmeitzner 2023)

Particularly in the context of corporate resilience, customers often expect their suppliers and service providers to successfully certify their management systems as a contractual requirement. However, the certificate is not the only priority for customers. Rather, they value high-quality, error-free product delivery, optimal service provision and consistent compliance with specific customer requirements as well as legal and official regulations. Organizations that take a systematic and coordinated approach tend to achieve better results than those without a structured process. As part of the environmental management system, compliance with legal requirements, for example in the areas of occupational health and safety and the environment, is crucial

in order to avoid negative public perception and the associated delivery failures. It is therefore essential to continuously comply with legal requirements, which can be guaranteed by a certified management system. The decisive factor here is that customers expect an effective management system in the long term - and not just at the time of certification - which also meets the requirements of the certification standards (Schäfer 2023-B).

ISO/IEC TS 33061:2021 can be used to meet external but primarily internal requirements and to achieve a corresponding level of resilience in the management system. This defines process maturity levels and can thus strengthen the resilience of companies. However, it is important to take a risk-based approach in order to identify relevant business processes in a constantly shifting market environment. Furthermore, from the perspective of the author of this paper, full implementation, or certification with regard to certain standards and norms is not mandatory. It is much more important to filter out the aspects relevant to the company from these standards and introduce them step by step. This can be done in different iterations depending on the organizational structure, available resources, or specific challenges. It is essential to recognize the relevance and individual benefits of these standards and norms and to understand their supporting function during implementation. Basically, it can be said that certification is beneficial if it contributes to increasing the efficiency of a management system, the associated processes and ultimately the products.

The ISO 22316:2017 standard on organizational resilience provides organizations with clear guidelines if they want to promote organizational resilience. It focuses on the assessment of resilience factors and the development of a culture of resilience in companies. Behavioral aspects as well as risk management structures and shared values are taken into account. The successor standard, ISO/AWI 22316, is expected to continue to focus on strengthening organizational resilience. Experts agree that the normative framework designed for this purpose helps companies to be successful in a constantly changing world (Ferdinand & Prem 2020; Heller 2019; Katz 2018). The ISO standard acts as a concisely formulated guideline for organizations that want to strengthen their immune system in a systematic and sustainable way. With this holistic approach, the standard provides support in determining the current situation and the steps required to increase the company's resilience. Furthermore, according to Hübner (2023), it is essential to recognize that every company needs a tailor-made strategy and a specific concept in order to be able to react effectively in the event of disruptive events. Such a concept must: Be precisely tailored to the company's specific requirements; clearly define adequate processes and be equipped with the appropriate systems as well as models. Such a customized action plan is invaluable. It prevents companies from falling into paralysis in times of crisis, wasting valuable resources in hectic ad hoc measures or even falling into a passive, wait-and-see attitude.

DIN SPEC 91461:2021 offers a high-quality supplement to the standards listed. It provides a comprehensive reference framework for stress tests, the review of resilience strategies and the application of standards in various sectors. In the present work, it serves as a tool to assess the ability of management models to recover from extreme events or shocks. Its primary objective is to assess and strengthen corporate resilience under different conditions. The relevance of this specification has increased significantly in the wake of events such as the 2008 financial crisis or the Fukushima disaster, which have underlined the need to prepare organizations for unforeseen threats and risks (Schäffer 2020). However, the effective application of DIN SPEC 91461 is limited by challenges in terms of validity, comparability, and reproducibility, which makes the development of standardized methods essential. In a world characterized by disruptive innovations and information overload, the understanding and management of risks plays a central role. The specification extends and deepens the standards discussed so

far and makes a significant contribution to improving the anticipation and management of unexpected challenges, particularly with regard to critical infrastructure and cyber threats. In this way, it contributes to a coherent resilience management strategy and supports organizations in securing their future viability (Beuth & Jovanović 2021).

The standards listed support the management systems described below in order to better implement and compare the requirements for business resilience (Beuth 2023). As mentioned above, management systems provide a structured framework that enables organizations to effectively integrate the standards into the context described for the organization, monitor them, and continuously improve them. They also help to ensure that standards do not just exist on paper, but are anchored in the daily processes and, above all, in the culture of an organization. In this way, they enable standards to be lived systematically and the necessary compliance to become an ongoing, measurable, and optimizable practice.

TQM is a comprehensive, holistic concept that aims to establish a consistent focus on quality in all areas of a company. By involving every employee, a culture of continuous improvement is promoted that is geared towards exceeding customer requirements and optimizing processes. From the author's point of view, this can form an initial basis for management systems and thus also for corporate resilience. Despite the proven and stated benefits, there is a gap in the literature regarding the direct link between TQM and business resilience. However, TQM can be strengthened in terms of business resilience with the expanded aspects described in section 3.4.2.1. In general, however, there is a need to adapt TQM to today's dynamic and complex challenges in order to ensure comprehensive, dynamic resilience. The lack of empirical research on the application of TQM in the resilience context suggests that without extensions that focus on adaptability and holism, TQM alone may not be sufficient to meet current needs.

The EFQM Model for Excellence, on the other hand, offers an already more specific framework for evaluating and improving management practices in organizations. The model uses the RADAR logic for evaluation and improvement, which is applied to the fields of procedure, implementation, evaluation/improvement, relevance/benefit, and performance. The focus is somewhat less on the collection of key figures. It can be noted that specific resilience enablers are missing from the EFQM model. Although tools such as the EFQM Resilience Toolkit are available, the author of the paper considers a simple adaptation to be insufficient for the complexity of the resilience issue. It is also questioned whether the model, which is geared towards long-term change, can cope with sudden shocks. Nevertheless, it is seen as an open basis for further developments that could include specific resilience enablers. In Table 3-4 in section 3.4.2.2, the EFQM model is considered in the context of corporate resilience and expanded to include newly developed resilience enablers in the context of this paper.

From the author's point of view, the SGMM offers a first structured framework for the management, design, and organization of organizations, with a special focus on the integration of different influences and the representation of their interrelationships. It distinguishes between normative, strategic, and operational dimensions, each of which contributes to strengthening corporate resilience. Despite its strengths, it is critically noted that the SGMM does not take an end-to-end view of business processes, in particular the lack of consideration of backward corrective measures (backward chain). This missing aspect could complete the model and contribute to a more comprehensive view. Overall, however, the model effectively supports the integration of corporate resilience in companies.

The AQMM was developed to address the shortcomings of existing concepts, which often neglect organizational alignment and capabilities as well as feedback mechanisms. The model focuses on the management of goals and strategies, the optimization of organizational structures and processes and the promotion of a value culture. At the heart of this is the quality stream, which is made up of the quality forward chain for preventive measures and the quality backward chain for corrective actions. These structures promote a holistic view of the product life cycle and comprehensive information feedback (Huang et al. 2010). The resources and services as the third element reflect the capabilities required to achieve the objectives and support the company processes. The customer, management and operational perspectives are emphasized in the AQMM as central perspectives for increasing corporate resilience. The customer perspective is central to the alignment of market requirements and company performance, while the management perspective shapes the corporate strategy and identity, and the operational perspective ensures the implementation of objectives at an operational level (Pfeifer & Schmitt 2014). Overall, from the author's perspective, the AQMM emphasizes the importance of quality in all areas of the company and the need to strengthen resilience by striking a balance between market needs and company performance. It supports the development of agile organizational structures and takes into account the role of the company in global value chains.

Overall, the standards and norms presented here highlight the need and potential to increase the resilience of companies through the sustainable integration of procedural and cultural aspects into management models. Resilience is the key component in every situation. In the context of the elaboration, a company is considered resilient if its holistic approach - including the standards and management models applied - supports resilience. According to Gebhardt (2020), management must be able to identify vulnerabilities within the organization and take effective measures to address them in a timely manner. However, there are still gaps in research that have to be closed to ensure a comprehensive understanding and effective implementation of corporate resilience.

[b] Blueprint for RF Derivation and Assembly and Pathways to Crafting Sustainable Indicators (Input) Dimension

The second dimension of the RMMF in the context of corporate resilience contains the respective input factors [2] for the subsequent resilience assessment [3]. The guidelines for deriving and compiling RFs [5] play a central role in corporate resilience. Due to the diverse nature of companies, various strategies and methods are required for the selection and implementation of RFs. It is essential to involve DMs carefully, communicate transparently and select RFs specifically. Approaches such as the OECD method and the VCA emphasize the importance of transparency and RFs adapted to the respective context. Even if benchmarks with other organizations are possible, the individual situation of each company must be taken into account when selecting indicators. When developing sustainable indicators [6], a clear methodology ensures credibility and acceptance of the results. The approach to relevant KPIs is essential for effective and agile corporate action. Imprecise or overly general KPIs lose their usefulness as they are not measurable. Too many KPIs can also obscure the essentials. Events such as the COVID-19 pandemic have made it clear that external, uncontrollable factors can influence KPIs. KPIs should therefore also include measures that are independent of such factors. Instead of just following industry standard KPIs, companies should select KPIs that fit their individual strategy in line with the RFs.

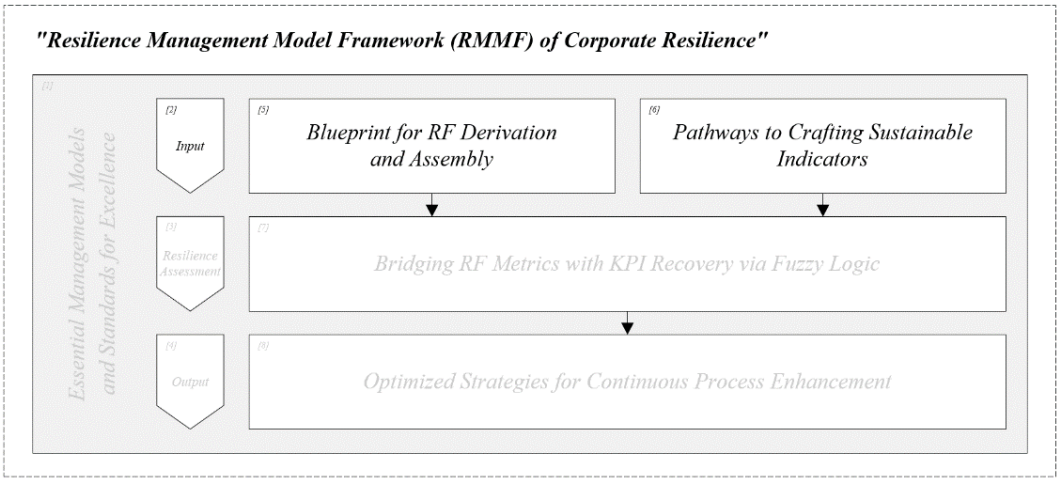

Figure 6-3: RMMF: Blueprint for RF Derivation and Assembly and Pathways to Crafting Sustainable Indicators (Input) Dimension (own illustration)

The Fuzzy Delphi Technique underlines the importance of careful selection and integration of DMs in order to facilitate rapid consensus building. It is important to take into account the different perspectives and expertise of the DMs. Clear questions and transparent communication are essential. With regard to the methodology and the selection of DMs, it has been shown that a top-down approach is preferable due to the importance of the topic. Corporate resilience is an essential management task and should therefore be dealt with at an appropriate management level. This promotes a focused approach, as the corporate objectives are clearly defined at this level and there is therefore little room for unnecessary deviations.

As part of the case study (refer to Chapter 5), the RFs were selected on the basis of existing literature. The GRI standard can serve as a supplementary tool to determine the relevant RFs just as clearly. The GRI Standards are applicable to organizations of all sizes and enable a transparent comparison between companies within a sector. A strategic selection of RFs is essential in order to strengthen corporate resilience. In view of the great diversity of organizations, it is necessary to apply or review various methodological approaches for the selection and implementation of RFs. The application of the GRI standard requires a structured selection and adaptation to the respective corporate context. A direct comparison with other organizations through benchmarking is possible but is not always expedient due to the unique corporate situations and is only recommended to a limited extent from the author's point of view. Ten RFs for manufacturing companies were identified in the study: Management commitment, learning, preparation, reporting culture, flexibility, self-organization, awareness, teamwork, fault tolerance and redundancy (Azadeh et al. 2014). It should be noted that there is a lack of models for researching the development of RFs in industrial companies. This paper is a contribution to expand the empirical research on this topic (Huber et al. 2023).

The OECD approach shows a method for aggregating indicators that aims to merge individual indicators into an overall indicator in order to make complex or multidimensional

phenomena tangible. Although composite indicators are useful for simplifying such concepts, there are challenges in weighting, normalizing, and merging these individual indicators (Fetzer & Benz 2004; OECD 2014-D). The development process of a composite indicator should be transparent and comprehensible in order to ensure the credibility and acceptance of the results (Tellie 2016).

From the author's perspective, there are two methodological approaches to determining KPIs, which can be used individually or in combination depending on the context. The importance of a systematic approach to KPI monitoring is emphasized in order to ensure efficiency and agility in companies. The KPI definition must be precise, as KPIs that are too general or unspecific are not measurable and therefore lose value. An excessive number of KPIs can also distract from the main objective. In addition, KPIs are often strongly influenced by external factors that cannot be controlled. It is therefore crucial to include indicators that are independent of external influences. The clear allocation of responsibilities for achieving KPI targets is also essential. The practice of benchmarking with identical KPIs from other companies is also viewed critically. Like Zhukova (2020), the author emphasizes the view that it is essential to adapt KPIs to the company's own corporate strategy.

Porter's VCA, extended by the concept of the backward chain (refer to Figure 4.3), provides a clear and comprehensive guide to identifying and optimizing a company's value creation processes. It aims to look at business processes from beginning to end and to identify both internal RFs and enable external reporting that complies with the GRI Standards. The VCA supports DMs in identifying relevant areas for risk factors and promotes the transparency and credibility of external communication.

As a result, VCA using the OECD method helps to strengthen corporate resilience by examining a company's supply chain for potential uncertainties and crisis scenarios. Careful selection and monitoring of KPIs enables performance measurement and improvement. The integration of the backward chain adds reactive measures to the model, completing the end-to-end view and strengthening the company's resilience. By deriving specific KPIs and RFs in line with the GRI Standards, reporting becomes not only comparable but also trustworthy for all interested parties. The application of the VCA ultimately leads to a robust corporate structure that can react flexibly to changes.

[c] Bridging RF Metrics with KPI Recovery via Fuzzy Logic (Resilience Assessment) Dimension

As a third dimension, the two-stage fuzzy logic presents itself as the central core of the work [7] as a resilience assessment [3]. In the first step, the degree of RFs of a process in an organization is determined using the Fuzzy Delphi Technique. For this purpose, the main processes and associated sub-processes of the organization are presented. Furthermore, a group of DMs with extensive knowledge and experience is identified. With the help of the proposed Delphi method, a consensus can be reached among the DMs regarding the RF levels in the organization under consideration. Furthermore, it is important to establish the KPIs that are managed at the level of the identified sub-processes. In the next step, the approach calculates the aggregated fuzzy value of the RFs for each KPI. The relationship between RFs and KPIs is also analyzed using scatter diagrams, among other things, and the recovery time of the KPIs is evaluated (Huber et al. 2023; Rathore & Gupta 2020).

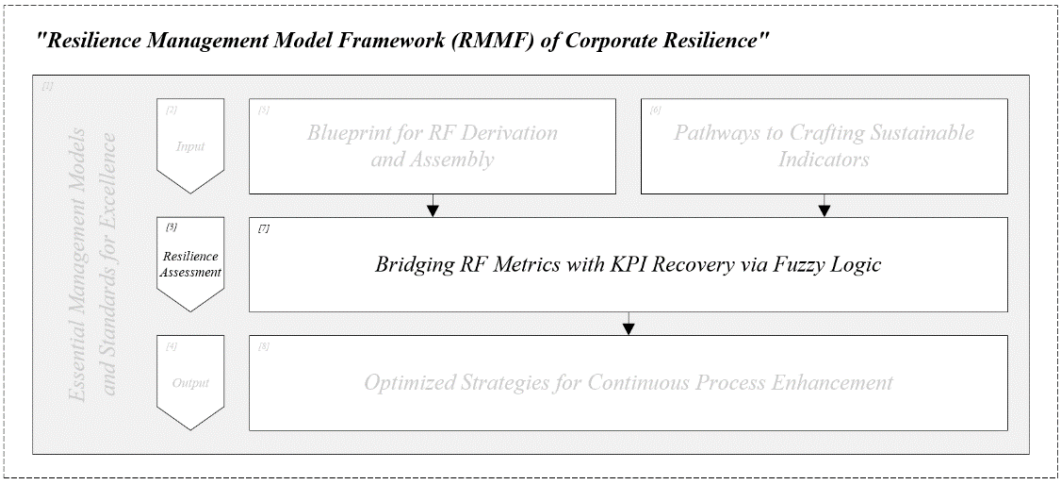

Figure 6-4: RMMF: Bridging RF Metrics with KPI Recovery via Fuzzy Logic (Resilience Assessment) Dimension (own illustration)

The core of the research focuses on a two-stage fuzzy model to analyze and improve product delivery processes in an industrial company. The model uses the Fuzzy Delphi Technique to evaluate RFs and examines their impact on key KPIs. The following two stages are carried out (Huber et al. 2023; Nyaga 2023):

- ***First stage:*** *Determination of the degree of RFs using the Fuzzy Delphi Technique;*
- ***Second stage:*** *Calculation of the aggregated fuzzy value for each KPI and analysis of the relationships between RFs and KPIs.*

The work is a contribution to developing the missing empirical studies that test the models and procedures for the development of RFs in industrial companies (Duchek 2019). It emphasizes the need for further empirical research to test and validate the approaches developed in the study.

The APQC framework and the PCF in particular provide a solid basis for analyzing and classifying business processes. The PCF serves here as a taxonomy and enables companies to name, organize and present processes and carry out benchmarking. It should be noted that there is no comparable approach to date that incorporates these frameworks in the context of the identified research gaps (Huber et al. 2023).

There are no fixed guidelines for the selection of KPIs. The procedure for identifying KPIs, for example, is explained in the previous section. However, companies should adjust their KPIs based on size, industry and other relevant factors mentioned. The study adjusts the selected KPIs according to the APQC framework to meet the specific requirements.

When selecting DMs, it is important that they are familiar with the relevant KPIs and business areas and have the ability to draw meaningful insights from the data. In this study, the

focus is on a selected group from top management to bring diversity and effectiveness to the decision-making process (Schlick 2009).

The Delphi technique is used to guide the DMs through several rounds in which assessments of problems are made and adjusted. The study ensures anonymity to avoid bias in the results in order to transparently assess the organization's resilience at different stages. The study shows a significant negative correlation between RF scores and KPI recovery times, indicating that higher RF scores lead to shorter recovery times. A scatter plot analysis confirms this correlation (Huber et al. 2023).

In conclusion, it can be emphasized that the selection of DMs from top management is quite challenging. However, the underlying model structure is characterized by its flexibility, which makes it possible to adapt the number of KPIs, RFs and DMs to the individual needs of an organization. Future studies should aim to further develop the Delphi technique, explore alternative methods of consensus building and test the model across different business processes and industries (Huber et al. 2023).

[d] Optimized Strategies for Continuous Process Enhancement (Output) Dimension

In the final fourth dimension, the respective output function [4], strategies for continuous process optimization are proposed [8]. Although this dimension is not the focus of this thesis, it has been hinted at in some chapters. Due to its ultimate importance, its potential and final content will be discussed in the following chapters. In the context of the corporate resilience of the RMMF, key aspects such as documentation, communication, validation, and audit management through to resource allocation are emphasized. All of these components are critical to ensure a holistic approach through the various stages of the Deming quality management cycle and to support and ensure a comprehensive, sustainable end-to-end corporate approach.

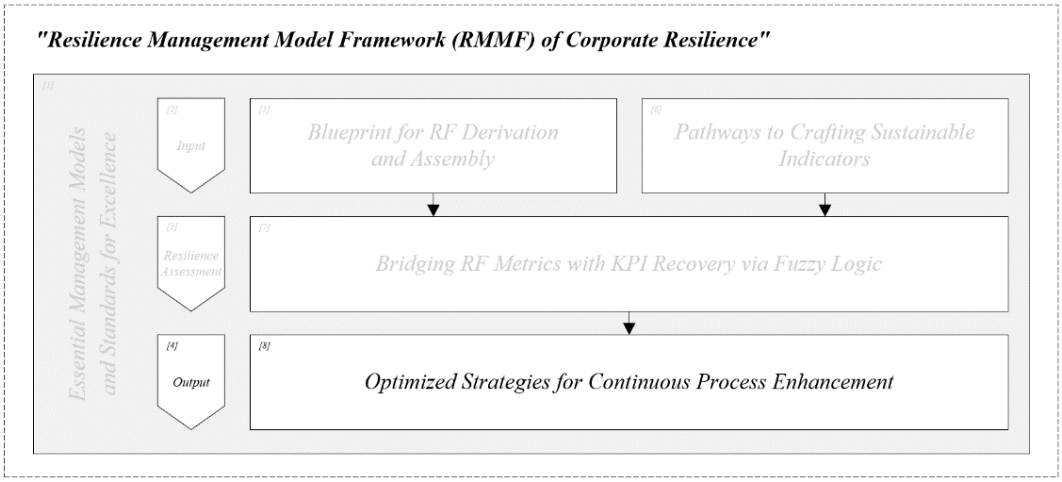

Figure 6-5: RMMF: Optimized Strategies for Continuous Process Enhancement (Output) Dimension (own illustration)

The final step combines various elements of process and improvement management and, in the author's view, is a small but often neglected step to ensure the sustainability of the aspects developed. It underlines the importance of documentation and communication of results, the implementation as well as validation of changes, auditing to ensure independence, feedback (is a gift) for continuous improvement and a targeted risk assessment. All of these elements serve the purpose of changing the structures in the company in such a way that the efficiency of the processes - and thus the productivity of the employees, the profitability of the organization and the overall corporate resilience - continuously increase (Komus 2011).

The following process flow integrates the newly developed elements of process and improvement management, which were used as further steps and measures in the case study:

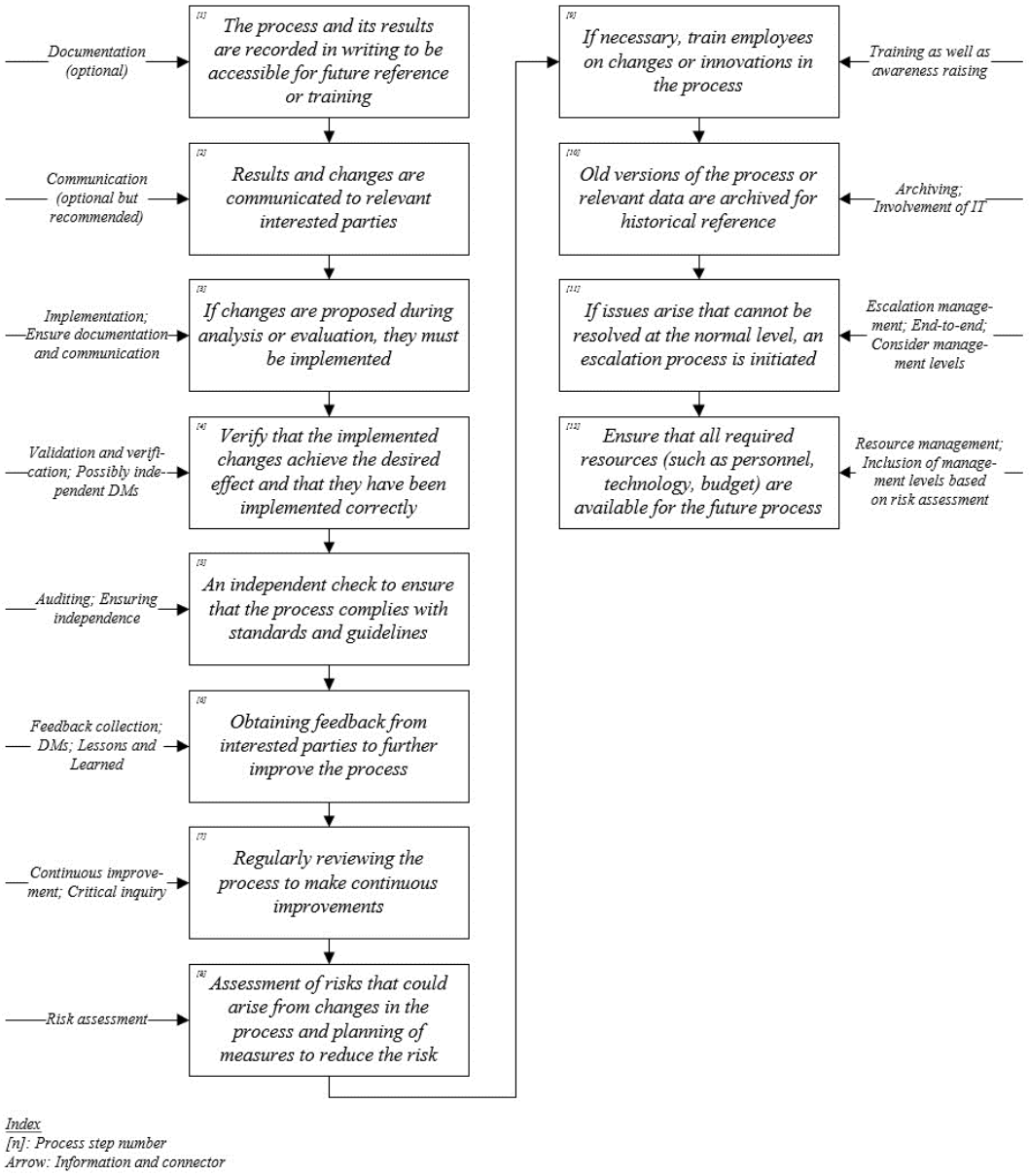

Figure 6-6: Consolidated Best Practices for Process Management and Continuous Improvement (own illustration)

Specifically, it must be ensured that the documentation of the overall process and its results is essential. Accordingly, it must also be deeply embedded in the organization. According to a survey by BP Trends, only 4 percent of companies document all of their processes (Atlassian 2023). It should be noted that due to the knowledge of the organization as well as the skills of the employees, full documentation should not be the goal, but it is also not possible or necessary. Nevertheless, according to McKinsey (Chui et al. 2012), the average employee spends almost two and a half hours a day (around 30 percent of the working day) searching for the required information (Di Noi 2018).

Example
"The technical documentation for products must be kept for 10 years. The date on which the product was manufactured for the last time counts. This means that the retention obligation can extend over the product life cycle for decades. Missing or incorrect documentation - of any kind - can cost a manufacturer dearly. If an accident occurs and the instructions were inadequately drafted or, in the worst case, missing altogether, the manufacturer is liable. If the technical documentation is inadequate or missing for a product that is to be imported into the EU, for ex-ample, the relevant supervisory authority is even entitled to destroy the product. Documentation pays off (Schneider 2020)."

Table 6-2: Missing or incorrect technical documentation and the consequences (Schneider 2020)

Efficient documentation combines all relevant information in a centralized and organized manner. It includes not only the documentation of the processes, but also that of the individual process activities. This enables a smooth workflow and provides the basis for optimizing potential weak points in the process. In addition, the knowledge gained through process documentation forms an important reference basis for future training measures and contributes to transparency and accessibility. Documentation therefore makes it easier to understand past activities and equally supports the derivation of conclusions for the future. It promotes the exchange of knowledge and thus the retention of knowledge within the organization.

Effective knowledge transfer requires transparent communication with all relevant interested parties, which is crucial for internal efficiency (Atlassian 2023). Clear communication about company processes and goals increases both employee motivation and loyalty. Internal communication serves as a strategic tool to strengthen the company's identity and convey its values. It is therefore an integral part of the corporate culture, which, as described above, supports corporate resilience. Effective communication must not be one-sided but should always promote dialog and actively involve all stakeholders. Good internal communication increases commitment and improves collaboration at all levels of the company. There are numerous channels and tools for communication, but they should be used in a targeted and comprehensive manner. Digital communication methods are of great importance in today's working world, but traditional, analog methods also have their place. In certain situations, such as in the case of pronounced process weaknesses or serious differences of opinion, a face-to-face meeting on site can be more effective. A balanced mix of communication channels is therefore recommended. According to Ottensmeyer (2022), the choice of means of communication depends on the purpose, the target group, and the message to be conveyed.

It is also advisable to implement change management with the following objectives (Wanner 2016):

- *Only necessary and sensible changes are implemented;*
- *Changes are checked using a standardized process;*
- *Changes are subject to a formalized decision-making and approval process;*
- *Ensuring transparency for all parties involved with regard to the changes and their effects.*

This element internalizes the above points by ensuring that changes bring the desired benefits and are implemented correctly. Careful documentation and communication of these changes are essential. Change management bundles these aspects into an overarching process and thus ensures efficient implementation.

It is also beneficial to regularly review the implemented overall process and individual sub-processes through independent audits or assessments. Although processes are usually consistent and well documented, there are often deficits at the interfaces, especially at the personal interfaces. In the context of the RMMF, particular attention should be paid to the different collection of systems, tools, processes, and procedures; their interaction should be examined intensively. This is the only way to effectively introduce improvements and minimize risks through systematic analysis. Audits and assessments make a significant contribution to the following points (DGQ n. d.; Lucini 2014; Moore 2013):

- *Overcoming operational blindness;*
- *Improve cross-organizational communication;*
- *uncover strengths and potential for improvement;*
- *To provide well-founded information for decisions and process optimization;*
- *Verify compliance with and feasibility of corporate goals and guidelines;*
- *Identify and prevent frictional losses, risks, and errors.*

According to the specialist literature (DGQ n. d.) and from the author's perspective, it should be noted that it is often difficult to quantify the benefits of audits or assessments in concrete figures. Although the cost savings from eliminating errors or optimizing processes are quantifiable in some cases, it becomes more complex when the primary focus is on risk minimization. The improvement of collaboration is influenced by many different factors, making it difficult to evaluate the impact of audits in isolation. In addition, sensitive findings about potential for improvement are rarely communicated externally. The benefits of an audit should therefore be presented cautiously and only in clearly comprehensible cases in figures, even if this occasionally meets with resistance from management.

Feedback is an element that is often underestimated but is crucial for corporate resilience. It is essential to obtain feedback from the interested parties concerned in order to continuously optimize both the processes and the future approach. A culture of constructive feedback helps to resolve various paradoxes and, according to Herzog (2020), offers the following advantages:

- *Identification of new development opportunities;*
- *Detection of weak points;*
- *Creating orientation, trust and security;*
- *Establishing a basis for learning and change;*
- *Increased adaptability through continuous learning and improvements;*
- *Gaining food for thought and ideas from different perspectives that serve as a basis for innovation.*

Feedback is therefore not only important for individual sub-processes but should also be seen as an integral part of the corporate culture and anchored in the entire process (Renz 2007). In contrast to planned and sometimes time-consuming audits, an ongoing feedback culture enables improvements to be initiated at any time. This offers the advantage that immediate progress can be made, for example, through ad-hoc assessments.

Risk assessment is another important step that is both possible and complementary. This serves to identify potential risks that could arise from changes at an early stage and to plan preventive measures to reduce them. Once risks to the organization have been identified, they should be subjected to a detailed qualitative and quantitative analysis. It is crucial to collect comprehensive information on each risk along the RMMF to enable a well-founded assessment by the organization (Fleig 2022). However, the aim is not only to look at past events, but to derive forward-looking trends from this data and relate them to the organization's strategies.

Furthermore, the role of training in the event of changes or innovations in the process should not be underestimated. Archiving documentation of past process versions or relevant data as a historical reference can also be beneficial. Trends can be identified from this archived data, which in turn can provide new impetus for process development.

In addition, well-defined escalation and resource management can be useful. This ensures that sufficient resources are adequately available for the realization of future process improvements (Teamhub 2023).

The RMMF of corporate resilience is a new and comprehensive approach to making organizations resilient in the future. This development can take place on several levels. These serve as helpful points of reference that can be adapted to the individuality of the organization.

It can also encourage people to discover new strategies that they have previously avoided - whether consciously or unconsciously (Drath & Heller 20218). The individual elements of the RMMF should not be viewed in isolation. Rather, they are embedded in a dynamic network of mutual influences and fulfill the following points, which the RMMF attempts to describe.

The RMMF of entrepreneurial resilience represents a comprehensive and innovative approach to sustainably strengthen organizations for future challenges. This approach can be implemented at various organizational levels and offers targeted orientation. It should be noted that it can also be tailored to the specific needs of each individual organization (Hick et al. 2021). Furthermore, the RMMF encourages the integration of new strategies that may not have been considered in the past, whether consciously or unconsciously (Drath & Heller 2018). The individual elements of the RMMF should not be viewed in isolation; they are part of a dynamic system of reciprocal relationships. From the author's perspective, the RMMF aims to describe and address the following key aspects:

- ***Perseverance and consistency:*** *The RMMF of entrepreneurial resilience expresses the idea of perseverance and consistency. Both are important characteristics of entrepreneurial resilience. A successful organization must remain steadfast in acute moments of shock;*
- ***Overcoming obstacles:*** *The ability to overcome obstacles and challenges is a key element of entrepreneurial resilience. The RMMF of entrepreneurial resilience implies the determination to overcome difficulties and to keep going despite setbacks;*
- ***Adaptability:*** *The RMMF of business resilience enables an organization to adapt quickly to change. This flexibility is crucial in order to respond to market fluctuations, technological change, new competitors and other external factors;*
- ***Continuous learning:*** *The RMMF of corporate resilience can be associated with continuous learning. Organizations learn from their experiences and constantly adapt to changing circumstances.*

6.2 Comparison and Interpretation

The methodological approach of the case study focuses on the concept of organizational resilience and its assessment. It is noted that despite increasing interest in corporate resilience, there is little agreement on the exact measurement. There are many reasons for this. This is also confirmed by the study mentioned in section 3.4 (The Economist Group 2022).

Measuring resilience is therefore a particular challenge for organizations. There are no generally recognized standard metrics and measurements, which means that 75% (refer to Figure 6.7) of the companies surveyed find it difficult to demonstrate progress. On the one hand, company boards would find it hard to justify shifting focus and resources to resilience without demonstrable profit. On the other hand, shareholders and other interested parties want to see that corporate resilience is increasing in a way that effectively protects the company from potential threats. But measuring such concepts is complex and requires a set of performance metrics that reflect an organization's resilience.

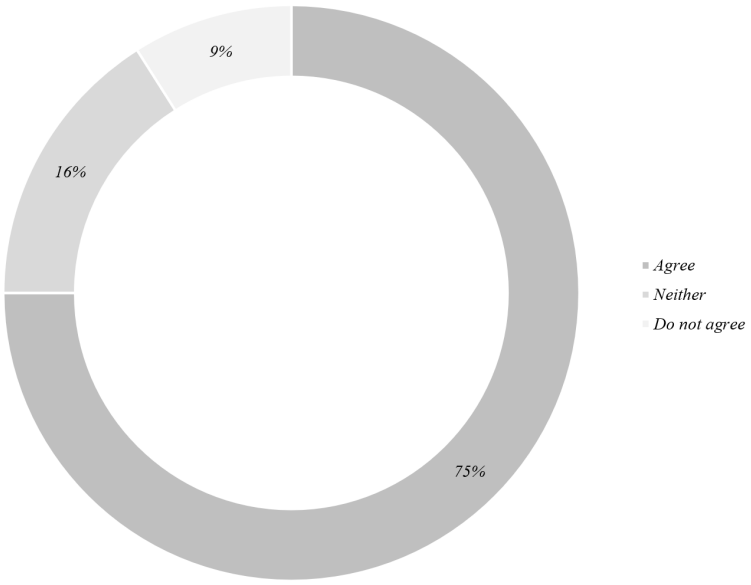

Figure 6-7: The difficulty of measuring resilience
(own illustration based on The Economist Group 2022)

A majority of organizations therefore see the difficulties in measuring business resilience as an obstacle to gaining management approval for necessary investments. Even if an expected risk materializes, a well-prepared organization may see little change in its operations or performance. This makes it difficult to justify investments in business resilience after the event. Margaret Millett, Head of Global Resilience at Uber, for example, recommends involving the finance department to assess the price of failures. It is useful *"if you can tell an executive that a disruption will cost a certain amount of money"* (The Economist Group 2022).

For most organizations, measuring corporate resilience is one of the biggest challenges for the future. Determining what to measure, how to measure it and how to define success are

tasks where the extent of resilience can often only be fully understood after an event (The Economist Group 2022).

The chosen research approach draws on the theory of fuzzy sets to quantitatively describe the uncertainties associated with personal judgments (Botto-Tobar et al. 2022). This method makes it possible to express resilience in the form of linguistic variables and to evaluate it conclusively. The case study aims to analyse the dependency between organizational RFs and the recovery time of KPIs. For this purpose, a team of DMs was formed who evaluated the RFs over two rounds of the Fuzzy Delphi Technique (Huber et al. 2023). The DMs were exclusively participants from top management. The decision rounds could be carried out efficiently and at short intervals in order to maintain the dynamics of the decision-making process (Kahraman et al. 2021). According to the study (The Economist Group 2022), it is nevertheless a challenge to build entrepreneurial resilience, especially when it comes to predicting and reacting to disruptive factors.

This requires a system-wide and coordinated response, but few organizations actually have a central function dedicated solely to business resilience. Only 12% of respondents report that a resilience or governance committee is involved in their resilience efforts. In just 3 percent of cases, this committee is responsible for driving resilience initiatives forward.

In addition, a certain complacency created by the pandemic could be contributing to the problem. Advocates of business resilience *"had the ear of senior management during COVID-19, but it's starting to wear off,"* says Margaret Millett. She recommends finding out what executives really want, providing them with relevant evaluations and always keeping a sense of future developments to understand that this is a necessary measure (The Economist Group 2022).

The Fuzzy Delphi method was used to reach agreement among the experts on uncertain information (Dawood et al. 2021). The assessments of the DMs were first recorded individually and then aggregated. The ratings in the first round showed a strong positive correlation after aggregation, which was confirmed in the second round. The resulting correlation coefficients showed a significant negative relationship between the aggregated RFs and the recovery times of the KPIs. This suggests that organizations with higher resilience scores can return to normal performance levels faster (Huber et al. 2023).

According to Esposito (2023) and studies by the University of Lisbon, Portugal (Carvalho et al. 2014), the result that a high level of entrepreneurial resilience also entails shorter recovery times can be endorsed. It is emphasized that organizations that want to survive structural change in the industry must face up to and carry out regular analyses. In today's world, the risk of data loss is almost greater than the loss of the physical materials themselves. A data leak can paralyse the entire processes within an organization. This is also highlighted in the aforementioned study (The Economist Group 2022). In particular, 48% of organizations report increased investment in security applications and data protection since the COVID-19 pandemic (43% before the pandemic). Accordingly, the entire organization should be synchronized as a remedy. Digitization and the sharing of information across all areas of the organization is therefore imperative. It is important here to constantly analyze the input variables developed for the KPIs and RFs. Only they make it possible to monitor the processes of the management system over a defined period of time and thus to make ongoing optimizations. This results in a dynamic comparison with the organization's objectives on the one hand and with all necessary activities on the other - but above all with customer expectations.

This discussion once again confirms that strengthening corporate resilience is an important but currently hesitant topic. One of the main reasons for this is the high investment costs, which are difficult to estimate. An organization that only passively focuses on security is taking a high overall risk. In contrast, organizations that are able to not only withstand a shock event, but also shorten the overall recovery time, can gain a market advantage. This ultimately leads to improved shareholder value as they are able to respond more quickly to market developments.

The paper also emphasizes that, in addition to developing a model for assessing corporate resilience, practical recommendations for organizations are also derived. These include standards and norms to provide organizations with a framework and guidelines. Management systems provide structures and processes that enable organizations to respond effectively to various changes and maintain or even quickly restore business operations. Building on this, the derivation of input variables for the KPIs and RFs as well as the final measurement of corporate resilience are included. Finally, this also includes establishing continuous learning and training, building a strong network, and using technology and digital transformation to improve process efficiency and resilience (Huber et al. 2023).

6.3 Critical Reflection

Not only the COVID-19 pandemic, but also other global crises have impressively demonstrated to organizations - including the industrial company in the case study - that the development of corporate resilience can be decisive for success or failure. Many organizations have shifted to a more comprehensive, system-wide resilience process approach in recent years, and this continues. These challenging times have served as the perfect catalyst for those organizations that have yet to make progress in corporate resilience and equally rewarded those that are already further along.

The implementation of best practices in corporate resilience is still not widespread. Few organizations have centralized their resilience efforts, embedded them at a high level in the organizational structure or allocated sufficient financial and human resources to them (Anstett 2022). As already explained (refer to Chapter 3.4.3), we now live in a world in which turbulence has become the new normal. There is therefore still a lot to do.

It is up to top management to demonstrate a clear vision and support for building corporate resilience and to provide the necessary resources (The Economist Group 2022). Their efforts should include the creation of organizational structures and thus management systems, standards and norms that facilitate communication and coordination in resilience building. In addition, you should focus on redesigning workplaces, improving data governance, placing more emphasis on sustainability, and increasing operational efficiency. Business practice shows that although the topic is taken seriously, this does not mean investing directly in resources. Especially not if you have - possibly even unknowingly - successfully managed the crises you have experienced in the recent past. Initiating change requires courage - as does knowingly and therefore unpreparedly heading into a crisis.

The research of the case study focuses on a two-stage fuzzy model. In the first stage, the degree of RFs in the product supply process as well as sub-processes of the selected industrial company is evaluated using the Fuzzy Delphi Technique. In the second stage, the model calculates the weighted aggregated fuzzy values of RFs for each KPI and analyzes their

relationships with each other. It is noted that there is a lack of research that empirically verifies this procedure as well as the relationships in the corporate context (Huber et al. 2023; Khan et al. 2020).

The relevant RFs for the industrial company were defined based on the literature. It should be noted here that models and methods for investigating the emergence of RFs in industrial companies are only available to a limited extent and are described in extremely general and therefore not very concrete terms, which also underlines the need for further empirical research. A corresponding procedure (refer to Figure 4.5) was proposed and developed in a practice-oriented manner.

The APQC framework, in particular the PCF, provides a taxonomy for business processes and enables organizations to establish a consistent terminology for the organizational structure of processes. The PCF is described as a flexible and adaptable framework that allows best practice to be identified regardless of industry, size, or geographical location (Schmieder 2008). The framework structures the key processes of an organization hierarchically and groups them to show their interrelationships. The main purpose is benchmarking, as it allows content and business processes to be derived directly from it. At first glance, this appears to save time. However, it should be noted that not all processes of a particular organization are listed and comparable in the framework. It is therefore advisable to take appropriate account of processes that are specifically tailored to the business context in order to ultimately achieve meaningful and relevant results.

Similar to the PCF, the following procedure is also recommended when selecting relevant KPIs: It is crucial to ensure that the selected KPI set also includes indicators that can be measured independently of external influences. Companies should adapt their KPIs to their size, industry and other context-specific factors or fall back on proven methods. KPIs can be precisely defined by applying the OECD method and the VCA. The integration of a backward chain into the extended VCA enables an end-to-end view and thus ensures a comprehensive business perspective, which is essential for the effective development of KPIs.

Similarly, work should also continue on the development of indicators and metrics that enable company management to measure the effects of their resilience measures and account for the results. Building resilience in this way can have a positive impact on the entire organization and is not only useful in times of crisis (The Economist Group 2022). It is important to recognize the clear benefits (not necessarily only monetary), otherwise it will not go beyond raising awareness and will end up as a kind of token exercise.

The selection of DMs is crucial. They should know the organization and the associated business areas and be able to derive meaningful insights from the data. The research focuses on a heterogeneous DM group to bring in different perspectives. One of the challenges here is to coordinate timely appointments with all relevant DMs, possibly across multiple rounds. In decentralized organizations, it is not absolutely necessary to involve only experts from top management. Many experts are in interface positions and often offer a deeper look into the data landscape due to their role. Nevertheless, a clear commitment from top management is essential. In addition, as part of the overall research, for example, an approach can initially be pursued in one area of the organization in order to gain initial experience that will be useful for a more comprehensive approach at a later date. This enables time and resource-efficient implementation and can generate additional approval through the use of best practices. The approach ultimately chosen should always be adapted to both the specific needs of the organization and the business case in question (Dumas et al. 2018).

Finally, it should be emphasized that research on business resilience using the Fuzzy Delphi Technique makes an important contribution as it provides a more accurate picture of the relationships between RFs and KPIs (Huber et al. 2023). It is suggested that future research should further develop the Delphi method and use alternative consensus verification methods to compare the results and extend the model to other business processes and industries.

It is also important to note that there are not many different studies on the chosen approach, as it is still a very young field of research, particularly in the context of entrepreneurial resilience. Further establishment of the method is therefore still pending. In comparison to the current state of research on entrepreneurial resilience, the RMMF of entrepreneurial resilience has enabled a conceptualization to take place that defines and operationalizes a clear procedure for achieving entrepreneurial resilience. A comprehensive approach to helping organizations become resilient in the future has not yet been carried out in the context of corporate resilience research and therefore extends the traditional analyses and majority of model studies in the literature.

"If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea."

Antoine de Saint-Exupéry (1900 to 1944): French writer.

7 CONCLUSION

This chapter summarizes the research results and provides an outlook on the work entitled: *"Assessment and Enhancement of Organizational Resilience in Complex Industrial Enterprises in Uncertain Environment"*. In the first substantive section, the results are presented and discussed in connection with the hypotheses set out above. It is discussed to what extent the hypotheses were confirmed or refuted and what conclusions can be drawn from them. The second section lists the lessons learned from the application of the developed model. Practical findings and experiences from the implementation of the model in the case study in an industrial company are discussed. This includes further recommendations for the effective application of the model in practice. The third section deals with the identification of potential areas for future research that could build on the findings and results of the present study. This includes new questions or research directions that have emerged from the current findings. The final chapter provides an outlook on possible developments and trends in relation to the topic of corporate resilience in complex industrial companies. The importance of research for both the economy and society is also highlighted.

7.1 Results and Discussion of Hypotheses

In this chapter, the results are presented and discussed in connection with the hypotheses set out in chapter 2.2. The extent to which the hypotheses were confirmed or refuted and the conclusions that can be drawn from them are discussed.

The first hypothesis A describes that the hybrid fuzzy model can be used to accurately determine the total value of RFs affecting each identified KPI (refer to Table 7-1).

Research Gap	Title	Description Hypothesis
Research gaps at model level		
A	Hybrid Fuzzy Models for KPI Optimization	By using the hybrid fuzzy model, the aggregate value of the resilience factors affecting each identified KPI can be precisely determined.

Table 7-1: Research Gap A

Hypothesis A is consistent with the results of the study and is therefore correct.

It is emphasized that the use of fuzzy logic makes it possible to take uncertainties into account through the use of fuzzy sets and linguistic variables (Kahraman et al. 2021). This approach enables a differentiated representation and thus a more precise evaluation of fuzzy terms. This leads to the assumption that a hybrid fuzzy model can be taken to determine precise values for each identified KPI. Chapter 5.2 supports and proves this hypothesis. The consistency of the scores is checked by an established procedure and the correlation coefficient between the first and second round scores by the DMs indicates a strong positive relationship. This indicates that the ratings are consistent and therefore reliable. The fact that the values obtained in the second round can be considered final reinforces the assumption that the fuzzy model provides accurate values for this purpose (Huber et al. 2023).

The second hypothesis B describes that there is a negative correlation between the total value of the RFs and the recovery time of the KPIs (refer to Table 7-2).

Research Gap	Title	Description Hypothesis
Research gaps at model level		
B	RFs and KPI recovery time: A negative correlation	A negative correlation exists between the aggregate value of the resilience factors and the recovery time of the key performance indicators.

Table 7-2: Research Gap B

The second hypothesis B is also consistent with the results of the study and therefore proves to be correct.

The study provides an analysis of the relationship between the weighted aggregated value of each RF and the recovery time of each KPI. The calculations performed and the correlation analysis show that the assumed negative correlation is confirmed: There is a negative statistical dependency between the values of the RFs and the time required to restore the KPIs. The determined value of the correlation coefficient shows that there is a statistically significant influence of the RF values on the recovery time of the KPIs. A negative value of the correlation coefficient indicates that an increase in the RF values is accompanied by a reduction in the recovery time. This result is shown in Table 5-4 (refer to Chapter 5.3) (Huber et al. 2023).

The third hypothesis C at model level states that the application of heuristic methods enables the identification of optimal strategies to improve RFs in a complex business environment (refer to Table 7-3).

Research Gap	Title	Description Hypothesis
Research gaps at model level		
C	Heuristic optimization of corporate RFs	The application of heuristic methods enables the identification of the optimal set of strategies to improve RFs in a complex enterprise environment.

Table 7-3: Research Gap C

The study deals with the application of heuristic methods to identify optimal strategies to improve RFs in complex organizations. The RFs that are considered essential for an industrial company are defined based on the literature (refer to Chapter 4.1.2) (Macuzić 2016). A key aspect is the lack of models and procedures that investigate the emergence of RFs in industrial companies. It is emphasized that empirical work is needed to determine them.

In this respect, the study presents the OECD method and the VCA as a practical approach to examining and optimizing an organization's value creation along its supply chain. This aims to strengthen an organization's ability to cope with uncertainties and crises (Weber 2023). By precisely identifying KPIs from the individual activities along the methods, the performance of an organization can be measured and improved.

The integration of a backward chain into the extended VCA also enables reactive measures that strengthen corporate resilience and establish comparability with the GRI Standards. The comparison of RFs with the GRI Standards enables a transparent comparison of organizations within a sector. This form of reporting makes the organization more transparent and trustworthy towards external interested parties. The relevant RFs should be selected strategically in order to strengthen corporate resilience, whereby transparency and adaptation to the corporate context are considered crucial.

Similarly, empirical validation confirms the effectiveness of the proposed Branch-and-Bound algorithm approach, which enables informed decision making based on optimized resource allocation. The use of Branch-and-Bound heuristics to optimize entrepreneurial RFs has provided precise insights into the performance of this approach. The results highlight a specific sequence of management techniques that should be applied to efficiently increase entrepreneurial resilience (Aleksić et al. 2024; Tadic et al. 2024).

The study summarizes that heuristic methods can be used effectively in complex organizational environments. They also enable the selection of efficient and optimal strategies to increase organizational resilience. The proposed methods can be more effective than traditional, strictly methodical approaches, especially in situations where complete information is lacking, or the situations are too dynamic for standardized solutions.

Thus, the third hypothesis C, based on the selected methods, is also consistent with the results of the study and therefore proves to be correct.

The first hypothesis D at a holistic level state that a dynamic approach to resilience management that integrates cross-phase activities will prove to be more effective in coping with disruptions and uncertainties than static resilience models (refer to Table 7-4).

Research Gap	Title	Description Hypothesis
Research gap at holistic level		
D	Effectiveness of a dynamic approach to resilience management	A dynamic approach to resilience management that integrates cross-phase activities is shown to be more effective in managing disruptions and uncertainties compared to static resilience models.

Table 7-4: Research Gap D

In the context of entrepreneurial resilience, the results of the study confirm hypothesis D, meaning that it can be regarded as accurate.

Managing corporate resilience requires far more than just the ability to deal with acute stress situations or shocks. The majority of organizations have a natural entrepreneurial resilience that enables them to remain stable even in difficult times. This entrepreneurial resilience is strengthened by experience from previous crises, as organizations learn to deal with new challenges. Entrepreneurial resilience is not static, but can be actively developed, in particular by recognizing and using opportunities for action in crisis situations (Lieb 2023).

In companies, this is reflected in the need to establish a dynamic and adaptable corporate culture (refer to Chapters 3.3.2 and 3.3.3). This includes transparent communication, targeted support for employees and investment in effective leadership. A dynamic approach to resilience management, which takes into account various activities and phases, enables organizations to react flexibly to changes and crises and to continuously adapt in line with the case study. This is in contrast to static models, which are less effective in a rapidly changing world (Huber et al. 2023).

In addition, the case study revealed that the organizational structure is also important. Particular emphasis was placed on the complexity of decentralized matrix organizations in which autonomous business units are part of a global supply chain. Although this structure is obviously a challenge, it is of great importance in the context of corporate resilience. The independent agility of the individual business units proves to be a key factor for the success of the industrial company. This gives rise to areas of tension between globally harmonized objectives and local requirements. Although these areas of tension are complex, they also offer the necessary degree of freedom to react flexibly and agilely to shocks. The consideration of different cultures and markets also plays a decisive role in the dynamic and cross-phase approach.

The final hypothesis E states that the normative implementation of corporate resilience can be permanently anchored and improved in organizations through sustainable management systems (refer to Table 7-5).

Research Gap	Title	Description Hypothesis
Research gap at holistic level		
E	Normative strengthening of resilience through management systems	The normative implementation of corporate resilience can be permanently anchored and improved in the company through sustainable management systems.

Table 7-5: Research Gap E

Taking into account all the circumstances of the study and the case study, the implementation of resilience in organizations requires the application of standards and norms as well as their integration into management systems (refer to Chapter 3.4.3). The standards and norms mentioned (refer to Chapter 3.4.1) serve as precise instructions and guidelines for implementation and can also relieve organizations of external pressure. Integrated management systems emphasize the importance of sustainability and promote innovations that contribute to strengthening resilience.

The application of international standards is essential for comparability in global markets. Being a resilient organization requires comprehensive integration and a cultural change that promotes cross-functional collaboration. The allocation of sufficient resources and a focused management level are equally important.

Standards and models such as the SGMM and the AQMM support the introduction of resilience in companies, shape the corporate culture and strengthen the understanding of resilience. However, anchoring corporate resilience is not a matter of course. It requires clear objectives, suitable resources, and the revision of existing working methods. In addition, the development of indicators and metrics is crucial in order to evaluate the organizational impact and prepare for future challenges in the long term.

In the context of hypothesis E, that the normative implementation of corporate resilience can be permanently anchored and improved in organizations through sustainable management systems, the results of the study confirm this hypothesis, which can therefore be regarded as accurate.

All of the hypotheses listed, and the resulting research gaps can be answered on the basis of the study. However, there is a lack of sufficient further research to further develop and adapt the theoretical ideal models described in the literature in a way that they can be implemented in organizations in a practical and implementation-oriented manner (Fecher et al. 2021). However, the study provides a first comprehensive approach to this, which is shown in the RMMF of entrepreneurial resilience.

7.2 Lessons Learned for the Application of the Model

This chapter begins by describing possible misunderstandings surrounding entrepreneurial resilience that emerged during the preparation of the study. The concept of entrepreneurial resilience is interpreted differently by experts (Drath & Heller 2018). The underlying research gaps and theories were derived from theses in order to then empirically test them in the case study on an industrial company and adapt them if necessary. In practice, this proves to be no easy task, as organizations are complex systems with multi-layered interactions. The resilience of an organization often only manifests itself over many years or even decades. It is therefore a challenging task to prove empirically that certain measures are effective. As far as the definition of corporate resilience is concerned, however, a basic understanding of how systems function and the application of logical considerations can be used to differentiate between more and less applicable approaches.

First Misconception: Organizations are Resilient when they use Agile Methods

Agile working is often seen as the key to making rigid organizations more flexible and, above all, more sustainable. Agile methods are not aimed at avoiding unexpected deviations in the course of a project or spontaneous changes to customer requirements. Instead, they enable errors or misunderstandings to be corrected quickly, thereby limiting the negative effects. A key feature of agile working is the self-organization of teams, which contrasts with traditional, hierarchical approaches. Here, employees take on tasks independently and flexibly, based on their capacity and expertise.

Although agile working methods originated in IT projects, they have spread to other organizational areas. Agile working can be useful in many areas by helping to shorten innovation cycles or reduce error costs. Provided the area of application is chosen wisely, it can even be beneficial for the long-term success of an organization. However, agile working alone is no guarantee of long-term success. It is merely a tool that is particularly effective in certain areas such as product development. However, it is not necessarily applicable in all departments, for example in the production of highly automated manufacturing companies.

Agile forms of working are therefore not a universal panacea, but a tool with a specific area of application that can enable real improvements and have a positive impact on entrepreneurial resilience under the characteristics described (Drath & Heller 2018).

Second Misconception: Organizations Believe that they are Resilient

Companies often only react with measures for corporate resilience when the situation becomes acute, whereby the success of these measures varies and often resembles a flash in the pan. A study (The Economist Group 2022) shows that it is time to invest resources specifically in building resilience in organizations. The majority of managers surveyed in the study (refer to Chapter 3.4) worldwide believe that corporate resilience can only be achieved through collaboration between all departments of an organization. The study found that, when implemented well, corporate resilience leads to significant improvements in the areas of customer satisfaction, employee retention, risk management and environmental, social and governance. Nevertheless, the institutional anchoring of corporate resilience by the management does not automatically mean that it is a priority at operational level. In almost 85 percent of cases, department heads were not involved in resilience initiatives at all. As a result, many organizations are not as well positioned on the topic as they assume (Ferguson 2022).

Third Misconception: Fire-Fighting Instead of Entrepreneurial Resilience

A study (Eidenschink 2020) shows that in organizations in which so-called *"fire-fighting"* frequently occurs, there is a direct correlation with the extent to which strategic planning is lacking. The term describes a situation in which organizations are constantly confronted with unexpected, urgent, and supposedly important problems. However, these are not provided for in the strategic plans and therefore have to be solved ad hoc by special teams in an emergency mode.

When an organization is mainly driven by this and the environment is dynamically changing, a culture of uncoordinated and actionistic fire-fighting emerges. Early signs of this are often ignored as the focus is strongly on the existing implementation and events that do not fit the plan are overlooked. In addition, there is often a communicative adjustment to the requirements of the hierarchy in order to maintain the illusion that everything is going according to plan. This leads to problems only being solved shortly before a deadline (Fecher et al. 2021).

In addition to high costs, fire-fighting has the significant disadvantage that it does not improve the organization. The experiences and results of the action are not integrated into the organizational memory. Rescue teams immediately turn to the next problem without analyzing the causes of previous problems, as such an analysis would call fundamental processes into

question. This leads to a lack of trust and a lack of focus on successful and unifying entrepreneurial resilience (Eidenschink 2020; Schmidt n. d.).

Fourth Misconception: Organizations are Resilient when Employees are Resilient

According to Drath and Heller (2018), the personal resilience of employees in an organization is not easy to measure or improve. It is also unlikely that all employees are or will become resilient. Resilient employees are characterized by good self-awareness and pronounced self-control. They are resourceful and creative, which is particularly beneficial for an organization's ability to innovate. These characteristics are important for an organization to be successful in the long term, as they enable flexibility and rapid adaptation to market requirements (Doleski 2015).

However, the resilience of employees alone is not enough to ensure the long-term resilience of an organization. Resilient employees are necessary, but not enough for the long-term success of an organization (Duchek 2019; Tjoa et al. 2024). Other factors, such as product development, are also crucial. Without this component, an organization could fail despite having resilient employees, for example through insolvency due to poor business decisions. Resilient employees are therefore an important, but not the only condition for the long-term survival of an organization (Dilroshan et al. 2022).

Fifth Misconception: Organizations feel Resilient when Information Systems are in place

Companies typically and historically use several information systems, but these are often not optimally coordinated. Problems arise from a shortage of standardization, inadequate information links between the systems or different levels of development (Malak 2023). Although this does not apply exclusively to highly decentralized and bottom-up organizations, it is more common in such structures than elsewhere.

One problem here is the technical incompatibility of data exchange between the information systems. There are many challenges, such as overcoming different import and export formats. Modern systems differ from older systems or systems that only know file interfaces. In addition, different versions of information systems can present a hurdle. Updates, upgrades, or the replacement of systems require that the new setup remains compatible with the existing IT landscape. This poses a further challenge, as the data processing method must remain consistent and integrated (Yenlo n. d.).

As a result, a lack of information, inadequate processes and unclear authority can often lead to wrong decisions in organizations, which can have serious consequences. The ability to make decisions is considered the supreme discipline of organizational management and therefore also of entrepreneurial resilience. The success of an organization depends heavily on the quality of its data and the decisions it makes (Senanayake et al. 2020). With digitalization and the associated increase in knowledge, the decision-making options have expanded considerably. Additional challenges such as VUCA (refer to Chapter 1) and crises increase the pressure on companies to make the right decisions. For many organizations, data integration is one of the most significant challenges of our time in terms of the necessary metrics and KPIs (Duchek 2019). With the increase in data sources, the complexity of data exchange also increases

significantly. For an effective and efficient approach, it is crucial to consider this increased complexity as well as a variety of relevant factors for business resilience (Kottbauer & Klein 2020).

Sixth Misconception: Management Systems have no Benefit

Organizations often strive to introduce an integrated management system according to specific standards or have already done so. However, these systems are often neglected in practice, resulting in low benefits - both in general and therefore in the context of corporate resilience. Although approaches to management systems exist, they are rarely up-to-date and effective.

Rather, it is seen as a necessary, expensive burden and a customer requirement, instead of fully exploiting the possibilities it offers. As a result, the systems are only used to the extent that the required standards are met. As a result, the benefits for both management and employees are minimal.

Furthermore, the implementation of a management system is often delegated and, contrary to the descriptions of the standards, is not part of top management. In addition to insufficient interest, the necessary respect to enforce the elements of a functioning management system is also lacking (Bühlmann 2020). Although management systems, standards and norms are important, they are not the sole condition for the long-term survival of an organization (Dilroshan et al. 2022). Contrary to the literature (Griga n. d.), they are only partially regarded as the operating system of an organization.

In summary, it is important to recognize that the factors that make traditional organizations durable are different from those that promote the crisis resilience of postmodern organizations (Duchek 2019). In many postmodern organizations, the focus is on speed and flexibility, using technological innovation to bring new products and services to the market faster than competitors (Liu et al. 2018). While mistakes in traditional organizations can quickly lead to crises, mistakes in postmodern organizations are often seen as a desirable side effect of creativity and innovation.

What enables a modern organization to operate successfully in chaotic market conditions is therefore fundamentally different from the factors that make a traditional organization resilient. In modern organizations, longevity often depends on the ability to standardize business processes and thereby make them scalable. In contrast, the focus of a traditional organization is on working together to find a meaningful way to combine a comprehensive understanding of the world with performance, thereby creating an organization with strong internal cohesion (Duchek 2019).

However, it is essential to note that an organization cannot develop beyond the developmental stage of its leadership (Drath & Heller 2018).

7.3 Insights for Further Research

In order to derive findings from the study, a comparison is first made with six groups of organizations in order to identify areas for further research into entrepreneurial resilience. In

this context, an attempt is made to bring these groups into line with the results of the study and at the same time to identify potential areas of research and further investigation.

In addition, there are references to further fields of research in almost all chapters, which are explicitly mentioned in the respective concluding conclusion. It is important to consider and critically scrutinize these references in relation to this chapter.

What Organized Crime teaches us about Resilience

The world of organized crime, particularly the Mafia, which has existed for hundreds of years despite government persecution and journalistic investigation, offers insights into unique principles of resilience. The Mafia is a tribal organization in which power, loyalty and subordination play central roles. Various international mafia organizations such as the Russian Solntsevskaya Bratva, the Japanese Yakuza, the Italian Camorra, the `Ndrangheta or the Mexican Sinaloa Cartel are described as resilient in terms of their historical development, organizational structures, and business models. Despite different approaches and fields of activity, each of these organizations shows a remarkable ability to adapt and survive in a hostile environment.

Despite their illegal nature and disregard for social rules through various actions and strategies, the groups have managed to secure their existence and even gain public support and recognition in some cases. The Robin Hood image of the Sinaloa cartel and its connection to the local population and authorities is cited as an example. The analysis of these organizations thus offers useful insights into entrepreneurial resilience in extreme and challenging environments (Drath & Heller 2018).

In the context of corporate resilience in this thesis, organized crime represents an interesting perspective by highlighting the longevity and, above all, the adaptability of organizations. But what characterizes adaptable organizations, especially in the context of the case study conducted (Huber et al. 2023)? Based on a study (Reimer & Schäffer 2022) on this question, the following aspects can serve as a guide in the field of corporate resilience in the future:

- *Adaptability is crucial in a volatile environment;*
- *The focus is on processes as well as cultural and organizational aspects;*
- *Adaptable companies are more likely to set relative targets compared to less adaptable companies;*
- *Adaptable companies update their forecasts regularly;*
- *Less adaptable companies place greater emphasis on cost awareness and often approve investments gradually;*
- *Continuous feedback is more important in adaptive organizations because they focus on learning, development, and growth in performance appraisal;*
- *Financial bonuses in adaptable companies are more strongly linked to success compared to competitors;*
- *Adaptable companies foster a strong sense of belonging and inspire their employees through common corporate goals and shared values.*

The adaptability of organizations stands and falls with the corporate culture and the organizational framework. A culture based on transparency, autonomy and a consistent focus on the customer is the key to greater adaptability and therefore also to entrepreneurial resilience.

Differences according to company size, stock market listing, industry or cultural and organizational aspects only occur in isolated cases (Reimer & Schäffer 2022). The flexible adaptation and evaluation of processes and process model development (refer to Chapter 3.4.1.1) as well as assistance from standards and norms (refer to Chapter 3.4.1) could make a significant contribution. However, there is a lack of research on the partial application of process maturity levels to support risk-based approaches (refer to Chapters 3.4.1.2 and 3.4.2.2) (Duchek 20219; Huber et al. 2023).

Drawing Lessons from the World's oldest Organizations

In 552, the Buddha's teachings were brought to Japan by Korean monks, where they were supported by Empress Suiko, enabling the rapid spread of Buddhism throughout the island kingdom. However, at this time Japan lacked expertise in building the characteristic Buddhist temples with pagoda-shaped roofs, which is why foreign experts were needed. In 578, the renowned Korean carpenter and temple builder Shigemitsu Kongō was invited to Osaka by Empress Suiko to build the Shitenno-ji temple. This was the beginning of a long company history in Japan for Kongō Gumi Co, Ltd, which was to remain in family ownership for a full 1,428 years.

In Japan, family businesses are strongly imbued with a shared value system that focuses on the long-term nature of the organization. The organization is seen as an integral part of the family, and individual interests of family members are subordinated to the interests of the company. Japan has a remarkably high number of companies that have existed for several generations. In contrast, few family businesses in the Western world reach the fourth generation. This raises the question of what makes organizations successful in the long term and thus entrepreneurially resilient (Doleski 2015).

Below are the five oldest organizations in the world (Nikolic 2020):

Founding Year (AD)	Name	Country	Sector
578	Kongō Gumi	Japan	Construction
771	Genda Shigyō	Japan	Paper Industries
862	Staffelter Hof	Germany	Winery
864	Monnaie de Paris	France	Coin press
885	Tanaka Iga	Japan	Religious articles

Table 7-6: The oldest organizations in the world
(own illustration based on Nikolic 2020)

The focus on tradition and long-term decision-making are certainly important factors. This also includes continuous family leadership and the will to plan for the long term (Drath & Heller 2018). This raises the question of whether the will to take the long view is a key to long-term success and therefore also to the entrepreneurial resilience of organizations.

In the summary of the EFQM model (refer to Chapter 3.4.2.2), it is stated that the model is geared towards long-term change management. Although the model may therefore have

difficulties coping with abrupt shocks, it nevertheless offers an open basis for expansion. As described in the literature (Kumm 2020), this is in itself a contradiction. On the one hand, organizations must not only withstand the challenges of the VUCA world today and in the future, but also emerge from them successfully and stronger. They must therefore learn to adapt to these changes in a smart way time and again. On the other hand, crises and shocks cannot be forecasted in the long or medium term (Duchek 2019).

Example
"The Finnish company Nokia was founded in 1886 by Finnish engineer Fredrik Idestam, initially as a paper factory. Around 30 years later, it was also active in electricity generation and also produced rubber boots and bicycle tires. It was not until 1989, around one hundred years after the company was founded, that Nokia entered the mobile phone business and became the market leader at the end of the 1990s. Overall, the company achieved a total turnover of up to 51 billion euros. However, the company missed out on the trend of emerging smartphones and sales slumped to just under twelve billion euros in 2014. During the decline of the cell phone division, which ultimately led to Nokia selling the division to Microsoft in 2013, the company invested in the development of geo services and network technology. While the mapping services were sold off again in 2015, the capital generated from their sale was invested in the takeover of competitor Alcatel-Lucent a year later. In 2017, the reorganized company generated a turnover of 23 billion euros (Schneider 2020)."

Table 7-7: Nokia (Schneider 2020)

However, there is no question that long-term planning will be crucial in the face of rapid change and constant movement. However, it is equally obvious that due to the diversity and individuality of organizations, markets and other factors, no single system or approach can apply to all. In addition to the aforementioned longevity due to continuous planning, this approach, as well as the RMMF of business resilience, can be extended to include adaptive and flexible characteristics. In this respect, the author of the paper sees two or even several levels that can be harmonized with each other. This can be done in a similar way to various iterations, which can be recorded and monitored in metrics, for example. Standards and norms also play an important role, especially in management systems, which serve as a basic framework and thus ensure continuity in the area of corporate resilience (Duchek 2019). It is therefore essential to describe the interfaces between personal, systemic, and organizational resilience (refer to Chapter 3.3.4) in greater detail.

Learning from Organizations with high Reliability

Organizational psychologist Karl E. Weick and management theorist and physician Kathleen Suthcliffe have specialized in the study of organizations in which failure is not an option. These organizations, such as operations centers, nuclear power plants or aircraft carriers, are referred to as high reliability organizations because they are very reliable in coping with unforeseen events that can often have serious consequences. In their book *"Managing the Unexpected"*, Weick and Suthcliffe focus on the analysis of the organizational culture in British surgical centers, particularly in connection with the treatment of newborns with severe cardiac anomalies. These centers were established in the 1980s and pooled critical skills for high-risk procedures where pediatric surgeons performed open heart surgery on very young patients. The high number of cases in each hospital was necessary to ensure the required expertise and experience of the medical staff. These research findings are of great importance for the development

of entrepreneurial resilience, especially with regard to the ability to react quickly to unforeseen events (Drath & Heller 2018; Duchek 2019).

The text makes it clear that the focus is on preventing mistakes, as these can have serious consequences. All organizations should strive to minimize errors and implement preventive measures to strengthen business resilience, even if the goal seems difficult to achieve at first glance. Nevertheless, the goal should be zero error tolerance, even if it may not always be achieved. From the author's point of view, this is nevertheless crucial in order to be able to achieve the desired goal in terms of resilience in the very first place (Santamarta et al. 2022). Of course, there are exceptions where a risk-based approach is necessary and should be integrated into holistic resilience management. However, there is a lack of empirical research in the literature that examines and reviews corporate resilience as a whole in the context of industrial companies (refer to Chapter 3.3.4).

As highlighted in the previous sections, organizational culture is a relevant aspect. Organizations should promote a culture that supports open communication (refer to Chapter 4.1.2) and an awareness of potential risks and sources of error, particularly with regard to business resilience (King et al. 2022). A culture of resilience requires sustained implementation, in which management systems can play a crucial role as they provide an internal organizational framework and proactively address and promote these issues (refer to Chapters 3.4.3 and 3.4.1.2). However, the description and anchoring of a culture of resilience is scarce in the literature and requires further investigation.

In order to achieve and maintain these goals, bundled skills, expertise and continuous training and experience are crucial to effectively manage tasks. This applies not only to getting started with corporate resilience, but also to monitoring and evaluating the RMMF of corporate resilience in relation to the respective output function (refer to Chapter 6.1). By collecting and providing expert knowledge, organizations can overcome unforeseen challenges more sustainably. The organization must define and maintain the required knowledge (refer to Chapter 3.4.1). This includes regular training and simulations (refer to Chapter 3.4.1.1) to prepare employees for various shock scenarios and improve their skills. The developed output functions of the RMMF of business resilience require validation and possible improvements in the process flow.

Top Companies as Role Models

Jim Collins and Morten T. Hansen are renowned management experts and have conducted extensive research in their book *"Great by Choice"* to identify organizations that perform at least ten times better than comparable competitors in the same industry over a long period of time (Fingerle & Wink 2020; Duchek 2019). Their aim was to find out whether these successful organizations are managed differently and whether entrepreneurial resilience plays an important role in this. Given the increasing complexity, speed, and uncertainty in the global economy, they were interested in why some organizations were successful in the long term and others were not (Drath & Heller 2018).

From a list of more than 20,000 organizations, Collins and Hansen ultimately selected seven organizations and compared them to the overall market and other organizations in the same industry. To identify common patterns in decision-making, risk-taking, innovation and more, they reviewed numerous documents from the history of these organizations and conducted interviews. In total, their analysis spanned over 6,000 years of company history to

understand the differences between these organizations and their competitors (Drath & Heller 2018; Duchek 2019).

Below are the seven successful organizations that were examined as part of the study by Collins and Hansen (Drath & Heller 2018):

Name	Sector	Performance vs. market	Performance vs. industry
Amgen	Biotechnology	24-fold	77-fold
Biomet	Medical Technology	18-fold	11-fold
Intel	Information Technology	21-fold	46-fold
Microsoft	Software	56-fold	119-fold
Progressive Insurance	Insurance	15-fold	11-fold
Southwest Airlines	Airline	63-fold	550-fold
Stryker	Medical Technology	28-fold	11-fold

Table 7-8: The most successful organizations examined in the Collins and Hansen study (own illustration based on Drath & Heller 2018)

A key finding of the study concerns the speed and data with which organizations operate. The most successful organizations were not necessarily the fastest at making decisions. Instead, they were able to differentiate between situations where quick action was required and those where it made more sense to analyze data thoroughly first. This enabled them to make more informed decisions (Drath & Heller 2018).

With regard to the study, the ability to make decisions quickly and effectively is described as crucial to the success of an organization in the constantly changing business world (refer to Chapter 5.2) (Gupta 2023). In addition, the Delphi method, as an iterative process for forming opinions, also supports rapid consensus building (refer to Chapter 4). During the implementation of the decision-making process with the DMs, it became clear that it makes more sense to hold timely, coordinated rounds, as otherwise information and knowledge that has already been developed and discussed will be lost again over time, despite careful data quality (ISO Templates 2019). A structured and closely timed approach also increases the likelihood that the group judgment, which is formed from the individual subjective opinions, comes closer to the actual facts. However, this should be checked and validated in future comparative studies.

Nevertheless, it is crucial to establish a well-defined decision-making process that is both timely and successfully implemented (Kahraman et al. 2021). In practice, it became clear that the selection of DMs is of great importance. This is based on the assumption that the relevant people in the various divisions are aware of the key performance indicators and the associated business areas that are relevant to their respective areas of responsibility (Huber et al. 2023). It is essential that these individuals not only understand the KPIs, but also have the ability to extract meaningful insights from the available data. Despite these assumptions, it has not yet been verified whether top management must necessarily fulfill these requirements. Although it is assumed that the summarization and interpretation of KPIs is clear at this management level, there is still room for interpretation when it comes to the actual data basis of the KPIs. These must be subject to careful review, as this is the only way to ensure that the risk of incorrect data quality is minimized. In addition, consideration should be given to whether a

statistical procedure should accompany the entire RMMF process in order to recognize and identify weaknesses at an early stage. In this way, these weaknesses could be minimized or even eliminated (Duchek 2019; Hakikur 2021).

The Lessons of Agile Organizations

In 1986, Japanese management professor Hirotaka Takeuchi published an article describing a new trend in product development in Japanese organizations. Instead of sequential development phases, small interdisciplinary teams worked together on all phases of a new product. In 1993, the American medical doctor and IT specialist Jeff Sutherland developed the Scrum method for software development based on these ideas. Scrum is based on self-managing teams and daily stand-up meetings. This method made it possible to complete projects more quickly and efficiently (Söderholm 2020). In 2001, the term *"agile"* was coined and a manifesto was adopted that defined the core values of agile software development. These values emphasize the importance of individuals and interactions, collaboration with customers and the ability to adapt to change (Drath & Heller 2018).

The RMMF of entrepreneurial resilience (refer to Chapter 6) combines agile methods that are interlinked throughout the entire process. According to Heller (n. d.) and Nissen (2018), agile structures also help to detect weak signals at an early stage, as they can identify deviations from the *"normal state"* more quickly due to frequent iteration. Stabilization after a shock is facilitated by agile and small-scale working. Modern companies, which are highly complex systems - analogous to the case study - can no longer be developed effectively according to a *"master plan"*; instead, they must be able to stabilize themselves. Agile collaboration is therefore based on self-organization and personal responsibility. Every member of an organization should therefore be aware of their responsibility in the process and be able to actively address disruptions and obstacles at an early stage in order to maintain agile processes. At the same time, agility can promote and increase corporate resilience (Duchek 2019; Huber et al. 2023).

There is widespread agreement that corporate resilience is a key requirement that can be used as a basis by the systems described. However, the essential question is how the comprehensive approach, such as the RMMF of business resilience, is communicated and implemented to all employees in the organization. This is also another question of organizational culture, which is crucial for anchoring corporate resilience throughout the entire organization. Standards and models such as the SGMM and the AQMM (refer to Chapter 3.4.3) in conjunction with the Backward Chain (refer to Chapter 4) can be helpful here. In addition, the continuous development of indicators and metrics (refer to Chapter 3.5) is crucial to assess organizational impact and adequately prepare for future challenges. It is important to further deepen and empirically investigate this aspect in order to continuously improve the newly developed RMMF approach to organizational resilience (Duchek 2019; Huber et al. 2023; Kayes 2018).

Lessons from Mindful Organizations

Evolutionary organizations that focus on the meaningfulness of action and the wholeness of the person instead of concentrating exclusively on turnover and profit - does that work? These organizations aim to preserve and develop a community by exchanging loyalty, performance, and self-sacrifice for belonging and status. The Ark Movement, inspired by Gandhi, serves as an example of such organizations. Ark houses are both living communities and

economic enterprises based on principles such as sustainable agriculture and intercultural dialog. These communities are self-reliant and emphasize spiritual practices. Although some established communities have had to give up due to social changes, the Ark Movement remains active. Over the years, the Ark Movement has gained rich experience in community building that can be used as a template for evolutionary organizations. The principles of entrepreneurial resilience in these organizations have emerged and can potentially serve as a guide for others (Duchek 2019).

These cohabiting communities are generally responsible for their own affairs and organize themselves autonomously. Despite this autonomy, however, they are closely integrated into a network (organization) with other communities (usually internal organizations in a corporate structure) (Drath & Heller 2018).

According to Holicky (2023), employees are experts in their respective tasks and are often more familiar with the day-to-day challenges than others. It is important to give them the space to solve problems independently. Ultimately, it is the employees who develop relevant systems, implement regulatory requirements, record and develop customer-specific requirements, provide sales and service, track metrics and make a significant contribution to corporate resilience with their expertise. The organization's management system forms the framework for this (refer to Chapter 3.4). Although this point is not necessarily technical in nature and is considered a soft factor, it should not be neglected as it is important in the overall context of fulfilling all relevant tasks in the context of business resilience. Top management should provide the process and system map, the *"cookbook"* so to speak, so that the ingredients required for the recipe can be completed and passed on together as projects or tasks within the team.

The RMMF of corporate resilience also takes this view into account from a centrally organized perspective (refer to Chapter 6). In decentrally organized organizational units, an iterative approach to implementation could therefore be chosen. This means that the results can be consolidated at sub-level, for example at country or regional level, division level or at a level appropriate to the respective organizational context. In addition, as described at the beginning, employees should be empowered. For example, the initial KPIs and RFs could focus on employees in order to capture the breadth of corporate resilience. This will achieve a deeper involvement of employees and at the same time strengthen trust in the organization. This therefore requires further empirical research with regard to the newly developed RMMF of entrepreneurial resilience, especially at the input level in relation to the metrics (Duchek 2019; Fecher et al. 2021; Huber et al. 2023).

Overall, the chapter shows the diverse approaches and instruments for strengthening entrepreneurial resilience and underlines the need for further empirical studies in this area (Drath & Heller 2018).

7.4 Practical Implementation

In this chapter, further practical implementation options based on the previous chapter are discussed and compared in detail.

According to Kumm (2020), the development and establishment of healthy corporate resilience undoubtedly represents a strategic competitive edge and should therefore be considered essential in every organization (Duchek 2019). However, when designing the

corresponding cultural aspects, it is important to noted that corporate resilience cannot be created by a standardized culture according to DIN standards (IEST 2024).

Of course, certain characteristics are required, but these should always be based on the individual organizational personality, which should ideally be clearly highlighted. Every organization has its own unique, evolved culture. Products and services can usually be exchanged, but the organizational personality and culture form a strong unique selling point (Lopes 2024).

Similar to the personal development of an individual, development processes in organizations are also about recognizing potential. Which strengths should be further developed? Which aspects need to be newly developed, which are optional and that can be neglected? The development of healthy entrepreneurial resilience always involves intelligent management of the company's own resources in the respective environment (Kulkarni 2020).

The significance of resilience in a business context is relevant and beyond question (Powley et al. 2020; Radic et al. 2022). Nevertheless, it is clear that many organizations still have considerable room for improvement. Large corporations in particular often still focus too much on their core competencies and neglect corporate resilience. This view is supported by the rising number of corporate insolvencies in Europe following the COVID-19 pandemic. It is clear that comprehensive resilience management is often overlooked (Duchek 2019). Research into holistic resilience concepts in the corporate context is comparatively new, and there is therefore a lack of comprehensive overall contexts in this area. It is therefore important to further develop the theoretical ideal models of corporate resilience described to date and adapt them so that they can be put into practice in organizations.

The importance of standards and norms for strengthening corporate resilience in organizations should also be emphasized. Standards provide clear instructions and can relieve companies of external pressure, as they can prove that they comply with the relevant standards.

ISO/IEC TS 33061:2021 offers a promising solution for defining sub-processes and assessing process maturity levels. It can help to strengthen corporate resilience but requires a risk-based approach (Duchek 2019). This means that a step-by-step implementation is possible, in which only partial areas can be implemented initially instead of a comprehensive implementation. This can be particularly useful at the beginning in order to develop an initial understanding.

The ISO 22316:2017 standard supports organizations in developing a culture of resilience and takes into account corresponding behavioral aspects in its application. This standard provides clear guidelines for organizations that systematically strengthen their resilience (Fecher 2021; Lopes 2024).

DIN SPEC 91461:2021 is a *"hidden champion"* as it provides a comprehensive framework for stress tests and resilience measures. The following is taken into account activities that take place across different phases in the organization and are therefore linked to the management system. In this context, an extended and project-specific procedure is described in Appendix F, taking into consideration the specification listed (Huber et al. 2023; Teamhub 2023).

It has been shown that the implementation of corporate resilience requires the application of standards and their integration into management systems. Standards and models facilitate the introduction of resilience in organizations and strengthen the understanding of it (Duchek 2019). However, it is emphasized that anchoring resilience in the corporate culture is not a matter of course and requires clear objectives, appropriate resources, and a revision of existing working methods. If no structural elements such as management systems or resources

in terms of corporate resilience are present in the organization, the author considers the plan to make the organization resilient to have failed. Efforts that are not anchored in the organization usually tend to fizzle out after about two years and therefore prove to be worthless.

The Delphi method is used as an iterative opinion-forming process that aims to minimize uncertainties in decision-making. Clear questions, a careful selection of diversified DMs, clear communication and the right number of iteration rounds are essential for effective application. However, the result should be seen as a collection of subjective evaluations, not as objective truth (Bozdog et al. 2019; Duchek 2019; Huber et al. 2023).

VCA in the context of business resilience and using the OECD methodology fundamentally aims to optimize value creation along the supply chain and, above all, to provide guidance alongside the literature in the development of KPIs and RFs. By identifying KPIs and RFs as well as applying a backward chain, organizations can identify, measure, and improve their performance. The selection of KPIs does not necessarily require fixed recommendations but should correspond to the individual company requirements (Huber et al. 2023).

The GRI Standards offer an additional flexible basis for reporting and enable a transparent comparison of organizations. The relevant metrics should be selected strategically in order to strengthen corporate resilience. The RFs that are important for production companies according to Macuzić (2016) were correlated with the GRI index.

The presented two-stage fuzzy model enables the specification of the degree of RFs in an organization's product delivery process and the analysis of their relationships to the identified KPIs. However, empirical studies are still required to validate the model in a business context (Huber et al. 2023).

The APQC framework provides a solid foundation for analyzing sub-processes and establishing common terminology. Empirical studies are also required here in order to identify and validate such frameworks in the specific context (Rüegg-Stürm & Grand 2019).

The selection of DMs is crucial and should be based on people who know the KPIs and have the ability to derive meaningful insights from the data (Lopes 2024). The DM group should also be small and diverse to bring in different perspectives. This also results in the advantage of timely implementation.

The research results from the case study indicate that higher RF values correlate with shorter KPI recovery times. This indicates a statistically significant influence of RF values on KPI recovery times, which is additionally confirmed in scatter plot analysis. There is therefore a direct correlation between aggregated weighted RFs and KPI recovery times (Huber et al. 2023).

The RMMF of entrepreneurial resilience combines all the elements listed in one diagram and thus offers a new holistic and innovative approach to strengthening organizations for future challenges. It can be applied at different levels of the organization and provides an adaptable orientation in the context of corporate resilience. It encourages the exploration of new strategies that may have been previously overlooked. The individual elements of the RMMF are intertwined and aim to describe and address key aspects of business resilience (Duchek 2019).

The derived results of the RMMF of entrepreneurial resilience are characterized by their high practical orientation. This results from the methodical derivation based on a case study in

a representative industrial company. The RMMF thus reflects the increased research interest in what resilience actually means and how it might be shaped (Duchek 2019). The assessment of organizational resilience is complex and requires assessment models based on the assessments of DMs. This uncertainty is present in many management problems. The Fuzzy Delphi Technique is used to assess organizational resilience (Huber et al. 2023; Mostafa et al. 2010). This allowed for the first time a comprehensive review and adaptation of existing models based on real crisis experiences and the concept development of a concrete approach (Söderholm 2020): The RMMF of organizational resilience.

A key difference to most existing models is that the RMMF of entrepreneurial resilience not only defines criteria to describe a state, but also identifies specific factors that promote the development of entrepreneurial resilience and contribute to achieving resilient states. The model focuses on options for action and toolkits rather than simply formulating ideal states that are worth striving for.

Although there are theoretical models, such as those of ISO and BSI, which also offer recommendations in the form of activities, these models lack a direct link to real crisis experiences. The RMMF of corporate resilience, on the other hand, can provide specific insights that are not available in the aforementioned models due to its strong practical orientation. At the same time, it expands the existing approaches to include factors and aspects that have proven to be relevant in the companies and organizations surveyed but were not taken into account in previous models.

In summary, the analysis of the current situation confirms the existing ideas, recommendations, and models on corporate resilience in many respects. The RMMF of business resilience now enables the concrete application of these findings in practice by specifically formulating how organizations can meet the limitations and challenges of a shock. The RMMF of business resilience is a result that has been developed directly from practice for practice. The factors and aspects described therein are practicable enough to derive concrete recommendations for action that support companies and organizations in preparing specifically for future challenges and meeting them successfully (Bernard et al. 2022).

7.5 Outlook

The COVID-19 pandemic has put the world to the test (Dennis et al. 2022; Kulkarni 2020). It has shown the limits and revealed weaknesses in the business models and structures of organizations (Bernard et al. 2022). The RMMF of business resilience now offers a contemporary approach to managing resilience in organizations. The crisis has brought awareness of the importance of business resilience to the fore. Managers now have the opportunity to learn from this experience and make their organizations more resilient in the long term (Doleski 2015; Zhao 2021).

The crucial question for the future of organizations will be whether they view corporate resilience as an important management issue in the long term and build it up sustainably or whether they view the COVID-19 pandemic as a one-off event. The RMMF of business resilience offers a pragmatic approach to continuous improvement. It identifies proven factors and content that not only have a stronger impact in times of crisis (Duchek 2019).

A recent study (The Economist Group 2022) has shown that resilient organizations get through the crisis better. The RMMF of corporate resilience promotes the acceleration of current trends such as digitalization as well as flexibility and adaptability. It underlines the importance of continuous risk management and expands the concept to include unforeseeable high-impact events (Coffey 2023).

The framework for corporate resilience helps organizations to identify the right steps to survive difficult times and adapt at an early stage. These steps (refer to Chapter 6.1) should be firmly anchored as *"drivers"* in the strategy cycle of management processes (Huber et al. 2023).

The following figure illustrates the RMMF of corporate resilience as a driver of the strategic level.

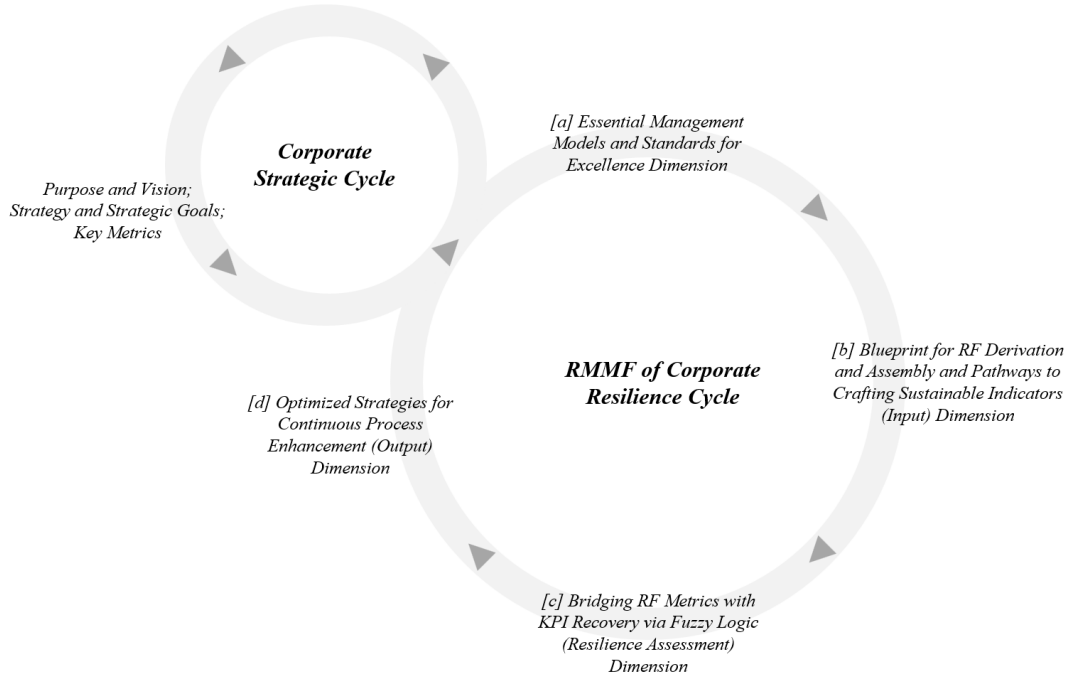

Figure 7-1: Integrative approach in the corporate strategy cycle of management processes, including the RMMF as a *"Driver"* (own illustration based on Benndorf 2021)

It will be interesting to see how organizations integrate the RMMF of business resilience into their future strategies. Will new change initiatives emerge as a result of the increased focus on business resilience? Will the lessons learned from the crisis be used to rethink outdated routines? The evolution of organizations and industries will provide us with lessons for continuous improvement and help make them more resilient and better equipped (Bernard et al. 2022).

In view of the growing body of literature on the subject of resilience, further findings in the area of corporate resilience can be expected. It would be desirable to examine the interactions at various levels in more detail and to extend the focus from entrepreneurial resilience to other levels (analogous to a further project, as listed in Appendix F). In addition, an increase in empirical studies, especially practice-oriented case studies that generally relate to all

organizations, is desirable (Niessen 2021). Corporate resilience is not an option that is only relevant for certain organizations or industries. In a constantly changing business world in which organizations can be confronted with various challenges such as natural disasters, political uncertainties, economic turbulence or pandemics, entrepreneurial resilience is the decisive capability (Duchek 2019).

APPENDIX

Appendix A - Overview of existing standards with specific reference to corporate resilience

Identification	Number	Name	Application
General Standards			
ISO	ISO 22300:2021	Security and resilience - Vocabulary	Terms and definitions
ISO	ISO 22301:2019	Security and resilience - Business continuity management systems - Requirements	Basic requirements for a business continuity management system
ISO	ISO 22313:2020	Security and resilience - Business continuity management systems - Guidance on the use of ISO 22301	Support with the implementation of ISO 22301
ISO	ISO 22316:2017	Security and resilience - Organizational resilience - Principles and attributes	Guidelines for the development of a resilient organization
ISO	ISO 31000:2018	Risk management - Guidelines	Guidelines for risk management systems
Organization-related standards			
ISO/TS	ISO/TS 22317:2021	Security and resilience - Business continuity management systems - Guidelines for business impact analysis (BIA)	Guidelines for a BIA
ISO/TS	ISO/TS 22318:2021	Security and resilience - Business continuity management systems - Guidelines for supply chain continuity management	Continuous operational management of supply chains
ISO	ISO 22319:2017	Security and resilience - Community resilience - Guidelines for planning the involvement of spontaneous volunteers	Specification of a structure for the preparation for the involvement of spontaneous helpers in emergency response
ISO	ISO 22320:2018	Security and resilience - Emergency management - Guidelines for incident management	Guidelines for the organization of Hazard prevention in the event of damage
ISO	ISO 22325:2016	Security and resilience - Emergency management - Guidelines for capability assessment	Guideline for the assessment of ability of an organization to deal with emergencies
ISO	ISO 22326:2018	Security and resilience - Emergency management - Guidelines for monitoring facilities with identified hazards	Guidance for the monitoring of Identified hazards

Identification	Number	Name	Application
ISO/TS	ISO/TS 22330:2018	Security and resilience - Business continuity management systems - Guidelines for people aspects of business continuity	Guide for the preparation of persons affected by an incident affected
ISO/TS	ISO/TS 22331:2018	Security and resilience - Business continuity management systems - Guidelines for business continuity strategy	Guide for the development and selection of a strategy for continuous operations management
ISO/TS	ISO/TS 22332:2021	Security and resilience - Business continuity management systems (BCMS) - Guidelines for developing business continuity plans and procedures	Guideline for the development of BCMS processes
ISO/DIS	ISO/DIS 22340	Security and resilience - Protective security - Guidelines for an enterprise protective security architecture and framework	Guideline for the necessary organizational structure for preventive security measures
ISO	ISO 22342:2023	Security and resilience - Protective security - Guidelines for the development of a security plan for an organization	Provides security guidelines for organizations to protect assets, excluding private security companies.
ISO	ISO 22343-2:2023	Security and resilience - Vehicle security barriers - Part 2: Application	Guidance on the selection, installation, and use of vehicle security barrier
ISO/TR	ISO/TR 22351:2015	Societal security - Emergency management - Message structure for exchange of information	Describes a message structure for the exchange of information between organizations
ISO	ISO 22361:2022	Security and resilience - Crisis management - Guidelines	Provides guidance on crisis management
ISO/TS	ISO/TS 22375:2018	Security and resilience - Guidelines for complexity assessment process	Guidelines for the application of principles and a procedure for assessing the complexity of an organization's systems
ISO	ISO 22380:2018	Security and resilience - Authenticity, integrity and trust for products and documents - General principles for product fraud risk and countermeasures	Establishes general principles for an organization to identify the risks related to various types of product fraud and product fraudsters
ISO	ISO 22381:2018	Security and resilience - Authenticity, integrity and trust for products and documents - Guidelines for establishing interoperability among object identification systems to deter counterfeiting and illicit trade	Guidelines for establishing interoperability among independently functioning product identification and related authentication systems, as described in ISO 16678
ISO	ISO 22383:2020	Security and resilience - Authenticity, integrity and trust for products and documents - Guidelines for the selection and performance evaluation of authentication solutions for material goods	Guideline for ensuring the authenticity of products over the life cycle
ISO	ISO 22384:2020	Security and resilience - Authenticity, integrity and trust for products and documents - Guidelines to establish and monitor a protection plan and its implementation	Gives guidelines for assessing product security-related threats, risks, and countermeasures
ISO	ISO 22392:2020	Security and resilience - Community resilience - Guidelines for conducting peer reviews	Guidelines for organizations of their disaster risk reduction

Identification	Number	Name	Application
ISO/AWI	ISO/AWI 44001 (previously: ISO 44001:2017)	Collaborative business relationship management systems - Requirements and framework	Specifies requirements for the effective identification, development, and management of collaborative business relationships
ASIS	ASIS SPC.1-2009	Organizational resilience: Security, preparedness, and continuity management systems - requirements with guidance for use	Specifies requirements for an organizational resilience management system
BS	BS 65000:2022	Organizational resilience - Code of practice	Provides guidance and recommendations on what constitutes organizational resilience
COSO	COSO ERM Framework:2020	Compliance risk management - Integrating with strategy and performance to the management of compliance risks	Application of the enterprise risk management
DS	DS 3001:2009	Organizational resilience: Security, preparedness, and continuity management systems - Requirements with guidance for use	Requirements of an organization for a resilience management system
NIST SPB	NIST SPB 800-53:2020	Security and Privacy Controls for Information Systems and Organizations	Provides a catalog of security and privacy controls for information systems and organizations to protect organizational operations and assets
Standards for issue-specific resilience			
ISO/IEC WD	ISO/IEC WD 27000	Information technology - Security techniques - Information security management systems - Overview and vocabulary	Provides the overview of information security management systems
ISO/IEC	ISO/IEC 27001:2022	Information security management systems	Provides companies of any size and from all sectors of activity with guidance for establishing, implementing, maintaining, and continually improving an information security management system
ISO/IEC	ISO/IEC 27002:2022	Information security, cybersecurity, and privacy protection - Information security controls	Provides a reference set of generic information security controls including implementation guidance
ISO/IEC	ISO/IEC 27003:2017	Information technology - Security techniques - Information security management systems - Guidance	Provides explanation and guidance on ISO/IEC 27001
ISO/IEC	ISO/IEC 27005:2022	Information security, cybersecurity, and privacy protection - Guidance on managing information security risks	Guidance on risk analysis and on risk management in Information Technology
ISO/IEC	ISO/IEC 27010:2015	Information technology - Security techniques - Information security management for inter-sector and inter-organizational communications	Provides guidelines in addition to the guidance given in the ISO/IEC 27000
ISO	ISO 28000:2022	Security and resilience - Security management systems - Requirements	Specifies requirements for a security management system
ISO	ISO 28001:2007	Security management systems for the supply chain - Best practices for implementing supply chain security, assessments, and plans - Requirements and guidance	Good practice guide for the practice for the implementation of supply chain security systems

Identification	Number	Name	Application
ISO	ISO 28002:2011	Security management systems for the supply chain - Development of resilience in the supply chain - Requirements with guidance for use	Specifies requirements for a resilience management system in the supply chain
ISO	ISO 28003:2007	Security management systems for the supply chain - Requirements for bodies providing audit and certification of supply chain security management systems	Contains principles and requirements for bodies providing the audit and certification of supply chain security management systems
ISO	ISO 28004-1:2007	Security management systems for the supply chain - Guidelines for the implementation of ISO 28000 - Part 1: General principles	Provides generic advice on the application of ISO 28000
ISO	ISO 28004-3:2014	Security management systems for the supply chain - Guidelines for the implementation of ISO 28000 - Part 3: Additional specific guidance for adopting ISO 28000 for use by medium and small businesses (other than marine ports)	Has been developed to supplement ISO 28004-1 by providing additional guidance to medium and small businesses
ISO	ISO 28004-4:2014	Security management systems for the supply chain - Guidelines for the implementation of ISO 28000 - Part 4: Additional specific guidance on implementing ISO 28000 if compliance with ISO 28001 is a management objective	Provides additional guidance for organizations
NIST SPB	NIST SPB 800-34 Rev. 1:2010	Contingency Planning Guide for Federal Information Systems	Guide for emergency plans for Information Technology
Standards for the resilience of society			
ISO/DIS	ISO/DIS 22328-2	Security and resilience - Emergency management - Part 2: Guidelines for the implementation of a community-based early warning system for landslides	Guidelines for a landslide early warning system
ISO	ISO 22328-3:2023	Security and resilience - Emergency management - Part 3: Guidelines for the implementation of a community-based early warning system for tsunamis	Guidelines for the implementation of a community-based disaster early warning system
ISO	ISO 22341:2021	Security and resilience - Protective security - Guidelines for crime prevention through environmental design	Guide to procedures for the reduction of crime in new or existing premises
ISO/DTS	ISO/DTS 22360	Security and resilience - Crisis management - Concept, principles, and framework	Basic requirements for crisis management (under development)
ISO/TR	ISO/TR 22370:2020	Security and resilience - Urban resilience - Framework and principles	Describes a framework and principles that are coherent with the 2030 agenda for sustainable development
ISO	ISO 22379:2022	Security and resilience - Guidelines for hosting and organizing citywide or regional events	Guidance on hosting and organizing citywide or regional events
ISO	ISO 22396:2020	Security and resilience - Community resilience - Guidelines for information exchange between organizations	Guidelines for the exchange of information between organizations

Identification	Number	Name	Application
ANDRR	A/CONF.224/ CRP.1:2015-2030	Sendai framework for disaster risk reduction	Framework to make societies and communities more resilient to disasters

Table 1: Overview of existing standards with specific reference to corporate resilience (own illustration based on Ferdinand & Prem 2020 and ISO 2023-C)

Appendix B - Input data for the application of Branch and Bound algorithm

Assessment by DMs ($e = 1, e = 2, e = 3$).

Management Technique	$j = 1$	$j = 2$	$j = 3$	$j = 4$	$j = 5$	$j = 6$	$j = 7$	$j = 8$	$j = 9$	$j = 10$	*AT*[2]	*Costs*[3]
$m = 1$ Arrow Diagram	(1,2,2)	(4,4,5)	(3,3,4)	(2,2,3)	(2,2,3)	(2,3,3)	(5,5,6)	(2,2,3)	(7,6,6)	(3,3,4)	80	18'000
$m = 2$ Balanced Scorecard	(6,6,7)	(7,6,7)	(6,7,7)	(6,7,7)	(7,7,7)	(6,6,7)	(6,7,7)	(5,5,6)	(6,7,7)	(5,5,6)	320	95'000
$m = 3$ Checklist (Generic)	(5,6,5)	(3,3,4)	(4,3,4)	(5,6,6)	(6,5,6)	(5,6,5)	(6,6,5)	(6,6,7)	(6,7,7)	(6,7,7)	50	7'500
$m = 4$ Contingency Diagram	(1,2,1)	(5,4,5)	(5,4,5)	(4,3,2)	(7,7,7)	(7,7,7)	(5,4,4)	(4,4,5)	(4,4,5)	(7,7,7)	80	16'500
$m = 5$ Continuum of Team Goals	(5,5,4)	(5,4,5)	(6,5,6)	(4,3,2)	(4,4,5)	(5,4,5)	(5,6,4)	(7,7,7)	(6,6,6)	(4,4,5)	100	15'000
$m = 6$ Flowchart (Generic)	(6,5,6)	(7,6,7)	(5,6,6)	(6,5,5)	(6,7,6)	(6,7,6)	(6,5,6)	(6,6,7)	(6,6,7)	(5,6,6)	50	10'000
$m = 7$ Gantt Chart	(4,5,3)	(5,5,6)	(4,5,5)	(5,6,6)	(3,3,4)	(3,2,3)	(6,6,6)	(4,4,5)	(6,6,7)	(3,3,4)	80	35'000
$m = 8$ Matrix Diagram (Generic)	(2,2,1)	(4,4,5)	(5,4,5)	(3,3,2)	(5,5,5)	(6,6,7)	(5,4,4)	(6,6,7)	(6,5,6)	(5,5,6)	80	17'000
$m = 9$ Mind Map	(2,3,3)	(6,6,7)	(7,6,7)	(6,6,6)	(3,4,4)	(7,7,7)	(6,7,7)	(7,7,7)	(3,5,4)	(4,4,5)	25	7'500
$m = 10$ Plan-Do-Study-Act Cycle	(6,7,7)	(7,7,7)	(7,7,7)	(6,6,7)	(7,6,7)	(7,7,7)	(6,6,7)	(5,5,6)	(7,7,7)	(6,6,7)	160	35'000
$m = 11$ Plan-Results Chart	(2,1,1)	(5,4,5)	(5,5,6)	(2,3,2)	(5,5,6)	(5,4,5)	(4,5,5)	(3,3,4)	(6,6,6)	(4,4,5)	80	17'500
$m = 12$ Potential Problem Analysis	(5,4,4)	(5,5,6)	(5,6,6)	(2,1,2)	(7,7,7)	(6,6,6)	(5,3,4)	(4,4,5)	(5,5,6)	(7,7,7)	100	19'500

[2] The time required to implement the technique in working days (AT).
[3] The costs required to implement the method [in EUR].

Management Technique	$j = 1$	$j = 2$	$j = 3$	$j = 4$	$j = 5$	$j = 6$	$j = 7$	$j = 8$	$j = 9$	$j = 10$	AT^2	$Costs^3$
$m = 13$ Process Decision Program Chart	(4,5,5)	(5,5,6)	(5,6,6)	(4,2,4)	(7,6,7)	(6,6,6)	(6,4,5)	(4,4,5)	(6,6,7)	(7,7,7)	100	19'000
$m = 14$ Relations Diagram	(7,6,6)	(6,7,7)	(6,5,6)	(7,6,7)	(5,6,5)	(7,7,7)	(7,7,6)	(6,6,7)	(6,6,6)	(5,6,6)	80	18'000
$m = 15$ Stakeholder Analysis	(7,7,6)	(7,7,7)	(7,7,7)	(7,7,7)	(6,6,7)	(6,5,6)	(7,6,7)	(5,5,6)	(7,6,7)	(5,5,6)	50	25'000
$m = 16$ Table (Generic)	(2,1,2)	(3,3,4)	(3,3,4)	(1,2,1)	(2,1,2)	(2,1,2)	(2,3,4)	(3,2,3)	(3,3,2)	(2,2,3)	25	6'000
$m = 17$ Tree Diagram (Generic)	(2,1,2)	(4,4,5)	(4,4,5)	(1,2,1)	(4,4,5)	(5,4,5)	(2,1,1)	(5,5,6)	(6,6,7)	(5,5,6)	50	16'500
$m = 18$ Affinity Diagram	(6,5,5)	(5,5,6)	(6,5,6)	(6,5,6)	(5,5,6)	(6,6,7)	(6,6,5)	(7,7,7)	(5,4,5)	(6,6,7)	50	18'000
$m = 19$ Benchmarking	(6,5,6)	(7,6,7)	(6,6,7)	(7,6,6)	(7,7,7)	(6,6,7)	(6,5,6)	(3,3,4)	(7,5,6)	(4,4,5)	160	70'000
$m = 20$ Brainstorming	(5,5,5)	(6,5,6)	(7,6,7)	(6,7,6)	(3,4,4)	(7,7,7)	(6,6,5)	(7,7,7)	(6,5,7)	(4,4,5)	25	7'000
$m = 21$ Brainwriting	(4,5,5)	(5,5,6)	(7,6,7)	(6,6,6)	(3,3,4)	(7,7,7)	(5,5,5)	(7,7,7)	(6,5,5)	(4,4,5)	25	7'000
$m = 22$ Desired-Result Fishbone	(2,1,2)	(5,5,6)	(5,5,6)	(2,2,3)	(6,6,7)	(6,6,7)	(1,3,2)	(5,5,6)	(5,4,5)	(6,7,7)	50	18'000
$m = 23$ 5W2H Method	(5,4,4)	(4,4,5)	(5,4,5)	(5,6,7)	(5,5,6)	(5,5,6)	(6,5,6)	(5,5,6)	(6,5,6)	(5,5,6)	25	8'000
$m = 24$ Nominal Group Technique	(1,2,1)	(4,4,5)	(6,5,6)	(3,2,3)	(4,3,4)	(6,5,6)	(3,2,2)	(6,6,7)	(6,5,5)	(4,4,5)	50	15'000
$m = 25$ Storyboard Method	(2,1,1)	(4,4,5)	(5,4,5)	(4,3,2)	(2,3,3)	(3,3,4)	(2,1,3)	(5,5,6)	(5,5,5)	(3,3,4)	80	15'000
$m = 26$ Cause and Effect Matrix	(5,6,5)	(5,5,6)	(6,5,6)	(5,6,5)	(6,6,7)	(6,6,7)	(2,2,3)	(4,4,5)	(5,6,7)	(6,6,7)	100	18'000
$m = 27$ Critical-to-Quality An.	(5,5,6)	(6,7,7)	(6,6,7)	(5,5,5)	(5,5,6)	(6,6,6)	(5,4,5)	(3,3,4)	(5,5,6)	(5,5,6)	100	27'500
$m = 28$ Critical to Quality Tree	(5,5,6)	(6,7,7)	(6,6,7)	(5,5,5)	(5,5,6)	(6,6,6)	(3,2,3)	(3,3,4)	(5,5,6)	(5,5,6)	100	27'500
$m = 29$ FMEA Method	(5,6,6)	(7,7,7)	(6,7,7)	(6,7,7)	(7,7,7)	(6,6,6)	(5,5,6)	(4,4,5)	(5,7,6)	(7,7,7)	160	70'000
$m = 30$ Req. and Measures Tree	(1,1,2)	(5,5,6)	(5,5,6)	(2,2,3)	(5,5,6)	(5,5,6)	(2,4,3)	(4,4,5)	(5,6,5)	(5,5,6)	100	27'500
$m = 31$	(6,5,6)	(6,7,7)	(6,6,6)	(4,3,5)	(6,7,7)	(6,7,7)	(5,6,6)	(5,5,6)	(6,5,6)	(5,6,6)	80	18'000

Management Technique	$j = 1$	$j = 2$	$j = 3$	$j = 4$	$j = 5$	$j = 6$	$j = 7$	$j = 8$	$j = 9$	$j = 10$	AT^2	$Costs^3$
SIPOC Diagram												
$m = 32$ Contingency Table	(2,1,1)	(4,4,5)	(7,4,4)	(2,1,2)	(4,5,4)	(4,4,5)	(2,1,1)	(3,3,4)	(6,5,5)	(4,4,5)	80	16'000
$m = 33$ Control Chart	(7,6,6)	(6,6,7)	(5,5,6)	(6,6,6)	(5,6,6)	(5,6,6)	(6,6,5)	(2,2,3)	(5,4,4)	(6,6,7)	160	28'000
$m = 34$ Design of Experiments	(5,4,5)	(5,6,6)	(6,5,6)	(2,1,1)	(4,5,5)	(5,5,6)	(5,5,6)	(2,2,3)	(5,6,5)	(5,5,6)	160	62'500
$m = 35$ Histo-gram	(3,4,4)	(4,5,5)	(6,4,5)	(5,4,4)	(3,4,4)	(3,4,4)	(1,2,2)	(2,2,3)	(5,4,3)	(3,3,4)	100	17'000
$m = 36$ Pareto Chart	(4,4,3)	(6,6,7)	(5,6,6)	(4,5,5)	(6,6,7)	(6,7,7)	(5,4,5)	(3,3,4)	(4,4,5)	(5,6,6)	100	18'000
$m = 37$ Performance Index	(6,5,5)	(5,5,6)	(5,5,6)	(5,4,5)	(5,5,6)	(5,5,6)	(3,2,1)	(3,3,4)	(5,6,4)	(4,4,5)	130	26'000
$m = 38$ Process Capa-bility Study	(6,5,6)	(6,6,7)	(5,6,6)	(5,5,6)	(5,5,6)	(5,5,6)	(2,1,3)	(3,3,4)	(5,5,5)	(5,5,6)	160	28'000
$m = 39$ Radar Chart	(4,4,5)	(4,5,5)	(4,5,5)	(5,4,5)	(4,5,5)	(4,5,5)	(2,2,3)	(4,4,5)	(4,4,5)	(4,5,5)	100	18'000
$m = 40$ Decision Matrix	(5,5,5)	(5,5,6)	(6,5,6)	(5,4,4)	(6,6,6)	(6,6,7)	(1,2,2)	(5,5,6)	(5,5,4)	(5,5,6)	100	18'000
$m = 41$ Decision Tree	(5,4,5)	(5,5,6)	(6,5,6)	(5,4,4)	(6,6,6)	(6,6,7)	(2,2,2)	(5,5,6)	(5,5,4)	(5,5,6)	100	18'000
$m = 42$ Sampling Method	(4,5,3)	(4,5,5)	(4,5,5)	(1,2,1)	(3,4,4)	(3,4,4)	(1,3,2)	(2,2,3)	(3,4,3)	(3,4,4)	100	15'000
$m = 43$ Prioritization Matrix	(2,3,2)	(6,6,7)	(6,6,7)	(2,3,1)	(7,7,7)	(7,7,7)	(2,2,3)	(6,6,7)	(3,2,2)	(6,6,7)	100	18'000
$m = 44$ Scatter Diagram	(3,2,1)	(4,5,5)	(4,5,5)	(4,5,4)	(4,5,4)	(4,5,5)	(2,3,2)	(4,4,5)	(3,4,3)	(4,5,5)	100	16'000
$m = 45$ Stratification Method	(1,1,1)	(4,4,5)	(4,4,5)	(1,1,1)	(3,4,4)	(3,4,4)	(2,2,2)	(3,3,4)	(3,2,3)	(3,4,4)	100	14'000
$m = 46$ Survey Method	(4,4,5)	(7,7,7)	(7,6,7)	(6,6,7)	(6,6,7)	(6,5,6)	(2,2,3)	(7,7,7)	(3,2,2)	(5,6,6)	160	30'000
$m = 47$ Fishbone Diagram	(4,5,5)	(6,6,7)	(6,6,7)	(5,5,6)	(7,7,7)	(7,7,7)	(2,2,3)	(6,6,7)	(6,7,7)	(7,7,7)	100	18'000

Table 2: Assessment of Management Techniques

Appendix C - First round of proposed Fuzzy Delphi

Sub-processes	RFs	$e=1$	$e=2$	$e=3$	$e=4$	$e=5$	$e=6$	$e=7$	$e=8$	$e=9$
$p=1$	$j=1$	B5	B5	B5	B5	B5	B5	B5	B4	B3
	$j=2$	B5	B5	B4	B4	B3	B5	B4	B5	B3
	$j=3$	B5	B5	B4	B5	B4	B4	B4	B5	B3
	$j=4$	B5	B4	B5	B5	B4	B3	B2	B3	B3
	$j=5$	B5	B5	B5	B5	B3	B2	B3	B3	B4
	$j=6$	B5	B5	B5	B5	B5	B3	B4	B5	B3
	$j=7$	B4	B5	B3	B5	B4	B3	B2	B5	B5
	$j=8$	B5	B5	B5	B5	B5	B5	B5	B5	B5
	$j=9$	B5	B3	B2	B4	B4	B2	B2	B4	B3
	$j=10$	B5	B5	B5	B4	B4	B5	B5	B5	B5
$p=2$	$j=1$	B5	B5	B5	B5	B5	B4	B5	B4	B3
	$j=2$	B5	B5	B5	B3	B3	B4	B5	B4	B3
	$j=3$	B5	B5	B4	B4	B4	B4	B4	B5	B3
	$j=4$	B5	B4	B5	B5	B4	B3	B2	B3	B3
	$j=5$	B5	B5	B5	B5	B3	B2	B3	B3	B4
	$j=6$	B5	B5	B5	B5	B5	B3	B3	B5	B3
	$j=7$	B4	B5	B3	B5	B4	B3	B2	B5	B5
	$j=8$	B5	B5	B5	B5	B5	B5	B5	B5	B5
	$j=9$	B5	B3	B3	B4	B4	B2	B2	B4	B3
	$j=10$	B5	B5	B5	B5	B4	B5	B5	B5	B5
$p=3$	$j=1$	B5	B5	B4	B4	B5	B5	B4	B5	B5
	$j=2$	B5	B4	B2	B4	B3	B4	B3	B3	B3
	$j=3$	B5	B5	B4	B4	B4	B5	B4	B5	B3
	$j=4$	B5	B3	B4	B4	B4	B4	B2	B3	B4
	$j=5$	B5	B5	B4	B4	B4	B2	B2	B2	B3
	$j=6$	B5	B5	B4	B4	B5	B3	B4	B5	B4
	$j=7$	B4	B5	B2	B4	B4	B3	B2	B4	B3
	$j=8$	B5	B5	B5	B5	B5	B5	B5	B5	B5
	$j=9$	B5	B3	B3	B3	B4	B4	B2	B4	B3
	$j=10$	B5	B5	B5	B4	B4	B4	B5	B5	B5
$p=4$	$j=1$	B5	B4	B4	B3	B5	B5	B3	B3	B5
	$j=2$	B5	B3	B2	B4	B2	B4	B3	B3	B3
	$j=3$	B3	B4	B4	B3	B4	B3	B4	B4	B3
	$j=4$	B4	B3	B2	B3	B4	B4	B2	B4	B4
	$j=5$	B4	B4	B3	B4	B4	B3	B2	B2	B2
	$j=6$	B5	B5	B3	B4	B5	B3	B3	B3	B3
	$j=7$	B3	B3	B2	B4	B4	B2	B2	B4	B4
	$j=8$	B5	B5	B5	B5	B5	B5	B5	B5	B5

Sub-processes	RFs	$e = 1$	$e = 2$	$e = 3$	$e = 4$	$e = 5$	$e = 6$	$e = 7$	$e = 8$	$e = 9$
	$j = 9$	B5	B3	B2	B3	B4	B3	B2	B4	B2
	$j = 10$	B4	B3	B5	B3	B3	B4	B5	B4	B4

Table 3: Assessment of DMs - First round

RFs	The aggregated value in the first round	The linguistic expression
$j = 1$	(5.53,7,8.50)	B4
$j = 2$	(4.70,6.19,7.75)	B4
$j = 3$	(4.48,6.07,7.72)	B3
$j = 4$	(3.97,5.33,6.83)	B3
$j = 5$	(4.33,5.65,7.06)	B3
$j = 6$	(5.30,6.72,8.20)	B4
$j = 7$	(4.27,5.67,7.17)	B3
$j = 8$	(7,8.50,10)	B5
$j = 9$	(2.69,4.06,5.65)	B3
$j = 10$	(5.61,7.15,8.72)	B4

Table 4: Aggregated RF values (First round) - SP: Align supply chain resources (p = 1)

RFs	The aggregated value in the first round	The linguistic expression
$j = 1$	(5.53,7,8.50)	B4
$j = 2$	(4.45,5.87,7.37)	B3
$j = 3$	(4.14,5.77,7.48)	B3
$j = 4$	(3.97,5.33,6.81)	B3
$j = 5$	(4.33,5.65,7.06)	B3
$j = 6$	(5.08,6.43,7.84)	B4
$j = 7$	(4.27,5.67,7.17)	B3
$j = 8$	(7,8.5,10)	B5
$j = 9$	(2.71,4.14,5.72)	B3
$j = 10$	(5.99,7.51,9.04)	B4

Table 5: Aggregated RF values (First round) - SP: Procurement materials and services (p = 2)

RFs	The aggregated value in the first round	The linguistic expression
$j = 1$	(5.47,7.03,8.63)	B4
$j = 2$	(2.73,4.20,5.78)	B3
$j = 3$	(4.64,6.21,7.85)	B3
$j = 4$	(3.04,4.67,6.39)	B3
$j = 5$	(3.33,4.72,6.25)	B3
$j = 6$	(4.64,6.21,7.85)	B4
$j = 7$	(2.87,4.39,6.03)	B3
$j = 8$	(6.90,8.39,9.89)	B5
$j = 9$	(2.73,4.20,5.78)	B3
$j = 10$	(5.33,6.90,8.51)	B4

Table 6: Aggregated RF values (First round) - SP: Test product (p = 3)

RFs	The aggregated value in the first round	The linguistic expression
$j = 1$	(4.28,5.71,7.23)	B3
$j = 2$	(2.54,3.88,5.39)	B3
$j = 3$	(2.33,4.08,5.86)	B3
$j = 4$	(2.29,3.97,5.73)	B3
$j = 5$	(2.05,3.64,5.32)	B3
$j = 6$	(3.68,5,6.43)	B3
$j = 7$	(2.69,4.09,5.65)	B3
$j = 8$	(6.90,8.39,9.89)	B5
$j = 9$	(2.52,3.83,5.31)	B3
$j = 10$	(3.51,5.07,6.72)	B3

Table 7: Aggregated RF values (First round) - SP: Manage logistics and warehousing (p = 4)

Appendix D - Second round of proposed Fuzzy Delphi

Sub-processes	RFs	$e=1$	$e=2$	$e=3$	$e=4$	$e=5$	$e=6$	$e=7$	$e=8$	$e=9$
$p=1$	$j=1$	B4	B3	B3	B2	B3	B3	B3	B2	B2
	$j=2$	B4	B4	B3	B3	B2	B3	B3	B4	B2
	$j=3$	B4	B2	B2	B3	B3	B2	B3	B3	B2
	$j=4$	B4	B3	B3	B3	B2	B2	B1	B2	B2
	$j=5$	B4	B5	B3	B3	B2	B1	B2	B2	B2
	$j=6$	B5	B4	B2	B4	B3	B2	B2	B4	B2
	$j=7$	B3	B3	B1	B3	B2	B2	B1	B3	B3
	$j=8$	B5	B5	B4	B4	B5	B5	B5	B5	B3
	$j=9$	B3	B2	B1	B2	B2	B1	B1	B1	B1
	$j=10$	B4	B3	B3	B2	B2	B3	B3	B4	B4
$p=2$	$j=1$	B5	B4	B4	B4	B3	B4	B4	B4	B3
	$j=2$	B4	B3	B3	B2	B3	B3	B3	B3	B3
	$j=3$	B3	B3	B3	B2	B2	B3	B3	B3	B2
	$j=4$	B4	B3	B3	B3	B2	B2	B1	B2	B2
	$j=5$	B4	B4	B4	B3	B2	B1	B2	B2	B2
	$j=6$	B4	B4	B2	B3	B3	B2	B2	B3	B2
	$j=7$	B3	B3	B1	B3	B2	B2	B1	B3	B3
	$j=8$	B5	B5	B4	B4	B5	B5	B5	B5	B3
	$j=9$	B3	B1	B1	B2	B2	B1	B1	B1	B2
	$j=10$	B4	B3	B3	B2	B2	B3	B3	B3	B3
$p=3$	$j=1$	B3	B2	B2	B2	B2	B3	B2	B3	B3
	$j=2$	B3	B2	B1	B2	B1	B3	B2	B2	B3
	$j=3$	B3	B3	B2	B2	B2	B2	B3	B4	B2
	$j=4$	B3	B2	B3	B3	B2	B2	B1	B2	B2
	$j=5$	B3	B4	B3	B2	B2	B1	B1	B1	B2
	$j=6$	B4	B3	B3	B3	B4	B2	B2	B3	B3
	$j=7$	B2	B3	B1	B3	B3	B2	B1	B3	B2
	$j=8$	B5	B4	B5	B4	B5	B5	B5	B5	B4
	$j=9$	B3	B1	B1	B1	B2	B2	B1	B2	B2
	$j=10$	B3	B3	B3	B2	B2	B2	B4	B3	B2
$p=4$	$j=1$	B3	B1	B2	B1	B2	B2	B1	B1	B2
	$j=2$	B3	B1	B1	B2	B1	B2	B1	B1	B1
	$j=3$	B2	B2	B2	B1	B2	B2	B2	B2	B1
	$j=4$	B3	B2	B1	B2	B2	B2	B1	B2	B2
	$j=5$	B3	B2	B1	B3	B2	B2	B1	B1	B1
	$j=6$	B3	B4	B2	B2	B3	B2	B2	B2	B2
	$j=7$	B2	B2	B1	B2	B2	B1	B1	B2	B2
	$j=8$	B5	B5	B4	B4	B5	B5	B5	B5	B5

Sub-processes	RFs	$e = 1$	$e = 2$	$e = 3$	$e = 4$	$e = 5$	$e = 6$	$e = 7$	$e = 8$	$e = 9$
	$j = 9$	B3	B2	B1	B1	B2	B2	B1	B1	B1
	$j = 10$	B2	B1	B2	B1	B1	B2	B3	B3	B3

Table 8: Assessment of DMs - Second round

RFs	The aggregated value in the second round	The measure of consensus achieved
$j = 1$	(3.06,4.71,6.45)	0.80
$j = 2$	(4.03,5.59,7.29)	0.94
$j = 3$	(2.91,4.49,6.16)	0.50
$j = 4$	(2.73,4.20,5.78)	0.90
$j = 5$	(3.45,4.78,6.25)	0.88
$j = 6$	(4.35,5.69,7.12)	0.76
$j = 7$	(2.29,3.97,5.73)	0.91
$j = 8$	(6.45,7.97,9.49)	1.00
$j = 9$	(1.15,2.47,3.97)	0.79
$j = 10$	(4.03,5.59,7.23)	0.85

Table 9: Aggregated RF values (Second round) - SP: Align supply chain resources (p = 1)

RFs	The aggregated value in the second round	The measure of consensus achieved
$j = 1$	(5.61,7.15,8.72)	0.59
$j = 2$	(3.33,5.14,6.99)	0.61
$j = 3$	(2.69,4.56,6.45)	0.62
$j = 4$	(2.73,4.20,5.78)	0.90
$j = 5$	(3.67,4.96,6.37)	0.92
$j = 6$	(3.38,4.86,6.44)	0.74
$j = 7$	(2.29,3.97,5.73)	0.91
$j = 8$	(6.45,7.97,9.49)	1.00
$j = 9$	(1.15,2.47,3.97)	0.79
$j = 10$	(3.20,4.93,6.72)	0.71

Table 10: Aggregated RF values (Second round) - SP: Procurement materials and services (p = 2)

RFs	The Aggregated Value in the Second Round	The Measure of Achieved Consensus
$j = 1$	(2.13,3.82,5.54)	0.71
$j = 2$	(1.18,3.41,5.04)	0.55
$j = 3$	(2.75,4.25,5.84)	0.56
$j = 4$	(1.18,3.47,5.12)	0.70
$j = 5$	(2.52,3.83,5.31)	0.86
$j = 6$	(3.64,5.27,6.98)	0.78
$j = 7$	(2.08,3.70,5.40)	0.84
$j = 8$	(6.68,8.18,9.68)	0.50
$j = 9$	(1.20,2.56,4.07)	0.88
$j = 10$	(2.91,4.49,6.16)	0.69

Table 11: Aggregated RF values (Second round) - SP: Test product (p = 3)

RFs	The aggregated value in the second round	The measure of consensus achieved
$j = 1$	(1.20,2.56,4.07)	0.68
$j = 2$	(0.94,2.41,3.90)	0.94
$j = 3$	(1.60,3.09,4.67)	0.60
$j = 4$	(1.29,2.73,4.26)	0.58
$j = 5$	(1.53,2.94,4.50)	0.77
$j = 6$	(2.58,4,5.53)	0.87
$j = 7$	(0.82,2.22,3.70)	0.72
$j = 8$	(6.79,8.29,9.79)	0.66
$j = 9$	(0.67,2.01,3.48)	0.50
$j = 10$	(2.05,3.64,5.32)	0.59

Table 12: Aggregated RF values (Second round) - SP: Manage logistics and warehousing (p = 4)

Appendix E - Weighted Aggregated Fuzzy Value of KPI-level RFs

RFs	$i = 1$	$i = 2$	$i = 3$
$j = 1$	(4.59,16.49,35.48)	(22.95,47.10,64.50)	(15.30,30.62,51.60)
$j = 2$	(20.15,36.34,58.32)	(2.02,11.18,25.52)	(30.23,44.72,69.26)
$j = 3$	(14.55,29.19,49.28)	(21.83,35.92,58.52)	(14.55,29.19,49.28)
$j = 4$	(20.48,33.60,54.91)	(20.48,33.60,54.91)	(20.48,33.60,54.91)
$j = 5$	(17.25,31.07,50)	(25.88,38.24,59.38)	(17.25,31.07,50)
$j = 6$	(13.05,28.45,49.84)	(2.18,11.38,24.92)	(13.05,28.45,49.84)
$j = 7$	(1.15,7.94,20.06)	(6.87,19.85,40.11)	(6.87,19.85,40.11)
$j = 8$	(9.68,27.90,52.20)	(48.38,79.70,94.90)	(19.35,39.85,66.43)
$j = 9$	(5.75,16.06,31.76)	(0.58,4.94,13.90)	(0.58,4.94,13.90)
$j = 10$	(30.23,55.90,72.30)	(2.02,11.18,25.31)	(6.05,19.57,39.77)
Weighted aggregated fuzzy value of RFs	(12.90,30.94,49.45)	(22.05,36.40,51.81)	(16.45,30.14,50.68)

Table 13: Weighted fuzzy value for KPI-level RFs - SP: Align supply chain resources (p = 1)

RFs	$i = 4$	$i = 5$	$i = 6$
$j = 1$	(42.08,57.20,82.84)	(28.05,46.48,69.76)	(42.08,71.50,87.20)
$j = 2$	(24.98,51.40,69.90)	(16.65,33.41,55.92)	(5,17.99,38.45)
$j = 3$	(13.45,29.64,51.60)	(1.35,9.12,22.58)	(1.35,9.12,22.58)
$j = 4$	(13.65,27.30,46.24)	(20.48,42,57.80)	(20.48,33.60,54.91)
$j = 5$	(18.35,32.24,50.46)	(18.35,32.24,50.46)	(5.51,17.36,35.04)
$j = 6$	(25.35,38.88,61.18)	(25.35,38.88,61.18)	(5.07,17.01,35.42)
$j = 7$	(6.87,19.85,40.11)	(3.44,13.90,31.52)	(3.44,13.90,31.52)
$j = 8$	(19.35,39.85,66.43)	(9.68,27.90,52.20)	(19.35,39.85,66.43)
$j = 9$	(1.73,8.65,21.84)	(0.58,4.94,13.90)	(0,0,9.93)
$j = 10$	(4.80,17.26,36.98)	(4.80,17.26,36.98)	(16,32.05,53.76)
Weighted aggregated fuzzy value of RFs	(20.47,35.28,55.46)	(16.10,29.95,48.44)	(17.07,31.70,48.46)

Table 14: Weighted fuzzy value for KPI-level RFs - SP: Procurement materials and services (p = 2)

RFs	$i = 7$	$i = 8$	$i = 9$
$j = 1$	(3.20,13.37,30.47)	(15.98,38.20,55.40)	(6.39,19.10,38.70)
$j = 2$	(1.77,11.94,27.72)	(8.85,27.28,47.88)	(3.54,17.05,35.28)
$j = 3$	(20.63,34,55.48)	(13.75,27.63,46.72)	(8.25,21.25,40.88)
$j = 4$	(8.85,27.76,48.64)	(8.85,27.76,48.64)	(5.90,22.56,40.96)
$j = 5$	(12.60,24.90,42.48)	(7.56,19.15,37.17)	(18.90,30.64,50.45)
$j = 6$	(10.92,26.35,48.86)	(18.20,34.26,55.84)	(1.82,10.54,24.43)
$j = 7$	(6.24,18.50,37.80)	(3.12,12.95,29.70)	(3.12,12.95,29.70)
$j = 8$	(20.04,40.90,67.76)	(10.02,28.63,53.24)	(10.02,28.63,53.24)
$j = 9$	(9,20.48,38.67)	(6,16.64,32.56)	(6,16.64,32.56)
$j = 10$	(14.55,29.19,49.28)	(8.73,22.45,43.12)	(14.55,29.19,49.28)
Weighted aggregated fuzzy value of RFs	(10.53,26.17,46.13)	(11.01,26.54,45.88)	(9.35,21.87,40.54)

Table 15: Weighted fuzzy value for KPI-level RFs - SP: Test product (p = 3)

RFs	$i = 10$	$i = 11$	$i = 12$
$j = 1$	(6,16.64,32.58)	(9,25.60,40.70)	(9,25.60,40.70)
$j = 2$	(7.05,19.28,37.05)	(7.05,19.28,37.05)	(7.05,24.10,39)
$j = 3$	(4.80,15.45,32.69)	(12,24.72,44.37)	(8,20.09,37.36)
$j = 4$	(3.87,13.65,29.82)	(6.45,17.75,34.08)	(9.68,21.84,40.47)
$j = 5$	(11.48,23.52,42.75)	(11.48,23.52,42.75)	(11.48,23.52,42.75)
$j = 6$	(7.74,22,38.71)	(7.74,22,38.71)	(12.90,28.60,44.24)
$j = 7$	(1.23,7.77,20.35)	(2.46,11.10,25.90)	(2.46,11.10,25.90)
$j = 8$	(20.37,41.45,68.53)	(33.95,53.98,78.32)	(20.37,41.45,68.53)
$j = 9$	(3.35,13.07,27.84)	(2.01,10.05,24.36)	(1.01,7.04,19.14)
$j = 10$	(6.15,18.35,37.24)	(6.15,18.35,37.24)	(10.25,23.86,42.56)
Weighted aggregated fuzzy value of RFs	(8.84,20.97,38.72)	(13.11,25.41,42.74)	(10.57,24.39,41.88)

Table 16: Weighted fuzzy value for KPI-level RFs - SP: Manage logistics and warehousing (p = 4)

Appendix F - Evaluating the Resilience of an International Health Industry Company to Disruptive Supply Chain Threats (Note: Proposal for the application of the concept proposed and developed in the Thesis)

[1] Project Objective

The proposed project aims to assess the resilience of an international health industry company in the face of disruptive supply chain threats. We will analyze three main industry sites of the company, situated in different international locations but adhering to the same Corporate Social Responsibility (CSR) / Environment, Social, Governance (ESG) policies. Data will be collected from the main company, aggregated from site data (Jovanović 2024).

[2] Threats and Extreme Threats (XTs)

To achieve this, we will define threats using main indicators such as:

- *Unexpected general shortages of critical raw materials or semi-finished products on the market (e.g., the Suez Canal blockage);*
- *Failure/default of the company's main supplier (N-1 principle[4]);*
- *Unexpected and significant increases in prices (e.g., due to war);*
- *Unexpected and significant issues in the delivery process (e.g., strikes).*

Based on these, scenarios will be defined in terms of narrative, timeline, actors, drivers, factors, and amplifiers, with indicators quantified/measured. A simplified Delphi approach will be utilized (Jovanović 2024). (Note: Various profiles within the company including production, quality, finance, IT, ESG, and others may be consulted for all Delphi processes. Exploration of different aggregation models will also be conducted.)

[3] Resilience Indicators and Resilience Level (RL) Analysis

Data from CSR and other reports will define resilience indicators (FIs - functionality indicators), primarily economic indicators (e.g., those used in the Financial Annual Report, also those

[4] The (n-1) security refers to the principle that the failure of a system is prevented by redundancies in the event of a component failure.

of the World Bank) and ESG and UN Sustainable Development Goals (SDG) indicators (e.g., GRI indicators used in the CSR report), including their trend/variations over the years. Resilience level curves for the three plants will be created based on the above analysis (Jovanović 2024).

[4] Resilience Functionality Level (FL) Analysis (the 3x3 scenario-site matrix)

For each threat scenario (assume three), possible changes in resilience indicators over scenario time (the FL curves) for the three sites will be assessed (analogous Beuth & Jovanović 2021, page 15 f.). We will explore which sites are more vulnerable to specific scenarios. A simplified Delphi approach will be used for this analysis (Beuth & Jovanović 2021; Jovanović 2024).

[5] Stress-testing and XTs

Based on the FL analysis, one extreme threat scenario will be defined (e.g., by increasing the intensity of the most critical combination of site-scenario). An acceptability stress-test threshold curve will be established based on discussions with the company (analogous Beuth & Jovanović 2021, page 19). The results will answer the questions: *"Will the site survive the assumed XT and how (e.g., what is the expected recovery time/level)?"* (Beuth & Jovanović 2021; Jovanović 2024).

[6] Business Intelligence (BI) supported decision making ("What-If" Analysis)

Given the numerous uncertainties (e.g., those related to resilience and threat indicators) and qualitative assumptions (e.g., those involved in scenarios), decision-making will require *"What-If"* support. We suggest using a BI-based interface atop the above data, allowing consideration of a number of *"What-If"* scenarios (Jovanović 2024).

[7] Conclusions

The conclusions will include assessment of the analysis results, their applicability limits, uncertainties, and recommended improvement measures (e.g., training, improved asset management, risk mitigation) (Jovanović 2024).

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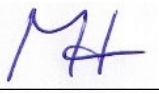

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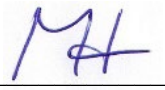

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