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Business Process Innovation in Manufacturing Companies – A Method for Creating more Agility in Complex Projects

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Editor’s Preface

Production engineering is crucial for the advancement of our industrial society because the performance of manufacturing companies depends heavily on the equipment and resources employed, the production processes applied, and the established manufacturing organization. A company’s full potential for corporate success can only be reached by optimizing the interaction between humans, operational structures, and technologies. Being able to remain competitive while balancing the varying and often conflicting priorities of complexity, cost, time, and quality requires constant thought, adaptation, and the development of new manufacturing structures. Thus, there is an essential need to reduce the complexity of products, manufacturing processes, and systems. Yet at the same time it is also vital to gain a better understanding and command of these aspects.

The objective of the research activities at the Institute for Machine Tools and Industrial Management (*iwb*) is to continuously improve manufacturing planning systems, manufacturing processes and production facilities. A company’s organizational, manufacturing, and work structures, as well as the underlying systems for order processing, are developed under strict consideration of employee-related requirements. Although an increasing degree of automation is unavoidable, labor will remain an important component in production processes. Thus, questions concerning the optimization of human involvement in the Idea-to-Offer process are of utmost importance.

The volumes published in this book series collate and report the results from the research conducted at *iwb*. Research areas covered stretch from the design and development of manufacturing systems to the application of technologies in manufacturing and assembly. The management and operation of manufacturing systems, quality assurance, availability, and autonomy are overarching topics, which affect all areas of our research. In this series, the latest results and insights from our application-oriented research are published. These will foster an improvement in the transfer of knowledge between universities and the wider industrial sector.

Gunther Reinhart *Michael Zäh*

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Ich danke allen Personen, die mich während dieses Projektes unterstützt haben.

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Abstract

Technical products, as well as the related production systems and value creation processes are facing an ongoing digitization wave referred to as *Industrie 4.0*. In combination with a growing trend towards sustainable manufacturing with novel technologies, transparent supply chains, zero emissions, or circular economies, not only product innovation, but also Business Process Innovation (BPI) is in focus.

The complexity of many BPI projects and the related dynamics bring manufacturing companies to their limits, especially when they keep relying on conventional plan-driven project management approaches only. Among software developers, Agile Project Management (APM) has gained remarkable popularity to cope with "hard-to-plan" situations, in both, science and industrial practice. In manufacturing companies, adopting these concepts has been emphasized in the recent years. First Hybrid Project Management (HPM) concepts dedicated to developing technical or physical products emerged. However, current approaches for HPM do not include existing complexity models, nor take a project manager's actual room for maneuver or already proven concepts from the Japanese Management Philosophy into account.

The research at hand is intended to address these identified shortcomings with an integrated method for the management of complex BPI projects by customizing and recombining the existing procedures in manufacturing companies. Guided by the Design Research Methodology (DRM), the procedure is based on an extensive literature review, two in-depth case studies, a web-based survey as well as numerous interviews and workshops with practitioners. Main results include an *Initial Assessment* of a BPI project to understand its complexity and essential prerequisites for a HPM approach (module 1), a *Hybrid Reference Framework* with guidance on a strategic, tactic, and operative layer (module 2), and a *Monitoring and Adaption* support for step-wise increasing agility in a project where it is helpful (module 3). The integrated method is applied and evaluated with two different manufacturing companies. Overall, this thesis contributes to industrial practice and to industrial management science.

Contents

Glossary

Business process
A business process refers to a structured set of operations for creating and delivering a product to the expectation of quality, time, and cost of a customer market in order to achieve an intended business result (based on a definition by DAVENPORT 1993).

Innovation
The search for, discovery, experimentation, development, imitation and adaption of new products, production processes, and new organizational structures (DOSI 1990).

Manufacturing company
Manufacturing companies are legal constructs whose primary objective is to generate profits with the development of new or adapted products based on customer requirements and by materializing them using knowledge, effort, and technologies (WILLE 2016).

1 Introduction

In the era of *Industrie 4.0*, where products are created in production networks and customers expect transparent information and latest technologies (REINHART 2017), the long-term competitiveness of European manufacturing companies is shaped by their active determination on technical innovations (ABELE & REINHART 2011).
Along with their inherent focus on product and production technologies, especially manufacturing companies expand their attention to the innovation of business processes (BALTES & FREYTH 2017) which specify the essential operations in their value chains (PORTER 1985). The radical redesign of such business processes – e.g. as part of a corporate digital or sustainability transformation to improve a manufacturing company's market position and overall long term value – is referred to as *Business Process Re-engineering* (BPR), *Business Process Re-Design* (BPRD), or later, *Business Process Innovation* (BPI) (DAVENPORT 1993).

1.1 Business Process Innovation in Manufacturing Companies

Typical BPI projects in manufacturing companies involve the introduction of a new or extensive update of the present Enterprise Resource Planning (ERP) system[1] as well as related auxiliary IT-tools and organizational structures. These projects exceed the efforts and complexity of regular continuous improvement programs (BRANDL et al. 2020).
Already in the early 1990's, when a new generation of ERP software came to the market[2] and the ideas of *Lean Production* were discovered in the West (cf. WOMACK

[1] An ERP system is a software product that maps all of a company's business processes for the most efficient scheduling of available resources for operational processes (HESSELER & GÖRTZ 2014).
[2] For example, SAP R/3 was first released in 1992 (`www.sap.com`).

et al. 2007), approaches to radically align corporate procedures and structures with customer wishes were proposed (cf. e.g. DAVENPORT 1993; GAITANIDES 1983; HAMMER & CHAMPY 2006; TENG et al. 1994). At that time, when the term BPR was predominant, many of such projects failed (ELZINGA et al. 1999). As a result, several first proponents of the idea itself later criticized its attitude for being too top-down, instructional, mechanistic, and not adequately considering the complexity of changing an organization. Eventually, BPR was associated negatively and mainly with cost-cutting programs (KHAN et al. 2018; QASIM 2013).
Despite the discredit, the primary motivation of the 1990's BPR programs was a higher customer orientation (HAMMER & CHAMPY 2006) and the conviction that incremental improvements alone do not achieve sufficient innovation leap to survive a turbulent market change (DAVENPORT 1993). MARCH (1991), NONAKA & TAKEUCHI (1995), or BULLINGER (2006) shared this standpoint and created awareness for a more bottom-up, explorative, and organic understanding of innovation in manufacturing companies.

During the recent years, ERP systems are still a major driver for complex BPI projects, however, as two German national newspapers suggest, many companies struggle with them: *Süddeutsche Zeitung* - "*Digitale Pleite*" (REXER 2016) or *Wirtschaftswoche* - "*SAP: Gefloppte Projekte bei Haribo, Lidl, Otto & Co*" (KROKER 2018). In both articles, the authors identified complexity- and change management-related problems, although these pattern of failure were already reported in earlier publications (see e.g. CHEN et al. 2009 or BARKER & FROLICK 2003). A focus on conventional project management approaches based on COOPER's *Stage-Gate* model (see COOPER 1990) might also contribute to these unsuccessful BPI projects. In such complex and volatile environments, the classical *Stage-Gate* approach is increasingly criticized for its linearity and inflexibility impeding continuous adaptations (COOPER 2014).

At the same time, a staggering amount of books and publications provide various guidelines on strategies, techniques, models, frameworks, tools, principles, or experiences how organizations like manufacturing companies should manage organizational change or transformation – summarized nicely e.g. by ROSENBAUM et al. (2018). Despite the availability of these, many authors point out that mastering the complexity involved in BPI projects requires companies to develop additional "dynamic capabilities" (TEECE 2007) or "adaption intelligence" (BALTES & FREYTH 2017). They need to learn and apply "instability leadership" which implies concepts for managing progress that differ from the "stability management" practiced daily in companies, as underlined by

KRUSE (2015). This differentiation has also been described by (SNOWDEN & BOONE 2007) who found out that the best mode of solving complex problems or situations is “emergent practice”, whereas the daily routine tasks can be handled with pre-defined “best or good practice”.

One opportunity that has been proposed by many authors to develop these new capabilities or practices in companies striving against complex planning projects is incorporating Agile Project Management (APM) in the common practice project management to gain hybrid structures that combine “agility” with “stability” (see e.g. CONFORTO & AMARAL 2016; COOPER & SOMMER 2018; SOMMER et al. 2015). An online survey conducted during this thesis project (see section 4.2) among top-management experts responsible for innovation projects in manufacturing companies revealed an increase of complexity in innovation projects and relevance of agile and hybrid project management methods in the manufacturing industry in general over the previous years (cf. BRANDL et al. 2019).

Problem statement

At the beginning of this thesis project, the author was involved in two BPI projects (presented and discussed in detail in section 4.3). Although the scopes and settings of these projects were different, certain similarities or common pattern could be observed. The project managers and their teams faced problems in coping with the effects of what was later identified as high complexity. In both projects, the effort for fire-fighting suddenly emerging technical problems was high, as well as the realization that such situations require a different approach from what these teams are commonly practicing. Based on these impressions in the field, the following problem statement was formulated:

Manufacturing companies – and their managers in particular – lack in methodical guidance for the management of complex Business Process Innovation (BPI) projects.

1.2 Objectives of this Thesis

Based on the problem statement, the superordinate objective of this thesis is *to support practitioners in managing complex BPI projects more effectively*. This shall be achieved by contributing to a better understanding of the current practice (O1), providing practical guidance and a procedural reference for understanding and addressing project complexity (O2) and managing it effectively (O3), as well as an integrated method to incorporate these elements in the project management environment of a manufacturing company (O4).

O1 Contribute to a better understanding of complex BPI projects in the industry.
The available information on complex BPI projects in the literature is limited, since the documentation and analysis of actual cases is a challenge since such projects tend to extend over several months and involve many organizational units, while occurring quite rarely in one company.

O2 Provide practical guidance for practitioners to address the complexity of BPI projects.
Helping managers to understand and address the specific characteristics that affect the complexity of individual BPI projects.

O3 Provide a procedural reference for managing complex BPI projects.
Offering managers a novel approach to organize and structure complex BPI projects with compliance to the latest scientific insights of modern project management more effectively.

O4 Provide a method to integrate the novel approach into manufacturing companies.
Offering managers an integrated method to incorporate these elements in the project management environment of a manufacturing company.

1.3 Scientific Approach

1.3.1 Research questions

In accordance with the problem statement and the objectives of this thesis, the superordinate research question asks: *how can a method support practitioners in managing complex BPI projects in manufacturing companies more effectively?* In reference to the four objectives of this thesis, the following research questions provide a general orientation and structure.

Q1 How are BPI projects in manufacturing companies managed to date and what challenges do exist in the industry?
The practical insight on actual BPI projects in manufacturing companies provides promising findings to be documented and challenges to be addressed.

Q2 How can the complexity of BPI projects be addressed?
Managing a BPI project effectively implies the awareness of complexity by all people involved.

Q3 Which procedural framework can support a more effective management of complex BPI projects in manufacturing companies?
A novel approach that addresses the involved complexity and change-related issues requires a reference framework and a procedural guidance for project managers and their project teams.

Q4 How can such an approach be incorporated and maintained in a manufacturing company?
The introduction of novel approaches is an organizational change itself and should be guided by an implementation method.

1.3.2 Research on *Industrial Management*

The research on *Industrial Management* is a branch of *Engineering Sciences* concerned with planning and operating socio-technical systems in manufacturing companies. Early documented research on *Industrial Management* (in German *Betriebswissenschaft*) dates back to Frederick Taylor's *The Principles of Scientific Management* (see TAYLOR 1913) and Henri Fayol's *Administration Industrielle et Générale* (see FAYOL 1917). Several decades of research later, Hopp & Spearman created a comprehensive base to this field with their contribution *Factory Physics* (see W. J. HOPP & SPEARMAN 2011), by overlapping the physics of manufacturing with operations management (J. KOCH 2017).
On this basis, recent research on *Industrial Management* focuses on the technical, organizational, and human-related aspects of the *Industrie 4.0*, including technologies and processes for manufacturing, the design, operation, and optimization of value creation systems, or the organization of human labor (REINHART 2017).

The international research on *Industrial Management* is attached to the *College International pour la Recherche en Productique* (CIRP)[3], created in 1951 to gather academic experts around the field of manufacturing. The *Wissenschaftliche Gesellschaft für Produktionstechnik (The German Academic Association for Production Technology)* (WGP) represents the scientific research and education of academic production engineering institutes in Germany.
In contrast to the *Natural Sciences* that create explanatory knowledge, *Engineering Sciences* produce applied knowledge in the form of technologies, models, methods, or tools to address technical problems (ZAHN 1995). Researching on models and procedures for managing complex projects in manufacturing companies involves solving technical problems and requires an interdisciplinary contribution from natural, formal, engineering, and social sciences (GERPOTT 2013).

1.3.3 Research methodology

In the scientific domain of engineering, the *Design Research Methodology* (DRM) proposed by BLESSING & CHAKRABARTI (2009) is a widely acknowledged and comprehensive methodology for structuring a research project with four iterative steps (cf. J. KOCH 2017).

General structure of this thesis project: DRM
Figure 1.1 summarizes the scientific approach of this thesis project by mapping the four stages of the DRM, applied methods, and inputs to the scientific and practical results in each chapter of this document, which are elaborated in detail during the following chapter.

Step 1: Research Clarification - Objectives
In the DRM, the motivation and objectives for a research are based on a literature study. The rationale of this thesis is derived from analyzing scientific publications in the relevant fields. In addition, an experienced-based selection and consultation of topic-specific experts for an online survey and personal participation within complex

[3] Engl.: The International Academy for Production Engineering

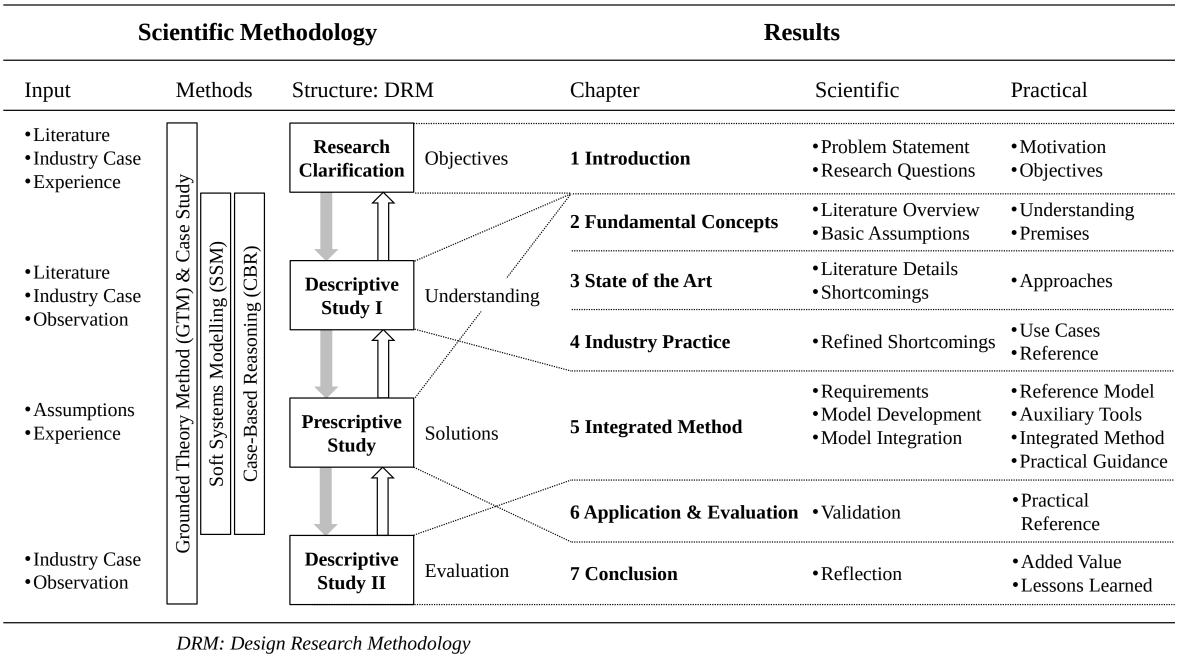

Figure 1.1: Structure of this thesis outlining the used input, scientific methodology, and expected results.

BPI projects in the industry contributed to formulating a problem statement, research questions, and objectives. The initial wide-ranging literature study was performed in several iterations with an expanding scope. The conducted survey's target population were managers of companies with a technical focus and designated as experts in the relevant field due to their given experience in innovation projects or agile techniques in manufacturing companies. The assumptions from this research clarification are consolidated in chapter 1 (*Introduction*).

Step 2: Descriptive Study I - Understanding

The knowledge gathered during the research clarification was refined based on a more in-depth literature review to develop an understanding of the fundamental concepts and formulate relevant premises for this work (see chapter 2 *Fundamental Concepts*). The literature study was performed on the scientific search engine Scopus using a set of specific keywords (cf. WEBSTER & WATSON 2002) and defined the perimeter for analyzing a reasoned selection of state of the art approaches. Therefore, the gathered hits were constantly reflected with insights from an online survey (based on techniques proposed by PORST 2011), an industrial case study with two companies (e.g., porposed by YIN 1984), and eight expert[4] interviews organized as semi-structured guided questioning and answering sessions conducted during the course of this research project, like proposed in the social sciences (see FLICK 2014). The details of these industry insights in managing complex BPI projects are captured in chapter 4 (*Best Practice & Actual Needs in the Industry*), refining the shortcomings identified from the literature (see chapter 3 *State of the Art Approaches in BPI*).

Step 3: Prescriptive Study - Solutions
The detailed exposition and explained linking of the multifaceted and prior ambiguously related group of themes *change*, *innovation*, *ambidexterity*, *complexity*, and *agility* in manufacturing companies (outlined in chapter 2 *Fundamental Concepts*) provides a deeper understanding of this matter and thus constitutes a scientific contribution per se. The state of research during this project did not provide an overview in a comparable way.
Conducting the case study and interviewing experts ether involved in these projects or working on similar approaches (chapter 4) also contributed to this solutions step significantly. The two accompanied firms can be regarded as best practice leaders in that area. Both companies allowed to follow actual complex BPI projects over a longer period of several months and accepted to adopt new concepts on the way based on scientific results. In contrast, the awareness and readiness of manufacturing companies in general to cope with complexity in projects was found to be limited during the period of this case study. Thus, the insights and experiences gained during the case study already make a valuable contribution to the scientific knowledge.
The proven concepts outlined in the literature (see chapter 3 *State of the Art Approaches in BPI*), industry best practices and actual needs were assembled to an integrated method for coping with complexity in BPI projects. The method design was guided by analogical induction[5]. According to this approach, proven solutions from various scientific fields or domains were analyzed, adapted, and then recombined to provide new solutions for the identified shortcomings and needs in the industry. As a result, the developed integrated method is a synthesis of documented best-practices, assumptions, and personal experiences from industrial projects.

[4] The eight experts selected for this more in-depth interviews are introduced with their respective background in chapter 4 and listed in table A.4 in the Appendix.
[5] see *Case-Based Reasoning* (CBR) in following section "Supplementary methodologies to the DRM"

Step 4: Descriptive Study II - Evaluation
During the second descriptive study, the developed method was evaluated by applying its modules in the two companies followed during the case study and by evaluating the observable improvements. This approach is inspired by the action research captured in the Soft Systems Methodology (SSM) (cf. CHECKLAND & SCHOLES 1990). An in-depth classification of the two cases and their contexts allows a generalization of the observations by inductive reasoning and thus a plausible justification of the general validity of the developed method in comparable environments. This procedure resembles an observational study with two test candidates (in this case, *Company I* & *Company II*). It is particularly noteworthy that the field study was conducted over an aggregated period of 24 months. Information was gathered through observation (personally by the author and with the help of student assistants[6] permanently on site) as well as through numerous workshops and discussions with various project participants.

Supplementary methodologies to the DRM
While the DRM provided the general structure for the thesis project, the research was also inspired by adaptions of the DRM and by other scientific methodologies. The *Soft Systems Methodology* (SSM) is corresponding to the DRM, but emphasizes an on-site evaluation of the developed models creating a rather focused scope and close to industry solutions (CHECKLAND & SCHOLES 1990). In accordance with the SSM's focus on action research, this research project emphasizes on local solutions for the challenges and shortcomings captured during the investigations on current practice of BPI in the industry (see chapter 4). To comply with the guidelines of the *Prescriptive Study* in the DRM, these exemplary real situations are put into proper context to demonstrate their suitability as realistic situations. This approach allows the inductive reasoning that the developed *local* solutions constitute reasonable archetypes for *generic* solutions.
Case-Based Reasoning (CBR) is a related approach that transfers and adapts solutions from similar problems to solve new problems via analogical induction (KOLODNER 1993; RICHTER & WEBER 2013).
The *Grounded Theory Method* (GTM) is a methodology from the social sciences that uses qualitative data to derive new concepts. In contrast to the classical scientific

[6] see table A.5 in the appendix A.4.

method, this approach is based on inductive reasoning, where an observer's gathered individual experiences and learnings become a synthesized general theory (HAMILTON 2004).
Scientific methods relying on inductive reasoning are criticized for accepting "anecdotal evidence" (expert observations). However, since the practical implications of complex BPI projects do not allow to design and conduct a reasonable experiment that generates statistically relevant empirical data[7] for verifying or falsifying a previously formed hypothesis (hypothetico-deductive model of the scientific method), a combination of the SSM, GTM and CBR[8] methods has been chosen. The proposed method in this thesis is intended as an universal approach and was validated by a case study capturing and describing the observable effects. It is a synthesis of literature insights, observed practice, and educated assumptions by the author.
The outlined scientific approach has been considered to be the most promising within the confines of this thesis project merging engineering sciences (specific characteristics of manufacturing companies) with social sciences (human behavior in the socio-technical system). In this field, research has produced considerable progress and refinements of previous models and approaches in compliance with Karl Popper's critical rationalism (see POPPER 2008) and by continuously addressing actual problems in the practice, which is also based on suggestions of applied science (see H. ULRICH et al. 1984; P. ULRICH & HILL 1976).

1.3.4 Research environment

For a better understanding of this thesis, the research project, the industrial context, the author's heuristic framework, and a direction-providing vision are presented.

Research project

The project was conducted at the Institute for Machine Tools and Industrial Management (*iwb*), Technische Universität München (TUM), in the context of

[7] Comparative studies are not feasible in a real industrial environment due to the substantial duration of several months or years, high resource consumption, and complexity of BPI projects. For this purpose, comparison groups would have to be formed within a company or in two very similar projects, which pursue the same goal in parallel.
[8] Another argument for the application of the CBR method was the wide spectrum of domains with similar problems, which is an ideal basis for analogies.

the Collaborative Research Center (CRC) 768 "Cycle management of innovation processes" and the sub-project "Cycle-oriented planning of changeable production resources". Several chairs and institutes from TUM and Ludwig-Maximilians Universität München (LMU) with a focus on engineering, economics, IT, psychology, and sociology make this CRC a highly trans-disciplinary research project with more than 15 sub-projects. The sub-project in which this thesis was written focused on the organizational agility of manufacturing systems and cooperated with chairs from product development and economic sociology, as well as research groups at the iwb, addressing topics in the field of technology & innovation management and human labor.

Industrial context

The research project itself was not bound to a specific industry partner. However, the data gathering from expert interviews, observational case studies, and an online survey profited from the industry-oriented educational curriculum at the *Institute for Machine Tools and Industrial Management (iwb)*. Within this program of four years, the author was regularly assigned to industrial projects in various companies[9] and sectors[10], and was thus able to gain his own experience and establish valuable contacts for potential application studies. The process of identifying and conducting the online survey, case studies, and expert interviews were assisted substantially by student research projects (see table A.5 in the appendix A.4), partly on site at the industrial partners.

Heuristic framework of the author

"First of all, it seems necessary for the researcher himself to gain clarity as to which theoretical direction or school shapes his current thinking and which alternatives to this exist." This statement by KUBICEK refers to the value of scrutinizing the background of own experiences when designing a research project in the social sciences and outlining it as a heuristic framework (cf. KUBICEK 1976).

The author's heuristic framework is mainly yielded by the knowledge gathered during the previously mentioned industry projects, by professional experience in consulting, and by his role as a teacher and trainer. It covers the fields of *Lean Management*,

[9] These companies can be of any size ranging from Small and Medium-sized Enterprises (SMEs) to international corporations, manufacturing products in small, medium or large series, or as projects, with locations in Europe.

[10] Among others: automotive, machinery, pharma, IT, consulting

Change Management, *Technology & Innovation Management*, *Conventional & Agile Project Management*, *Factory Planning*, *Business Organization & Process Design*, and *Supply Chain Management*. A deep fascination for the Japanese Management Culture and the *Toyota Production System* (TPS) in particular form the ideology for this thesis and provide the direction of the following guiding idea for the intended method.

Guiding idea for this thesis
BPI projects can be managed more effectively by gaining agility with explorative knowledge creation routines.
Learning fast and with low friction, is what distinguishes *Knowledge Creating Companies*: "These companies have become famous for their ability to respond quickly to customers, create new markets, rapidly develop new products, and dominate emergent technologies. The secret of their success is their unique approach to managing the creation of new knowledge. [...] In the knowledge-creating company, inventing new knowledge is not a specialized activity, the province of the R&D department or marketing or strategic planning. It is a way of behaving, indeed a way of being, in which everyone is a knowledge worker, that is to say, an entrepreneur" (NONAKA 2007).
Nonaka's portrayal of the *Knowledge-Creating Company* yields the idea for a more effective management of BPI projects in manufacturing companies. This approach is based on explorative knowledge-creation and motivated primarily by the people's "sense of identity with the enterprise and its mission" (NONAKA 2007).

2 Fundamental Concepts

With regard to the research questions stated in the previous chapter (see section 1.3.1), the subsequent fundamental concepts contribute to a better understanding of the basic characteristics and mechanics of Business Process Innovation (BPI) in manufacturing companies. The chapter also reflects a more in-depth rationale for the previously formulated research idea.

2.1 Business Processes in Manufacturing Companies

The right process will produce the right results.
(TAICHI OHNO)

Any profit-oriented organization attempts to exchange knowledge and effort for payment. On that account, offers are made and orders are accepted on a customer market resulting in the development and manufacturing of goods and services: *products* (KIENER 2006).

Manufacturing companies are legal constructs whose primary objective is to generate profits with the development of new or adapted products based on customer requirements, by materializing them using knowledge, effort, and technologies, and selling them to other businesses or private persons[1] (WILLE 2016).

[1] Enterprises of this type are listed by the European Union in the document of the Statistical Classification of Economic Activities in the European Community (NACE) "Manufacturing Sector" (*NACE Rev. 2: Statistische Systematik der Wirtschaftszweige in der Europäischen Gemeinschaft* 2008). The manufacturing sector generates almost a quarter of Germany's GDP and forms the basis for a prosperous and stable economy (ABELE & REINHART 2011).

2.1.1 Business processes & process models

Customer satisfaction is the basis for a strong market position of a manufacturing company and requires procedures that are client-oriented and free of waste (OHNO & ROTHER 2013). To balance highest quality, lowest costs, and shortest lead times effectively, profound planning of operations, information flows, and technologies is essential (PAWELLEK 2008). *Planning* is the "mental anticipation of future actions through the development of various alternatives and selection of the best alternative to achieve a goal" (KIENER 2006). Manufacturing companies plan in various areas and in different time frames, ranging from the short-time scheduling of production jobs to the corporate, strategic planning of product portfolios, organizational structures, and processes[2] (STEVEN 1994).

In general, *processes* represent "operations that use resources to transform input into results" (DIN EN ISO 9000). In the context of this thesis, they refer to *value creation* or *business* operations, including direct or core and indirect or secondary ones; *direct* processes create value for a customer and are supported or enabled by *indirect* processes like scheduling, purchasing or logistics (RÜEGG-STÜRM & GRAND 2019). Other authors further divide secondary business processes into support and control or management processes: support processes provide the essential resources, while management processes control the overall operations and make strategical decisions (DAVENPORT 1993; DOMBROWSKI et al. 2009). Following these definitions, business processes within this work refer to core processes as well as support and management processes.

A business process is a set of related activities carried out to achieve a desired business result (DAVENPORT 1993). Business processes regulate *what* is quintessentially to serve internal and external customers but also guide *how* to succeed (DAVENPORT 1993). In accordance with PORTER's model of the value chain (cf. PORTER 1985), business processes are cross-departmental and cross-divisional, and can extend across locations (DOMBROWSKI & MIELKE 2015). Business processes are assessed by Key Performance Indicators (KPIs) on the basis of quality, time and cost; all contributing to customer satisfaction (DAVENPORT 1993).

[2] The foundations of differentiating the structural from the process-oriented perspective of organizations date back to publications by NORDSIECK (1934) and KOSIOL (1976) (cf. BITZ et al. 1993, referring to GAITANIDES 1983).

In conclusion, a business process refers to a structured set of operations to create and deliver a product to the expectation of quality, time and, cost of a customer market in order to achieve an intended business result[3]. A core business process within manufacturing companies is the order fulfillment process (DOMBROWSKI et al. 2009), comprising various individual stages such as product development, order processing or production depending on the type of business (STAUD 2006).

Process models

BROWNING (2009) & BROWNING et al. (2006) characterize process models as an abstraction of reality including different perspectives and inconsistencies. Process models are developed and managed by various people or departments, and can also be ignored. The authors report that companies systematize and communicate their corporate knowledge with process models to provide a standardized basis for planning and accomplishing tasks during projects and day-to-day business. Process models combine a normative-prescriptive[4] with a declarative-descriptive[5] character. Over the years, various process model notation or modeling frameworks have been developed as universal languages to design, visualize and communicate material and information flows[6].

[3] The term *process* suffers from a significant ambiguity; its simplicity makes it difficult to assign processes to a specific meaning (BROWNING et al. 2006). In manufacturing, processes can also describe the smallest unit of value adding, e.g. the milling or assembly processes. Moreover, process exists as a legal term and denotes chemical reactions or biological sequences.
Unless specified specifically, in this work, the term *process* refers to a business process.

[4] "A prescriptive process model tells people what work to do and perhaps also how to do it. It is built deductively, perhaps drawing from an external standard and/or documentation from other projects. A prescriptive process is a standard process or procedure accompanied by a mandate to follow it exactly." (BROWNING et al. 2006)

[5] "A descriptive process model attempts to capture tacit knowledge about how work is really done. It tries to describe key features of the 'as is' reality. It is built inductively." (BROWNING et al. 2006)

[6] Commonly known are, among others, *Value Stream Map* (VSM), SIPOC, *Stage-Gate*, *Activity Networks*, IDEF, eEPC, or BPMN (J. KOCH 2017). Comprehensive insight provide e.g. AGUILAR-SAVEN (2004) & BROWNING et al. (2006)

2.1.2 Business Process Design (BPD)

Process engineers[7] with a strong customer orientation attempt to systematically achieve excellent product quality, short lead times, and low costs through a high degree of process stability (ROTHER 2010). They can have an major impact on said process stability by ensuring that new or adapted products are designed for manufacturability (SCHNEIDER 2015).

BPD in a manufacturing company is referred to as the "order-independent planning, design, and implementation of production systems" or tactical production planning[8], having significant influence on the operational factors of costs, time, and quality (SCHNEIDER 2015). While the strategic planning of production systems ensures a long-term competitive setting and sets the general course (KIENER 2006), the tactical level decides on the design or adaptation of the production system (GÜNTHER & TEMPELMEIER 2016). It also creates a framework for the operational planning to effectively and efficiently deploy the provided resources (STEVEN 1994).

The role of BPD in manufacturing companies

BPD creates an industrialization concept to facilitate the integrated design of products and production systems (cf. figure 2.1) (MATTMANN 2017). This involves, e.g., designing value streams, planning indirect activities, or dimensioning capacities, layouts, or IT-infrastructure (GÜNTHER & TEMPELMEIER 2016; KIENER 2006). BPD begins with the definition of product requirements and ends when the unit in charge with operational production planning takes over responsibility (cf. figure 2.1) (EIGNER & STELZER 2013). The therewith dedicated interdisciplinary team or department serves a coordinating role to provide an integration of cross-functional requirements and available technologies across an entire manufacturing company (HAB & WAGNER 2017).

As depicted in figure 2.1, BPD is related but distinct from NPD, which is understood broadly as turning a market opportunity into a product available for sale (LAW 2016)

[7] In many manufacturing companies, the team or department of persons that is responsible for the planning of processes regularly is referred to as *process planning* (SCHNEIDER 2015).

[8] This references to the distinction of strategic, tactical, and operational layers of planning (cf. e.g. KIENER 2006), that differ in four dimensions: temporal horizon, significance for the company, management level, and degree of aggregation in the underlying information (GÜNTHER & TEMPELMEIER 2016).

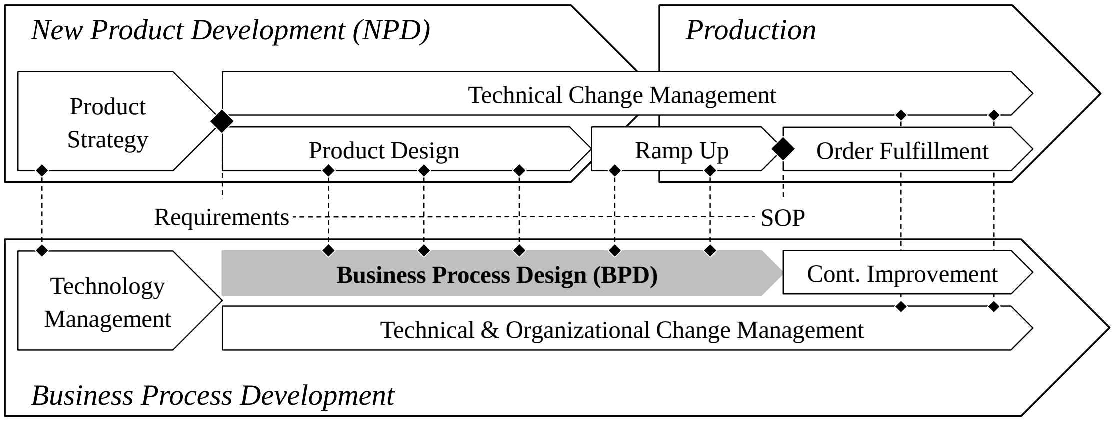

Figure 2.1: BPD in the context of NPD in manufacturing companies (own illustration based on concepts by DAVENPORT & SHORT *1990;* EIGNER & STELZER *2013;* HAB & WAGNER *2017;* MEIS *2017;* SCHNEIDER *2015;* TENG *et al. 1994).*

including the actual design of it. Early methods for technical product design, proposed for example by PAHL et al. (2007), suggested three basic steps: planning and task clarification, conceptual design, and detail design. EHRLENSPIEL & MEERKAMM (2013) later focused on the definition of system functions and their materialization using known basic solutions, similar to the *Theroy of Inventive Problem Solving* (TRIZ) method that applies proven patterns of technical evolution to solve recurring design problems (see ALTSHULLER 2000). With the *Münchner Vorgehensmodell*[9] postulated by PONN & LINDEMANN (2008), the authors put more emphasis on concretizing functional, operational, and structural requirements during the development of technical systems.

In the automotive industry, all required steps of translating product requirements into a car ready to go into mass production are captured in the *Produkentstehungsprozess* (PEP)[10], a widely accepted and holistic approach that includes not only NPD but also BPD (cf. BRAESS & SEIFFERT 2011). Joint milestones serve to synchronize incrementally emerging requirements, information, and decisions among the involved disciplines (HAB & WAGNER 2017), ensuring a product design convenient with op-

[9] It is also referred to as the *Munich Concretization Model* or the *PSS-Concretization Model*, PSS abbreviating product service system

[10] German for *Product Development Process*

erational realities (MEIS 2017). Right after the Start of Production (SOP), process engineers handover their responsibility for the production system to the responsible operator (in most cases the plant manager) to previously agreed cost, time, and quality targets (SCHNEIDER 2015). During the ramp-up phase and ongoing, persons previously involved in the BPD usually become processual rapid-response experts intervening when problems occur, later supporting the Continuous Improvement Process (CIP) as change managers (SCHNEIDER 2015). In manufacturing companies that build individual products according to the engineer-to-order[11] strategy, business processes operate on a higher level of flexibility, risk and uncertainty (WORTMANN 1983).

Products that do not require any adaptions to an existing production system tend to result in simple BPRD projects. On the other hand, when a disruptive technology, a radical market change, or a new business idea is involved, it usually requires novel solutions and transformation. These situations can manifest themselves as particular complex challenges for process engineers with fundamental parameters of the future state potentially being unclear or not accessible at the beginning and throughout the project. To address this specific character of these transformational BPD projects, the term Business Process Innovation (BPI) is used. (BRANDL et al. 2020)

2.1.3 Continuous improvement of business processes

In the era of *Industrie 4.0.* Designing and operating corporate structures and operations according to the ideas and principles of *Lean Management* still represents “the elementary basis for efficient, competitive, and modern material flow” (DICKMANN 2015). Most experts from the manufacturing domain use the term *Lean Management* to refer to the first western world’s interpretation of the TPS’s visual methods and tools (WOMACK et al. 2007). Against a range of early records, these tangible elements and the also often mentioned strong imperative for *standardization* do not build the only motifs in this philosophy which, to its full extent, is commonly visualized in the form of a temple (see figure 2.2) (OHNO & ROTHER 2013). According to its

[11] Make-to-stock, make-to-order, and engineer-to-order are common production concepts defined in the commonly accepted Supply Chain Operations Reference (SCOR) model (cf. SUPPLY CHAIN COUNCIL 2017).

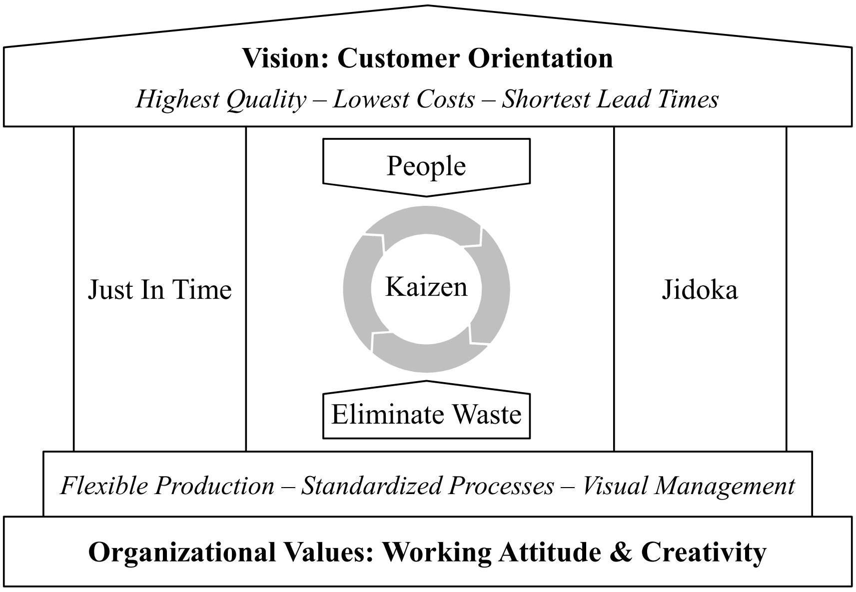

*Figure 2.2: TPS visualized as a temple (*OHNO *2006)*

creators, customer orientation marks the principal target in the TPS, characterized by a continuous effort to achieve the highest quality at lowest costs, and shortest lead times through the continuous elimination of waste (ROGGENHOFER et al. 2005). Waste is "any activity that involves resources consumed in any form (labour, land, machinery, etc.), with no value generated [...]" and the customer market dictates *what* adds value (GORECKI & PAUTSCH 2014). People or employees play a central role in reducing waste: they implement *Kaizen*[12] guided by the pillars Just-in-time (JIT)[13] and Jidoka[14]. The people's associated working attitude and creativity form the basis for continuous improvement for a company to remain competitive (KAMISKE 2012). Authors with several years of personal experience with the TPS, like BENDER-MINEGISHI (2018), LIKER (2004) and ROTHER (2010), associate a (true) lean organization with Toyota's (product-independent) organizational *Kaizen* culture, which is considered to

[12] *Kaizen* literally means "substituting the good for the better with small steps" (ZOLLONDZ 2013).

[13] DICKMANN (2015) condenses JIT to "providing the [right] material [or information] at the right time, at the right quality, in the right quantity, and at the right place", preferring smooth material flow and small batch sizes.

[14] Jidoka, also referred to as "auto*no*mation" or "automation with a human touch" extends conventional automation with the purpose of detecting and solving problems immediately, before a large number of defective parts is produced (or information is generated) and provided to the recipient. As a result, employees prevent problems permanently (OHNO & ROTHER 2013).

be transferable to other companies and domains. It is a benchmark for customer oriented management systems and applicable to all value creation or business processes (Bender-Minegishi 2018). Such a management philosophy only permanently achieves competitive advantage when embedded in the respective company's corporate culture harmonizing with values, principles, and methods (Rother 2010). At Toyota and other companies, *Kaizen*, or the CIP, constitutes an essential part of their daily business routine: all people in a company steadily follow a path towards process stability (Ohno 2006). This journey is visualized in figure 2.3 as a mountain top tour.

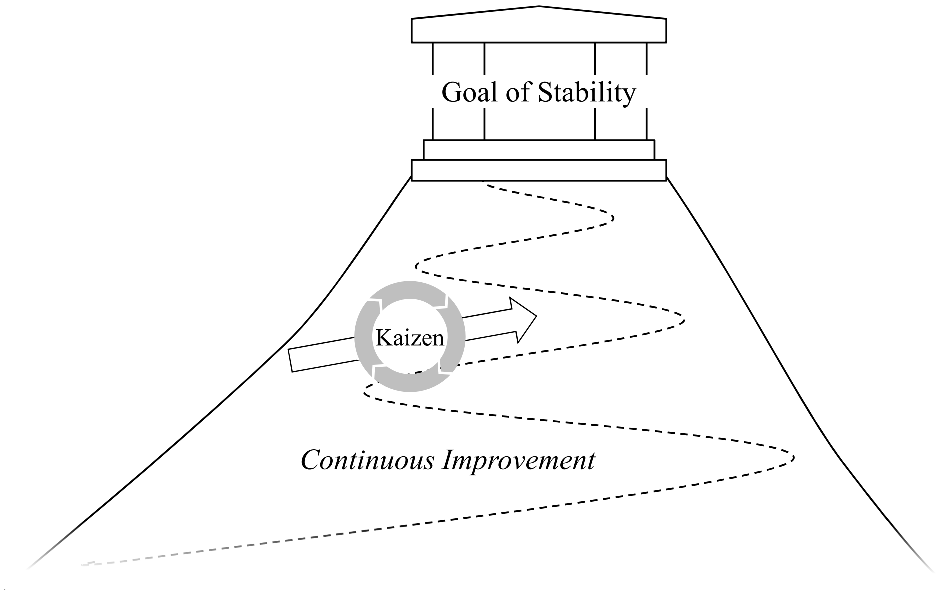

*Figure 2.3: Continuous improvement towards process stability - visualized as a path to the top of a mountain (*Womack *et al. 2007)*

2.2 Innovation in Manufacturing Companies

Process stability makes manufacturing companies more efficient and improves their starting position to compete on a turbulent market (Vanecek et al. 2018). However, at the same time, this dynamic market requires them to unfold temporal technological and organizational advantages more rapidly than their competitors (Brown &

EISENHARDT 2007). Innovation can open up new opportunities for a manufacturing company but requires the “the ability to change and adapt” (TROTT 2012).

Excourse in organizational & technical change management
The scientific understanding of change in organizations and the foundation of change management dates back to Kurt Lewin (GREIF et al. 2004). In his work *Frontiers in Group Dynamics* (LEWIN 1947), he defined any change as the "unfreezing", "moving" and "refreezing" of an initially state of equilibrium between the constantly competing forces of stability and change (GREIF et al. 2004). Agreeing on Lewin’s idea, many other authors proposed further refinements or related interpretations of this basic change model. The most referred are KOTTER’S (1996) directives for change management and KUEBLER-ROSS’ (2005) performance curve (cf. GOKSOY 2016). The latter was refined later in several publications (see e.g. CAMERON & GREEN 2020; FRANKLIN 2011). Both models capture a path every successful company goes through when managing organizational change caused by market slumps, financial crises, critical changes in legislation, or essential innovations for survival (STEFFEN 2019). Effective change management takes into account emerging human emotions (BREUER & FROT 2010) that can lead to frustration, resistance and fears in the workforce as well as in the management (KUSTER et al. 2019; LINES et al. 2015).
Various approaches in organizational and technical change management provide procedural guidelines and auxiliary models to minimize risks, time, and cost during changes. A change is the “assented definition of a new state, instead of a previous state” and also denotes the associated passage of temporal instability in between (LINDEMANN & REICHWALD 1998). The concepts of change and change management are associated with various scientific disciplines (cf. J. KOCH 2017). *Change Management* commonly refers to organizational change on a company’s business process level primarily focusing corporate elements or organizational units (cf. e.g. CZICHOS 2014; DOPPLER & LAUTERBURG 2008; KOTTER 1996; LAUER 2014; PATON & MCCALMAN 2008; VAHS & WEIAND 2010). Technical change or *Engineering Change* (EC) refers to products (cf. e.g. CLARKSON & ECKERT 2005; JARRATT et al. 2011; LINDEMANN & REICHWALD 1998). The term *Manufacturing Change* (MC) is becoming increasingly accepted in literature (cf. e.g. CICHOS & AURICH 2015; J. KOCH 2017; PROSTEP IVIP E.V. 2015; RÖSSING 2007) to highlight adaptions, replacements or removals of manufacturing equipment (J. KOCH 2017). *Engineering Change Management* (ECM) refers to the organization and control of the continuous

product change process (Clarkson & Eckert 2005), while *Manufacturing Change Management* (MCM) serves to coordinate changes when the planning of a production system is completed and operational (J. Koch 2017).

Changing a current state by introducing something new with an impact on the market is a basic mechanism of innovation (Sweezy 1943) as outlined in the following chapter.

2.2.1 Innovation theory

Joseph Schumpeter (1883-1950) first adopted the term *innovation* to the *Scientific Management* domain in the 1930s (Horsch 2003). Its interpretation is not consistent both in science and practice (Hartschen et al. 2015). Yet, all attempts associate it with characteristics of *novelty* and *change* of a state or process (Hauschildt & Salomo 2010). Etymologically originating from the Latin verb <innovare>, engl. to renew, innovation pointedly "concerns the search for, discovery, experimentation, development, imitation, and adaption of new products, production processes and new organizational set-ups" (Dosi 1990) that create a new practical value (Sweezy 1943). Further, three differentiating dimensions facilitate a better understanding of innovation in manufacturing companies: perspective, impact, and object of innovation.

Perspective of innovation
First, one can differentiate between an objective and a subjective innovation and thus between perspectives. Objective novelties are those which are regarded as new by everyone. It is a novelty to the world. Subjective novelties, however, are only new for one viewer or a limited group of people. (Horsch 2003)

Impact of innovation
At the same time, with regard to the impact of innovation, literature distinguishes sustaining from radical innovation (Hartschen et al. 2015). Sustaining innovation follows an evolutionary approach in which small incremental changes achieve an improvement of the established system or product (Hartschen et al. 2015). The term is therefore often used synonymously with continuous improvement (Horsch 2003). Improvements usually involve moderate risk, emerge bottom-up, and require limited resources (Davenport 1993). Radical innovation, in contrast, characterizes erratic,

radical change usually triggered by arising technological or socio-political opportunities (HARTSCHEN et al. 2015). It is far-reaching, requires a strategic vision, and therefore initiated top-down. It often takes place across departments and is associated with a high level of risk and complexity (DAVENPORT 1993). HENDERSON & CLARK (1990) summarize that “radical and incremental innovation are extreme points [...]. Radical innovation establishes a new dominant design and, hence, a new set of core design concepts embodied in components that are linked together in a new architecture. Incremental innovation refines and extends an established design. Improvement occurs in individual components, but the underlying core design concepts, and the links between them, remain the same.” In a recent comprehensive literature study on innovation C. HOPP et al. (2018) further distinguish disruptive from radical changes: disruption is also driven by a technological leap but additionally relates to a business challenged by new market entrants, whereas radical innovation usually strengthens a position.
On an operational level however, incremental innovation is the most significant contributor to the productivity gains necessary to stay competitive (TIDD 2001). Most manufacturing companies therefore focus very strongly on continuous improvement routines and quality management (BENDER-MINEGISHI 2018).

Object of innovation
For manufacturing companies, literature essentially distinguishes between five different types of innovation, corresponding to the impacted object: product, production, process, organizational, and management innovation (TROTT 2012). Process innovation concerns business processes that are required for the creation and distribution of products with regard to quality, cost, and time (HORSCH 2003), also including the indirect processes (DAVENPORT 1993). Process innovation imposes great challenges on the management since efforts of coordination and communication extend across internal and external interfaces (DAVENPORT 1993). Despite this distinction, all innovation types interact with each other and should therefore be considered mutually (BÖHLE et al. 2012).

Innovation management
Early milestones in technical innovation science suggested, that innovation management enfolds three key aspects: (1) it is gain-driven (i.e. by satisfying a need or taking an advantage), (2) it consumes (creative/monetary/technical) resources, and (3) it entails technical and organizational change (KELLY & KRANZBERG 1975).

Recent definitions of innovation management highlight its output-oriented objective (GERPOTT 2013) through an optimal coordination of resource-competing innovation projects in a company (VAHS & BREM 2015), organized by a standardized innovation process (HAUSCHILDT & SALOMO 2010). Despite the diverging characteristics of an innovation process, it generally represents a sequence of activities structured in successive phases (LINDEMANN 2016) and is frequently expressed as *searching*, *selecting*, and *implementing* and add *learning* (TIDD & BESSANT 2013).

Innovation project management

Project management plays a significant role for innovation (VAHS & BREM 2015). It comprises "all aspects of leadership tasks, organization, techniques, and tools for initiating, defining, planning, controlling and completing projects" (DIN 69901-5). Manufacturing companies commonly structure projects according to the *Stage-Gate* model (HAB & WAGNER 2017), a concept formalized by COOPER (1990) to facilitate design or development projects. Stages correspond to phases of operative work separated by gates. Gates give each phase a defined beginning or input and ending or output. They form quality checkpoints by assessing a stage's result and are often referred to as milestones or synchronization points (FELKAI & BEIDERWIEDEN 2015; HAB & WAGNER 2017). Each gate comprises assigned deliverables, on which go/kill/hold/recycle decisions are made. Only with a "go" the project proceeds to the next stage and the results of one phase form the input for the subsequent (COOPER 1990). *Stage-Gate* facilitates coordination, assures quality, minimizes risk, and stabilizes projects (COOPER 1990) through extensive initial planning (K. HOFFMANN 2008). It is also referred to as traditional or conventional project management (HAB & WAGNER 2017).

2.2.2 *The Innovator's Dilemma*

A closer look into the mechanisms of innovation reveals that a company's organization and experiences have significant influence on how innovation evolves (CHRISTENSEN 2008). HENDERSON & CLARK (1990) state, that a component-oriented departmentalization in companies favors incremental innovation on the respective component levels. Those local improvements succeed as long as "fundamental architecture does not require to change" and contribute to a "dominant design" (CHRISTENSEN 2008).

This correlation, so the author, remains valid vice versa: the structure of a company and the way its people have learned to work together defines how new products are developed (CHRISTENSEN 2008). As a result, companies are bound to their legacy systems, which can result in persistence on established patterns (CLARK 1985).
An innovation addressing or initiating fundamental changes on the market or in the society requires other competences and knowledge, e.g. to overcome a novel development or design problem (CHRISTENSEN 2008). Hence, companies often fail when they need to reorient previously cultivated competencies, structures, and values that otherwise make them successful (TUSHMAN & P. ANDERSON 1986).
Harvard professor CLAYTON M. CHRISTENSEN described these difficulties as *The Innovator's Dilemma* (CHRISTENSEN 2008). He was skeptical about the simultaneous optimization of existing processes and capabilities (exploitation of the reliable) and radically innovating them (exploration of new opportunities) (CHRISTENSEN 2008).

The innovation dilemma in manufacturing companies
In accordance with CHRISTENSEN's observations, KRUSE (2015) postulates a systematic *instability management* for transitional phases between two states of process stability. In manufacturing companies, the effective management of such phases is crucial, since fundamental changes cannot be implemented overnight, like patching a device's software to a new version, but involves considerable planning and implementation effort (J. KOCH 2017; LARSSON 2017). Expanding the analogy depicted in figure 2.3, the situation those companies find themselves in can be visualized as a path through a valley of inevitable instability in order to reach the top of a higher mountain (cf. figure 2.4). In this metaphor, the company's performance is depicted as height, which usually decreases during phases of instability[15]. As a consequence, radical innovation is particularly challenging for manufacturing companies and their operations manager in particular. Maintaining and exploiting the proven path of stability is their main job and success is measured by respective KPIs. Leaving this path, e.g., for exploring new ideas, increases the risk of failure and decreases performance. Only when tangible figures like efficiency, cost, or return on investment exceed a level where

[15] In accordance with the frequently adopted model originally postulated by psychiatrist Elisabeth Kübler-Ross (1926-2004) that characterizes performance during periods of substantial change as a valley of depression and under-performance (KÜBLER-ROSS 2005).

the old path has been departed, radical innovation achieves competitive advantage (in accordance with CHRISTENSEN 2008).

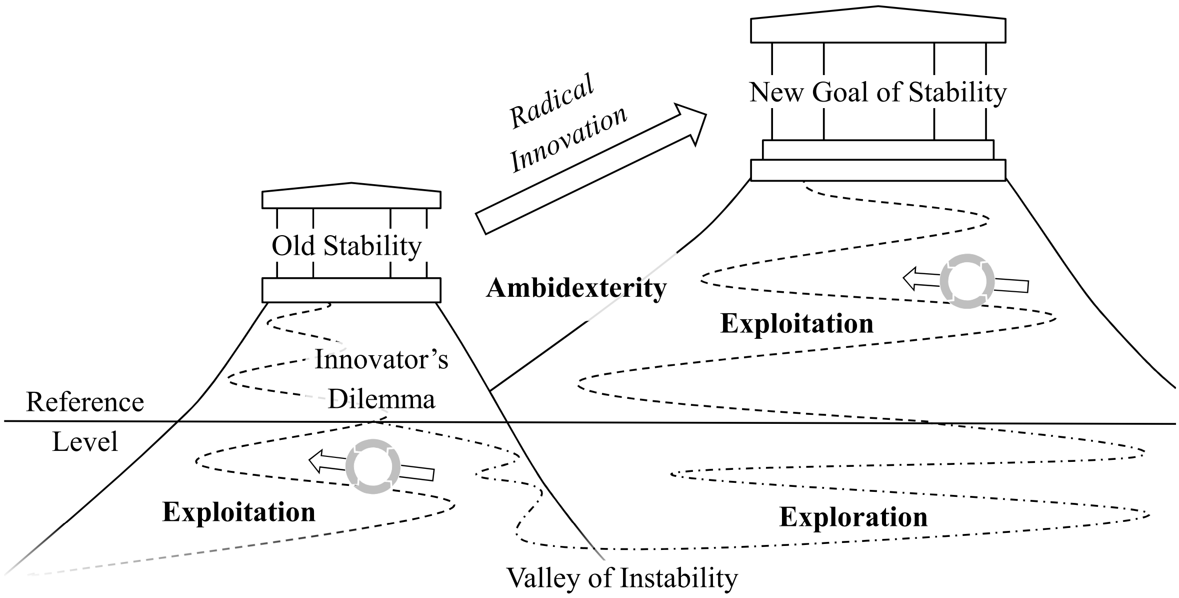

Figure 2.4: Radical innovation visualized as a path through a valley of instability in order to reach the top of another mountain (own illustration based on concepts by CAMERON & GREEN *2020;* CHRISTENSEN *2008;* GARAUS *et al. 2018;* KRUSE *2015;* KÜBLER-ROSS *2005;* LEWIN *1947;* OHNO *2006).*

2.2.3 Business Process Innovation (BPI) through exploration

Although CHRISTENSEN doubted that the innovation dilemma could be easily solved (O'REILLY & TUSHMAN 2008) and concluded "that established firms tend to be good at improving what they have long been good at doing" (CHRISTENSEN 2008), *organizational ambidexterity* is regarded to be a solution to this problem (GARAUS et al. 2018).

Organizational ambidexterity

In organization science, since the early 1990's, there has been a growing interest in how exactly companies gain knowledge to stay competitive in a dynamic market

(GARAUS et al. 2018). From this perspective, MARCH (1991) portrayed *exploration* and *exploitation* as two fundamentally different forms of organizational learning. He confirmed that *exploitation* builds on already established success patterns (GARAUS et al. 2018) and is associated with improvement, implementation, efficiency, and trivial learning (HE & WONG 2004). *Exploration*, however, is the generation of new knowledge and innovation (GARAUS et al. 2018), relating to the search, discovery, and experimentation with new things as well as risk-taking (HE & WONG 2004). The fundamental challenge for manufacturing companies is to cultivate comparable exploitative and explorative capabilities while balancing their extend (LEVINTHAL & MARCH 1993). While the predominance of exploitation can result in static persistence of a company in sub-optimal business situations, extensive exploration might lead to excessive costs and inefficiency (MARCH 1991). A company's maturity in managing this dilemma is called *organizational ambidexterity* which, especially within volatile and unstable market conditions, leads to a better innovation results and a longer company survival (O'REILLY & TUSHMAN 2008).
This model of organizational ambidexterity underlines the conclusion from the previous passage, that radical, disruptive, or revolutionary innovations, like complex BPIs, require systematic exploration (GARAUS et al. 2018).

Exploration in BPI projects

Exploration is the "activity of searching and finding out about something" (HEACOCK 2009). During BPI projects, exploration is closely related to a company's capabilities of solving technical problems and, therefore, its ability to systematically gain knowledge (NONAKA 2007). In order to guide manufacturing companies in managing complex BPI projects, the following sections of this chapter investigate how manufacturing companies can solve complex technical problems through explorative learning.

2.3 Complex Technical Problems

"The complexity of production systems has coevolved with the complexity of the environment in which they are situated" (ALLEN 2011), making "complexity theory [...] particularly relevant for organizations facing rates of external change that exceed their internal rate change" (P. ANDERSON 1999).

2.3.1 Complexity theory

According to NICOLIS et al. (1987), complexity is a term whose meaning is one of the problems it addresses. The word is exerted in various occasions to paraphrase something ”hard to grasp” and generally might just be understood as the “variety of relationships between the elements of a system” (*Gabler Wirtschaftslexikon* 2019). A complex system’s behavior seems to be confusing, chaotic, and perplexing for the observer (ENGELMANN 2009). Intuitively, complexity can also express “a measure of uncertainty” (SUH 2005).
Considering the various disciplines in academic research devoting attention to complexity (cf. e.g. GERALDI et al. 2011), the range of domain-specific definitions is immense (DAO et al. 2016) creating space for an inconsistent understanding (MATTSSON et al. 2016). GERALDI et al. (2011) summarize their extensive review on complexity literature, extending an early attempt on project and organizational associated complexity by BACCARINI (1996), with the conclusion that it represents an umbrella term subsuming *Variety* (structural), *Uncertainty* (known unknown), *Volatility* (dynamics), *Urgency* (pace), *Emergency* (unknown unknowns) and *Ambiguity* (social); a proclamation later affirmed by other researchers (see e.g. VELTE et al. 2017).

Complex vs. complicated
The complexity of a system generally makes it difficult and sometimes impossible to understand and recognize all its variables and all of the relationships among themselves (RAMASESH & BROWNING 2014). Hence, it is indispensable to draw attention to the common misconception of synonymously using ”complex” and ”complicated” (SNOWDEN & BOONE 2007). Complicated systems also consist “of many interconnecting parts or elements” (STEVENSON 2010). In contrast to complex systems however, they operate in patterned ways of order (SNOWDEN & BOONE 2007). Therefore, it is “possible to make accurate predictions about how a complicated system will behave” (SARGUT & MCGRATH 2011). Complexity however, obscures the relation of cause and effect which hampers the gain of anticipation (SNOWDEN & BOONE 2007). ELMARAGHY ET AL. (2012) remark that “what is complicated is not necessarily complex, and vice versa, and what is complicated for one person, may be complex for another less knowledgeable individual or a group with less technological tools”. The latter is in line with statements by BACCARINI (1996) or DAO (2016), who accredit organizational and technological aspects to complexity in a manufacturing context,

giving it a subjective connotation. On this premise, SCHOETTL (2016) introduces a complexity potential for the risk of a system's likelihood to be perceived as complex by a person interacting with it.

2.3.2 Identifying and managing complexity

Even larger than the variety of complexity models is the range of literature providing elaborate advice on how to approach complexity (see e.g. F. MALIK 2006; STÜTTGEN 2003; VESTER 2015; WILDEMANN 2014). Many authors particularly address product-related complexity (see e.g. LINDEMANN et al. 2009; SCHUH & RIESENER 2017) or offer guidelines purposed with the prevention and reduction of complexity, e.g. with variant management (see e.g. H. ELMARAGHY et al. 2009; WILDEMANN 2018) or the design for changeability relating to products (see e.g. LINDEMANN 2016; SCHUH et al. 2004) and production systems (see e.g. H. A. ELMARAGHY 2009; HAWER et al. 2016).

Identifying and managing complexity with the Cynefin Framework
The *Cynefin Framework* as a portfolio bases on a broad empirical analysis of a large number of problem situations (SNOWDEN & BOONE 2007). It primarily sensitizes for a better mindfulness towards complexity and facilitates an accurate response. The model distinguishes complex systems from simple, complicated, and chaotic ones, designating each type with an individual management strategy (see figure 2.5). In line with the framework, an effective approach to manage complex situations should rely on *Explorative Practice*, where adequate progress quickly adjusts to continuously emerging new knowledge. Complicated problems by contrast, require deep analysis and deploy *Good Practice*, while simple problems are categorized into *Best Practice* solutions to exploit organizational knowledge and experiences. Chaotic situations require instant action resulting in *Novel Practice*, and as long as definite assignment to one of the four categories is not yet achieved, it remains ”unclear”. The model also provides empirical evidence that people amplify complexity through their individual and often unpredictable decision-making based on personal paradigms and experiences of success and failure. (SNOWDEN & BOONE 2007)

Following the insights by SNOWDEN & BOONE (2007) and SUH (2005), complex systems are distinguishable from simple or complicated by discovering that

- elements evolve dynamically in mutual interaction,
- changes trigger disproportionately far-reaching consequences,
- causes and effects are unapparent,
- insights emerge and are gradually gained,
- constantly changing external factors prevent farsightedness,
- unknown unknowns are yet to be discovered, and therefore,
- only retrospective understanding is achievable.

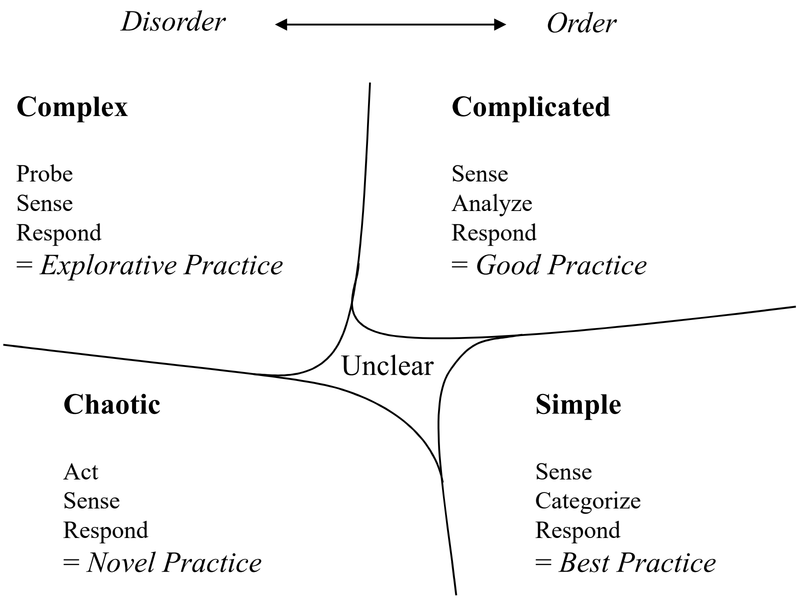

*Figure 2.5: The Cynefin Framework distinguishes simple, complicated, complex and chaotic problems, designating each type a corresponding management strategy (*SNOWDEN & BOONE *2007).*

2.3.3 Solving complex technical problems

During innovation projects, particularly when developing new technological know-how, a lot of early considerations turn out to be not feasible or uneconomic (SCHUH et al.

2017). With lacking experience and references, complexity rises (BOSCH-REKVELDT et al. 2011) and emerges as various technical problems[16].

Technical problem-solving

Technical problems cannot simply be overcome by accomplishing tasks (HORSCH 2003), instead, solving a problem requires "a novel combination of activities, which may be the very first time that they have been carried out in this form" (BETSCH et al. 2011). Problems are well or poorly defined, complex or simple, to be solved under time pressure, or require long reflection (SCHOTT et al. 2015). Technical problems directly affect the design of processes in BPI projects and, as a result, procedural and technological aspects of a manufacturing company (SCHUH et al. 2017). Process engineers that combine technical, economic, and social knowledge work for an effective solution of technical problems by generating "technologies, tangible technical know-how, and technical problem solutions" (BULLINGER & SEIDEL 2012). The skills and experiences of those experts are an essential success factor for complex technical innovation projects (BULLINGER 2006).

Daily business routine vs. explorative problem solving

Peter Kruse (1955-2005), a former professor of organizational psychology and management consultant, proposed an approach for explorative problem-solving during innovation and identifies organizational instability – pursuant to CHRISTENSEN (2008) – as an essential enabler for the required architectural change (KRUSE 2015). His guideline relates to the distinction of stability and instability as portrayed in the *Innovator's Dilemma* (see chapter 2.2.2) and the perception of complexity as depicted in the *Cynefin Framework* (see chapter 2.3.2) (cf. KRUSE 2015).

Projects primarily concerning the improvement of existing systems follow a general order (SNOWDEN & BOONE 2007). Exploiting reliable and approved pattern of good and best practice determine a suitable management strategy manifested in the daily business routine and trivial learning (KRUSE 2015). With complexity involved however, the accumulated experience no longer provides applicable instruction (KRUSE 2015) and a new stabilizing dominant design might not yet have emerged (CHRISTENSEN 2008). Instead, non-trivial learning drives the progress: individual explorative

[16] Problems can be referred to as barriers that "prevent the transformation of an initial state in an final state" (DÖRNER 1987).

problem-solving discovers what best suits the challenge and via self-organizing[17], the gained knowledge is spread throughout the company (NONAKA 2007), e.g. by building networks of knowledge (KRUSE 2015). According to SNOWDEN & BOONE (2007), what enables such explorative practice is to promote interaction and communication, to enable reflection, to allow self-regulation within defined arrays, to involve experts and non-experts for creative ideas and out-of-the-box-thoughts, and to rely on the iterative pattern *probe-sense-response*.

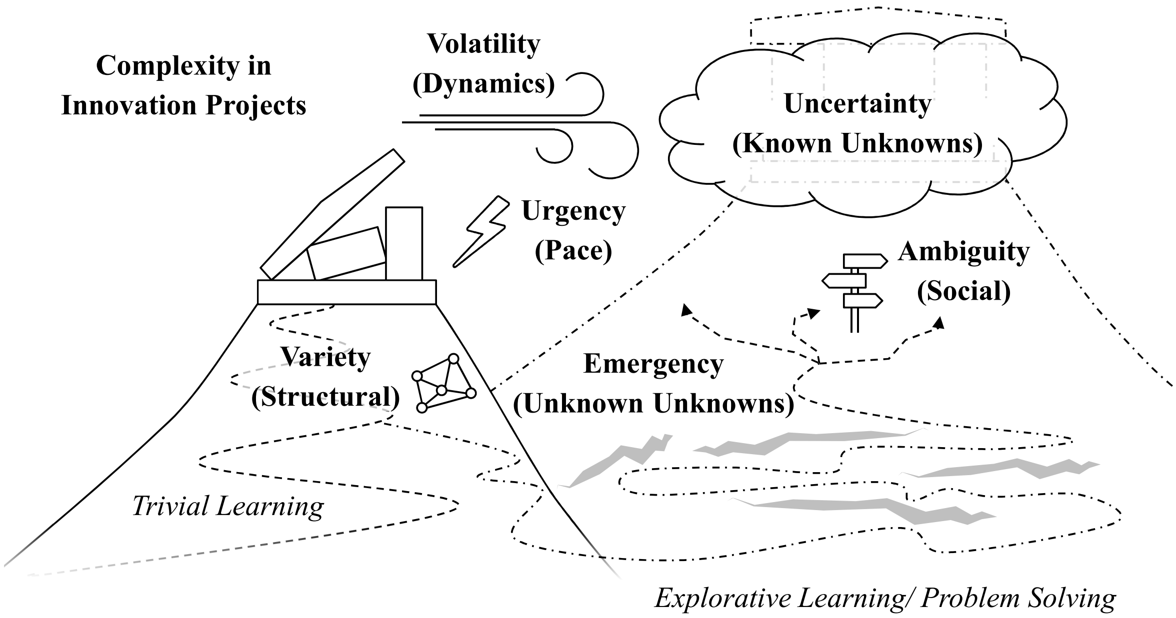

Figure 2.6: Complexity in innovation projects represented by various complexity facets: volatility, urgency, variety, emergency, ambiguity, and uncertainty (own illustration based on concepts by GERALDI *et al. 2011;* GOLL & HOMMEL *2015;* SNOWDEN & BOONE *2007;* SUH *2005).*

Explorative solving of complex technical problems

It gets harder to achieve intended goals, the later unknown technical problems emerge during innovation projects (KETTNER et al. 2010). SNOWDEN & BOONE (2007) as well as GOLL & HOMMEL (2015) warn in dealing with these "unknown unknowns" against wanting to gain control through excessive rules and order. Instead, an adapted

[17] The managerial concept of self-organizing systems dates back to the application of cybernetics to management and organizations (cf. e.g. BEER 1995; F. MALIK 2006).

procedure which helps to achieve an appropriate balance between "acting and planning, detailed and overview considerations, persistence and reorientation" is what supports managers to make appropriate decisions (SNOWDEN & BOONE 2007). Such a management strategy should build on flexibility, transparency, and trust in order to allow reduced planning effort and enable explorative learning during the course of a project (GOLL & HOMMEL 2015; K. HOFFMANN 2008).
Reusing the mountaineering analogy (see figure 2.6), snow bridges across crevasses, that form due to structural adjust in glaciers, represent particularly complex problems to overcome[18]. Since they withhold several unknown unknowns, such environments require a progress strategy that relies on fast explorative problem-solving allowing quick reactions, rather than extensive preparatory analysis, as KORN explains in a similar analogy of trespassing a frozen river (cf. KORN 2016).
As a result, explorative (technical) problem-solving solving can be defined as a systematic learning procedure based on the pattern probe, sense, respond. It focuses on quickly responding to emerging (technical) problems rather than planning them ahead in detail. The following chapter investigates, how *organizational agility* can affect explorative technical problem-solving, since "agility" is commonly seen as an explorative practice and an approach for handling complex problem situations (cf. e.g. GLOGER & SCHWABER 2013; KORN 2016; MAXIMINI 2018; SNOWDEN & BOONE 2007).

2.4 Systematic Exploration with Organizational Agility

"Not the big eat the small, but the quick get the slow." (EBERHARD V. KUENHEIM)

Albeit there is no definite consent on the interpretation of agility in the scientific literature, in the industrial practice, like a *Kienbaum Management Consultants* study suggests, it is widely paraphrased the ability to quickly perceive and beneficially react to emerging changes in the corporate environment, while maintaining steady output based on self-organization and team work (KIENBAUM 2015). Several experts from the software development domain define agility as "the ability to both create and respond to change in order to profit in a turbulent business environment", while "balancing

[18] COLGAN ET AL. provide a comprehensive insight to characteristics of crevasses (2016).

flexibility and stability" and describe it as a system's "permanent anchored ability" to change (HIGHSMITH 2006).

2.4.1 Agility theory

In the scientific domain of manufacturing, the interpretation of the term agility is traditionally linked to the definition in HOPP & SPEARMAN'S book *Factory Physics* (cf. chapter 1.3.2). They explained agility (or agile manufacturing) as the "ability to rapidly reconfigure a manufacturing system for efficient production of new products as they are introduced" (W. J. HOPP & SPEARMAN 2011). In this context, it is also related to flexibility: a system's calculated array of parameters, in which changes generate insignificant costs, efforts or risks (e.g. FRICKE & SCHULZ 2005; REINHART & H. HOFFMANN 2000; WIENDAHL et al. 2007; ZÄH et al. 2005).
In contrast, to H. A. ELMARAGHY (2009), changeability, adaptability or transformability describe how simple a system can be adapted to unforeseen changes, while agility also includes a timely perspective: it combines sensitivity and responsiveness giving an organization the ability to perceive changes or events in the corporate environment quickly and respond to them adequately. This understanding of agility is in line with BERNARDES & HANNA (2009) who define it as an "approach to organizing a system", for example, by establishing self-regulating routines (TAKEUCHI & NONAKA 1986) rather than a system property. Many authors further distinct these characteristics from several frequently used "ilities" in the manufacturing context, like e.g., H. A. ELMARAGHY (2009), PLEHN (2017), or J. KOCH (2017).

Agile Manifesto
Among practitioners, the term agility is mainly associated with the specific set of values, principles and practices of agile project management (KLEIN 2017). Agile experts consider the four values and twelve principles from the *Agile Manifesto* as a comprehensive, standard guideline for agile collaboration in business environments, which emerged in the software domain around 2001 to cope with complexity in project management (WELLS & WILLIAMS 2002).
The pyramid model in figure 2.7 depicts the integrative architecture of organizational agility. In general, values capture fundamental views of what is genuinely valuable in an organization. While principles offer an instructive pattern on how to comply

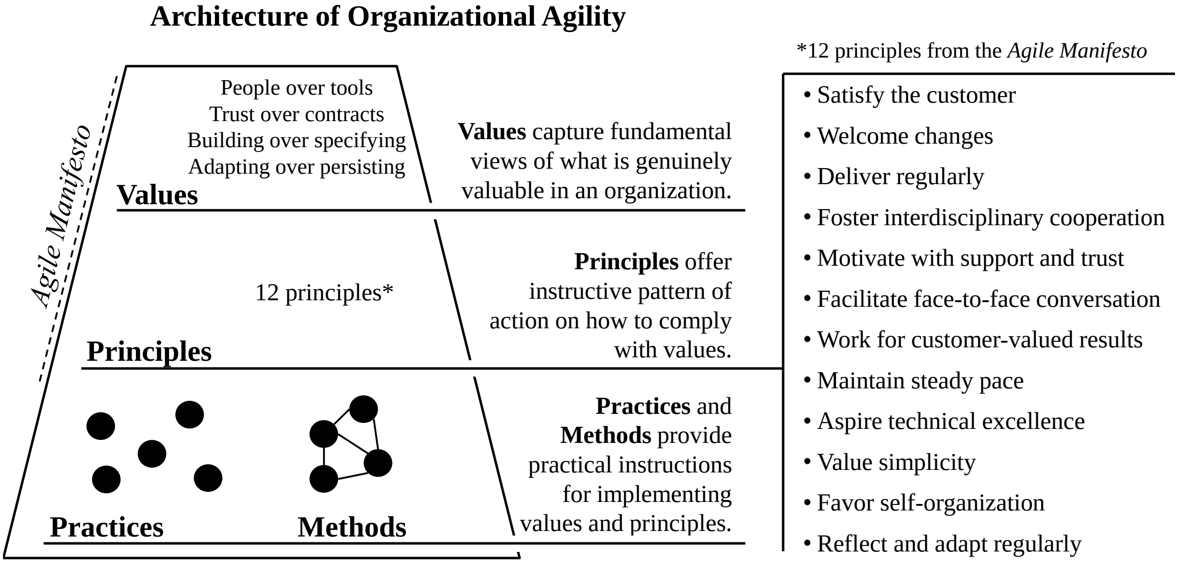

Figure 2.7: Organizational Agility complies to the Agile Manifesto by implementing its values and principles with tangible practices. Illustration developed with ROIDER *(2018) based on publications by* BRANDL *et al. (2021),* DOGS *&* KLIMMER *(2005),* FOWLER *&* HIGHSMITH *(2001), &* SCHNEIDER *(2015).*

with these values, practices provide tangible techniques for managers and employees, helping them to exercise in a certain or "good" way of working (BENDER-MINEGISHI 2018). According to this relation, agile practices are applicable techniques to operate in line with the values and principles of the *Agile Manifesto* (BRANDL et al. 2020). For instance, since interactions of *people* are more important than the *tools* they use (value), project teams and managers *foster interdisciplinary cooperation* (principle) to expand a group's knowledge and skills. In the *Scrum* framework, a very common set of techniques and routines based on the *Agile Manifesto* (cf. SCHWABER & SUTHERLAND 2017), a practice called *Daily Standup* brings together members of a collaborating group to mutually exchange new knowledge and feedback on their current work (GLOGER & SCHWABER 2013). Lately, scientific literature pays special attention to these modern project management approaches, also referred to as *Agile Project Management* (APM) (TIMINGER 2017).

2.4.2 Organizational agility in manufacturing companies

Organizational agility becomes an essential capability for manufacturers to stay competitive on particularly complex and unstable markets (J. KOCH 2017). Following the interpretation of organizational agility as a management capability, it is closely related to various approaches already known in manufacturing companies.

Agility & Change Management
Change Management, as presented in section 2.1.2, can also be interpreted as the intentional and systematic design, consulting, and assistance of change projects (BERGER et al. 2013). J. KOCH (2017), therefore, defines Change Management as an enabler for organizational agility in manufacturing companies.

HPM
The values and principles of the *Agile Manifesto* are considered self-sufficient and transferable to other domains (BRANDL et al. 2020) like agile production process planning (see SCHNEIDER 2015) or agile engineering of mechatronic systems (see KLEIN 2017). Approaches originating in the *Agile Manifesto* with the intention to enhance the agility of conventional project management, frequently are referred to as *hybrid frameworks* (HABERMANN 2013). Common examples are the *Hybrid-Stage-Gate* (see COOPER 2016), a derivative from the classical *Stage-Gate* model (see COOPER 1990), or the *Iterative and Visual Project Management 2* (IVPM2) framework (see CONFORTO & AMARAL 2016), both modifying and transferring *Scrum* (see SCHWABER & SUTHERLAND 2017) to a non-software-related domain. TIMINGER (2017) merges various approaches from the agile movement with conventional models under the umbrella term *Modern Project Management*.

Agility & the Japanese management philosophy
The Lean Management philosophy is also an integrated set of values, principles, and practices of "good" collaboration, putting emphasis on results that are coherent to what customers actually expect (BENDER-MINEGISHI 2018). Basic concepts of the *Agile Manifesto* are considered to be co-evolutionary related to the Japanese manufacturing industry and the TPS, as *The New New Product Development Game* by TAKEUCHI & NONAKA (1986) and a common emphasis on people development, personal observation, and work routines manifest (ROTHER 2010). Progress, in both philosophies, is primarily driven by – and originally descents from – a strong customer

orientation and a problem-solving routine, known as the *Deming Cycle* (cf. DEMING 1998). However, while the mindset at the *Toyota Motor Corp.* puts more emphasis on quality in the process (how value is created), the values and principles of the *Agile Manifesto* are generally result-oriented (what creates value) (BENDER-MINEGISHI 2018).

2.4.3 The *Knowledge-Creating Company*

The idea of the *Knowledge-Creating Company* originates from an article by Nonaka Ikujiro in the Harvard Business Review magazine in 1991. He describes how Japanese companies use organizational roles, structures, and practices to generate innovation through continuous improvement and knowledge creation, and thus create a sustainable competitive advantage. In a dynamic economy with volatile markets, organizational knowledge is considered to be the one reliable source of competitiveness (NONAKA 2007) and a strong driver behind innovation activities (CHAPMAN & HYLAND 2004). Japanese managers always underline the importance of learning from direct experience or from "trial and error" approaches (TAKEUCHI & SHIBATA 2012), which SNOWDEN & BOONE (2007) capture in their *Cynefin Framework* as "explorative practice". Organizational learning is not just a rational, intellectual process, but understood as a participatory, social experience that involves sense, emotion, intuition, and interaction (ARAM & NOBLE 1999).

Innovation in the Knowledge-Creating Company
Innovation implies to deliberately create instability, which entails risks and decreased performance (CHRISTENSEN 2008; KRUSE 2015). Such a strategy is sparsely appraised in conventional management models based on Management by Objectives (MBO) (ENGSTLER et al. 2015) that are predominantly build on quantifiable metrics for measuring the value of new knowledge in terms of increased efficiency, lower costs, or improved return on investment (NONAKA 2007). NONAKA observes, that most manufacturing companies in situations of complexity or crisis generally tend to use an instructional, commanding management style (NONAKA 2007). This “organized innovation” strategy (NONAKA & TAKEUCHI 1995), assigning explicit objectives to dedicated expert groups, uses authority as a form of structuring and motivation, what can result in resistance (BATE & BECKMANN 1997).

Analogous to the mountaineers utilizing their collective knowledge and techniques to cope with unknown problems in a field of crevasses (cf. figure 2.6), innovation teams in manufacturing companies need to operate in an adequate setting, that promotes pioneering skills, like systematic agility and quick learning (KORN 2016).
ROTHER (2010) accredits the capability of adapting an organization to unpredictable and dynamic market conditions to the concept of "people management" in a knowledge-creating company. Behind this simplistic term, first and foremost, lies a very distinct idea of "good work", which is then further broken down into precise and tangible instructions of how to achieve a respective work culture (BENDER-MINEGISHI 2018). In the Japanese manufacturing industry and at the *Toyota Motor Corp.* in particular, management is largely build on the assumption that the best-trained people will make the best products (BENDER-MINEGISHI 2018). From this basis, knowledge creating companies constantly challenge their employees to reflect what they take for granted, particularly in situations where architectural change is essential (NONAKA 2007). When confronted with complex challenges and phases of instability, managers in knowledge-creating companies provide a vision rather than explicit targets, and pay attention to systematic coaching more than instruction (NONAKA & TAKEUCHI 1995). This enables curiosity and dedication to knowledge creation among employees and as a result, drives radical innovation (BENDER-MINEGISHI 2018; NONAKA 2007).

Establishing knowledge-creating with the Toyota Kata Management Philosophy
In his book *Toyota Kata: Managing People for Improvement, Adaptiveness and Superior Results* ROTHER (2010) reveals that *Toyota's* achievements result from the invisible culture, mindset, and routines of experimentation and systematic coaching, rather than from the visible practices and tools often highlighted (ROTHER 2010). In Japanese martial arts, the term *Kata* describes "ways of thinking and behavior which, through constant practice and application, develop into routines that are performed almost reflexively" (KEITH 2019). Operative practice in the TPS involves two basic Katas, which every Toyota employee has naturally absorbed and managers carry out as their obligation: the *Improvement Kata* and the *Coaching Kata* (AULINGER & ROTHER 2017). While the *Improvement Kata* serves to systematically achieve problem-solving progress, with the *Coaching Kata*, managers teach the underlying mindset via mentor-mentee-relations throughout the organization (AULINGER & ROTHER 2017). This holistic management philosophy created a knowledge-creating on all hierarchy levels and departments, making the *Toyota Motor Corp.* efficient, successful in innovation,

and a sustainable, valuable organization (Rother 2010). This perception is profoundly portrayed and endorsed also by other authors (see, e.g., Aulinger & Rother 2017; Bender-Minegishi 2018; Liker 2004).

2.5 Conclusion

In this chapter *Fundamental Concepts*, basic terminology and mechanisms of BPI in manufacturing companies were outlined. First, reasons were adduced that manufacturing companies are experienced in exploiting proven pattern of incremental and continuous improvements to create stable business processes (section 2.1).
However, since a highly dynamic market urges them to ensure their long-term survival by investing in strategic technologies, they are confronted with complex BPI projects. These necessitate transitional phases of instability and, therefore, explorative capabilities (section 2.2).
Then, a deeper insight into approaches for managing the complexity of BPI projects in manufacturing companies revealed, that the emerging unanticipated technical problems in such projects require an explorative practice that systematizes problem-solving capabilities based on the pattern probe, sense, respond (section 2.3).
In the last section, organizational agility was introduced as a general approach for explorative practice in manufacturing companies. Insights into the *Toyota Kata* management philosophy revealed a systematized problem-solving routine and successful realization of the *Knowledge-Creating Company* concept. Gaining organizational agility with systematized problem-solving capabilities provides a novel perspective for managing complex BPI projects in manufacturing companies more effectively (section 2.4).

Working hypothesis
Based on the insights outlined in this chapter, the guiding idea formulated at the end of the previous chapter (1) can be for mulated as a working hypothesis, directing the focus for a more in-depth literature review:
The success of managing complex Business Process Innovation projects in manufacturing companies more effectively can be affected positively with organizational agility and explorative learning.

3 State of the Art Approaches in BPI

This chapter captures the state of the art in scientific concepts and approaches contributing to the effective management of BPI projects in manufacturing companies. The working hypothesis presented in section 2.5 opens up a wide perimeter for the literature research and constitutes the basis criteria for the identification of a research gap.

Perimeter for the literature research
As stated in the introduction and further outlined in chapter 2, supporting manufacturing companies in managing complex BPI projects requires a versatile set of organizational management capabilities. Since the field of operational science includes a broad spectrum (see subsection 1.3), this literature review focuses on methods and tools intended to facilitate transitional phases in manufacturing companies, characterized by complexity and instability: *Instability Management*. In contrast to many approaches in the field of manufacturing operations that can be classified as stability management, guiding through complexity and instability does require *Explorative Learning* and *Organizational Agility* rather than the optimization of established systems (MARCH 1991; NONAKA 2007; SNOWDEN & BOONE 2007).
As a result, the perimeter for the literature research includes publications in the fields of *Business Process Re-engineering* (BPR), *Organizational Change Management* (OCM), *Hybrid Project Management*, and *Explorative Validated Learning*, as depicted in figure 3.1. Publications in *Manufacturing Change Management* (MCM) or *Engineering Change Management* (ECM), as well as approaches for the *Agile Project Management* (APM) of strictly non-manufacturing related contexts are excluded.

The first section (3.1) explains why many BPR approaches turned out to be ineffective by analyzing their general ideas and shortcomings. One of the weak points is the lack of emphasis on the actual transformation of an organization including its people and habits.

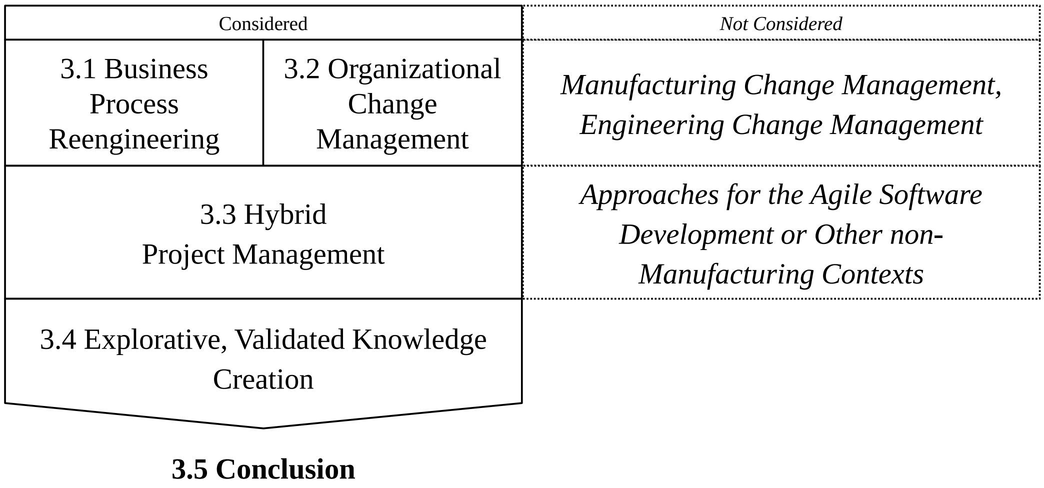

Figure 3.1: Scope of the literature research

Therefore, in section 3.2, OCM is presented as a field of research specifically addressing radical change and instability[1].
The combined findings from these two sections constitute a starting basis for assessing four *Hybrid Project Management* frameworks. The selected examples attempt to transfer agile approaches to specific use cases in manufacturing companies[2] (section 3.3).
In the fourth section (3.4), three distinct approaches were summarized under the headline *Explorative Validated Learning*. This section is strongly related to the management philosophy known as the *Knowledge-Creating Company*, mutually explanatory with the *Lean Management Philosophy*, and both emerging from the Japanese manufacturing industry.

[1] As outlined in subsection 2.1.2, from the perspective of manufacturing companies, managing change splits into organizational and technical categories, that also interact. Technical-oriented MCM process models are primary designed for "organizing and controlling the process of making alterations to a factory" (J. Koch 2017) and, therefore, rather can be categorized as concepts for incremental adaptions to manufacturing systems. The perspective of radical change in organizations is explicitly covered in Organizational Change Management (OCM) literature.

[2] The selected authors already successfully transferred *Scrum* to the manufacturing domain. This required profound modifications and as a result the creation of hybrid models. On this premise, the perimeter of the literature research does not include approaches for the Agile Software Development or other non-manufacturing contexts.

3.1 Conventional *Business Process Re-engineering* (BPR)

KHAN et al. (2018) provide a recent and comprehensive overview to the most common models in BPR. According to their in-depth analysis of four basic models by DAVENPORT & SHORT (1990), HAMMER & CHAMPY (2006), WASTELL et al. (1994), and JACOBSON et al. (1995), BPR follows a basic scheme of five phases: *Learning*, *Envisioning*, *Model Analyzing*, *Re-engineering*, and *Improvement* (KHAN et al. 2018). Figure 3.2 visualizes the resulting accumulated reference model.
According to the reference model by KHAN et al. (2018), all approaches propose an initial learning phase to identify processes, change enabler, and gather information. The authors agree that in the following phase, managers need to set an objective, a vision, or a directive based on actual levers and in compliance with values and the key business. Once the general direction is set, process engineers map current and define to-be processes by analyzing their gaps and deriving them hierarchically from the core value-creation. The actual re-engineering, so the authors, requires evolutionary implementation and change management effort. KHAN et al. (2018) conclude, that only a few procedural models consider the final continuous improvement by reflecting on the result and refining them , which is essential in any BPR project.

Conclusion
As already outlined in the introduction (see chapter 1), the classical BPR models have been criticized for being too top-down, instructional, mechanistic, and not adequately considering the complexity of changing an organization. Nevertheless, since these weak spots were revealed and they share a common goal of higher customer orientation and the conviction that incremental improvements alone do not achieve sufficient innovation to survive a turbulent market, the classical BPR models provide a valuable reference point for a novel BPI approach.

3.2 *Organizational Change Management* (OCM)

The implementation of re-designed business processes in manufacturing companies requires the systematic management of organizational change (HAMMER & CHAMPY 2006). The available amount of scientific and popular-scientific literature providing

KHAN ET AL. (2018)	**Learning**	**Envisioning**	**Model Analyzing**	**Re-engineering**	**Improvement**
DAVENPORT & SHORT (1990)	•Identify Process and IT	•Identify IT Levers •Set Objective Based on IT Capabilities	•-	•-	•-
WASTELL ET AL. (1994)	•Identify Enabler	•-	•Map and Define New Process	•Redesign Process by Evolution •Implement	•Analyze Result •Refine
JACOBSON ET AL. (1995)	•Gather Information	•Provide Directive •Identify Objective	•Hierarchical Architecture •Analyze As-Is Process	•Redesign Process Towards Objective •Implement	•-
HAMMER & CHAMPY (1993, 2006)	•Identify Process •Gather Information	•Set Vision Based on Values •Analyze Compatibility •Identify Key Business	•Analyze Gap As-Is/To-Be Process	•Redesign Process Based on IT Capabilities •Change Management	•-

Figure 3.2: Accumulated reference model for BPR by KHAN *et al. (2018) mapping the contributing models by* DAVENPORT & SHORT *(1990),* HAMMER & CHAMPY *(2006),* WASTELL *et al. (1994), and* JACOBSON *et al. (1995).*

models, processes, and frameworks under the search key *Change Management* is extensive. However, in their comprehensive analysis of OCM approaches, ROSENBAUM et al. (2018) come to the conclusion, that "all of the commonly used models" are basically refined versions of LEWIN'S three phases *unfreezing*, *moving*, *re-freezing* (see 2.4.2 or LEWIN 1947), substantiating it by "adding to apparent gaps, whilst focusing on different component parts". According to their study, many of the available approaches regard change as a *project* (see e.g. ACMP 2014; KOTTER 1996), others primarily as the systematic counteracting to individual *resistance* (see e.g. KÜBLER-ROSS 2005; PROSCI INC. 2003), and some concepts generally as a situational response by being *interpretative* in nature (see e.g. DUNPHY et al. 2007; NADLER et al. 1997) (cf ROSENBAUM et al. 2018). An excerpt of their study is visualized in figure 3.3. The authors conclude, that the various OCM approaches "are not unique characterizations of change on their own account; rather they can be viewed as the 'how to' of an enduring framework – Lewin's three-step model" (ROSENBAUM et al. 2018).

Conclusion

The comprehensive literature assessment by ROSENBAUM et al. (2018) reveals that the scientific community agrees on Lewin's basic model as a common ground for

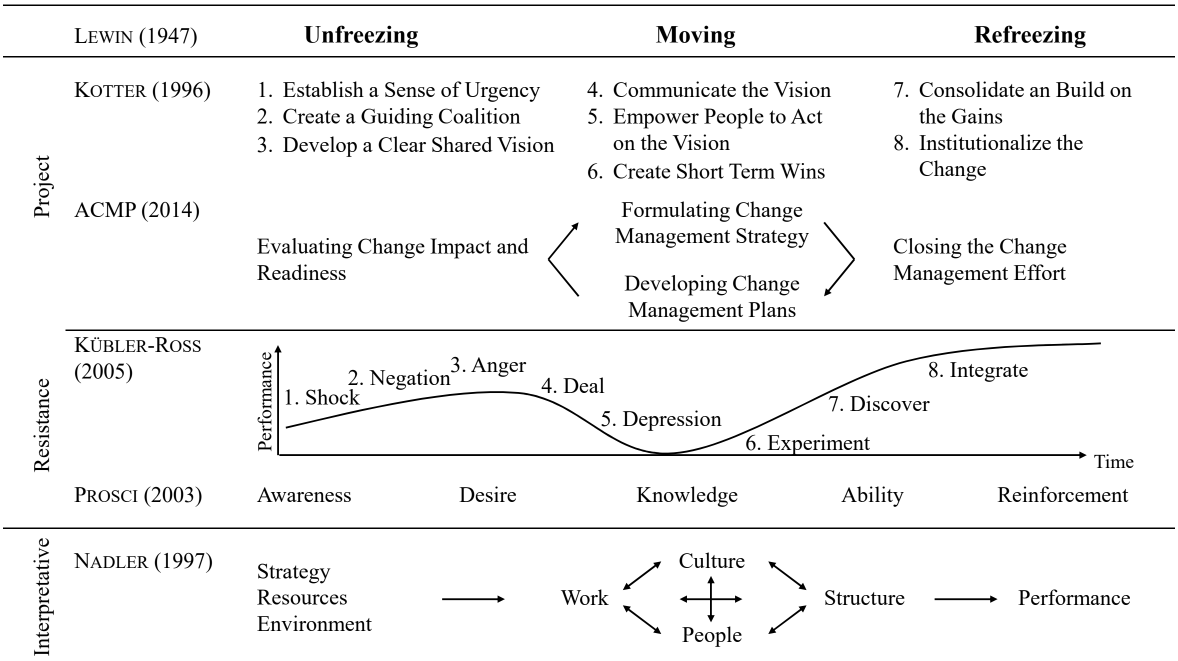

Figure 3.3: Excerpt of the accumulated approaches for OCM by Rosenbaum *et al. (2018) arising from Lewin's model (see* Lewin *1947) contributing the three predominant perspectives on change: project, resistance, and interpretative.*

any architectural change-related project in organizations. At the same time, the broad variety and distinct perspectives of the presented approaches suggest that the management of transitional phases in manufacturing companies requires a versatile set of change management aspects and case-specific model support for the coordination of emerging problems and resulting activities.

3.3 *Hybrid Project Management* (HPM) in Manufacturing Companies

Agile Project Management models (see section 2.4) are still heavily discussed in the scientific literature, as nearly 10.000 results on Google Scholar related to this topic from 2016 to 2020 suggest[3]. While agile frameworks are widely prevalent in the software development domain, in the manufacturing world they might have traversed

[3] Last checked: 12.06.2020

the *hype* peak and enter in the *disillusion* phase according to *Gartner's Hype Cycle*[4]. Yet, in manufacturing companies, particularly Hybrid Project Management models that combine agile with conventional elements gain in relevance due to the expectation of better competing on the complex market with constant innovation (COOPER & SOMMER 2018). The following models attempt to transfer the most prevalent agile framework *Scrum* (see e.g. GLOGER & SCHWABER 2013) to specific planning use cases in manufacturing companies.

3.3.1 *Hybrid-Stage-Gate*

SOMMER et al. (2015) were the first to coin the term *Hybrid* for describing their proposed symbiosis of conventional *Stage-Gate* models (see COOPER 1990) with *Scrum* to increase the flexibility and speed of development projects. They early recognized "a healthy tension between fixed planning and iterative problem solving, between process control and productive disorder" (SOMMER et al. 2015) as especially helpful when developing physical products.

COOPER (2016) later jointly proposed a three-layered planning model comprising a strategic, tactical, and operational project level (see figure 3.4). On the strategical planning level, classical *Stage-Gate* elements such as phases, milestones, and quality gates guarantee a project's general structure (SOMMER et al. 2015). To create more agility on the operational level, they insert elements from the *Scrum* framework. According to their concept, the operational project team identifies essential unknowns and uncertainties at the beginning of each project phase (or stage) and emphasizes on the critical assumptions with economic relevance. The team then gathers the missing information to validate these assumptions and formulates deliverables for the next gate to achieve. By this self-organizing routine, the group by itself defines its next tasks (COOPER & SOMMER 2018). On an intermediate tactical level, managers coordinate those tasks, provide required resources, and exchange knowledge between the strategic

[4] *Gartner's Hype Cycle* is a frequently adopted model for describing the visibility of technologies and trends comprising the five consecutive phases *trigger*, *peak*, *disillusion*, *enlightenment*, and *productivity*. Since multiple sources from various domains use and publish own versions of this framework, originally proposed by the *Gartner Inc.* (`www.gartner.com`), the validity of absolute statements is limited. However, the five phases provide a valuable, qualitative evaluation of how trends evolve.

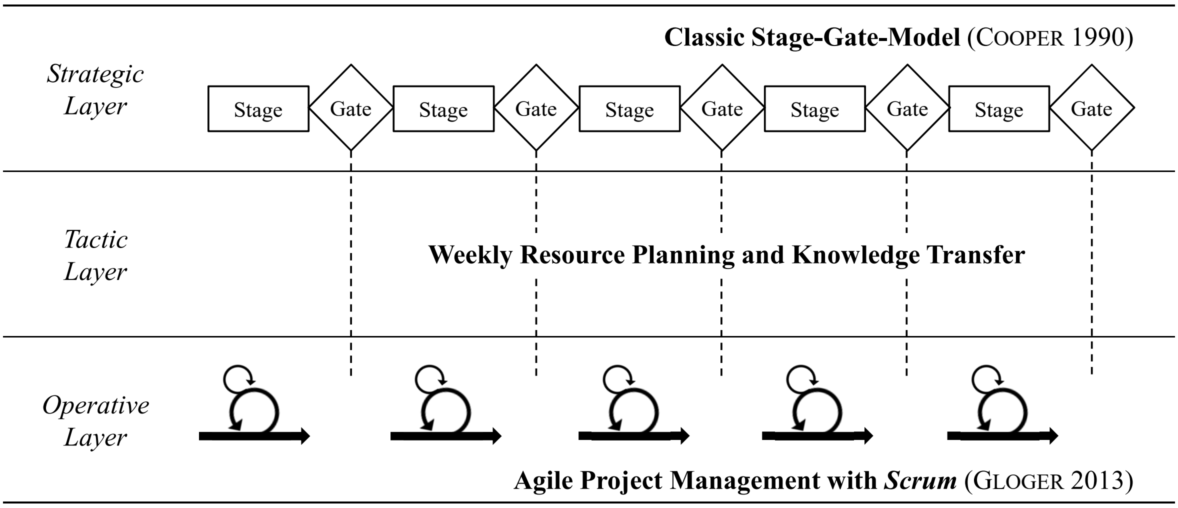

Figure 3.4: Hybrid-Stage-Gate according to COOPER *(2016),* COOPER *&* SOMMER *(2018), &* SOMMER *et al. (2015). The three-layered planning model integrates Scrum (see* GLOGER *&* SCHWABER *2013) on the operational level, maintaining the structure of stages and quality gates from Cooper's classic standard (see* COOPER *1990). Illustration developed with* ROIDER *(2018) and* RIDOLFI *(2020).*

and operational level (SOMMER et al. 2015).

The *Hybrid-Stage-Gate* provides a meta-structure for managing complex projects with more agility while maintaining the risk-limiting benefits of quality gates. However, SOMMER et al. (2015), COOPER (2016), and COOPER & SOMMER (2018) focus on the organizational structure. Problem-solving, workflows, or practical guidelines on how to increase agility on an operational level are not in focus. (RIDOLFI 2020; ROIDER 2018)

3.3.2 *Agile Process Planning* (APP)

With a similar intention, SCHNEIDER (2015) developed an *Agile Process Planning* (APP) framework for designing production processes in the automotive industry (see figure 3.5). The author adopts the short-cycle sprint iterations from the *Scrum* framework to create an incremental planning routine. Therefore, he distinguished between variable and invariable elements in the typical process planning approach applied by automotive manufacturers and specifically redesigned the variable elements. The proposed APP framework comprises agile principles, roles, artifacts, rules, practices, and a phase model based on the *Scrum* logic to restructure process planning projects. The approach starts with an exploration phase, in which the project team determines the organizational setting for the subsequent design, implementation, and ramp-up phases. The operational planners achieve their individual targets in sprints, corresponding to one increment[5]. At the beginning of each sprint, a tangible target is formulated as a list of open tasks. During a daily meeting, the team members discuss their progress and exchange knowledge. A sprint ends with the team presenting their results to the management and deriving lessons learned. (ROIDER 2018)

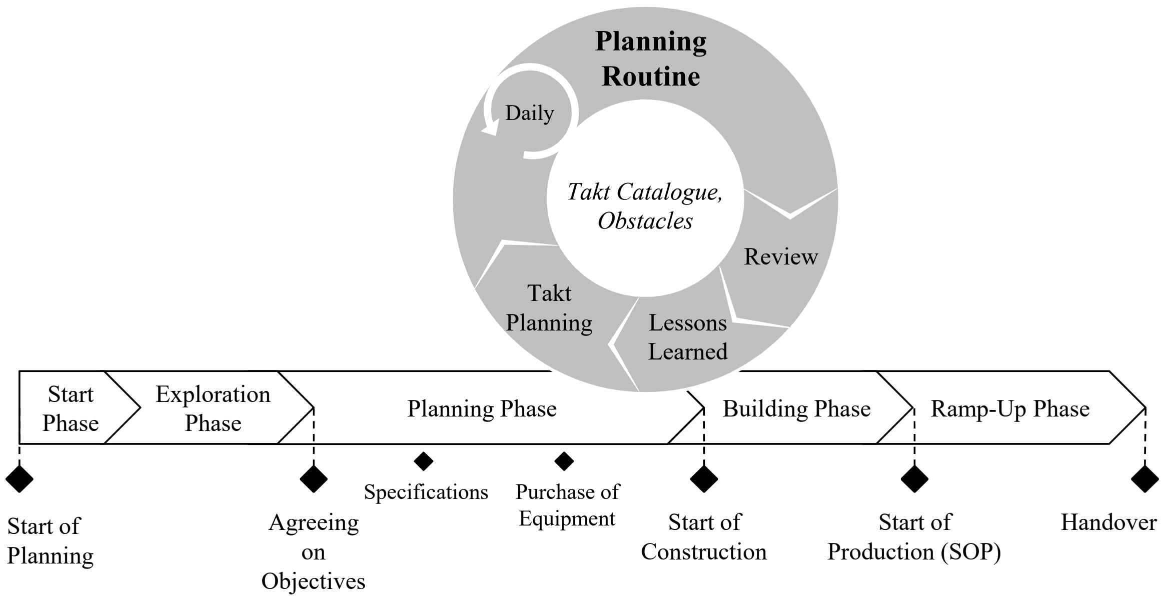

Figure 3.5: Agile Process Planning (APP) framework according to SCHNEIDER *(2015) adopting the short-cycle sprint iterations from the Scrum framework to create an incremental planning routine for designing production processes in the automotive industry.*

[5] In the *Scrum* framework, a *sprint* results in a product *increment*. both represent a central concept in the *Scrum* framework to express, measure and demonstrate work progress to a customer (GLOGER & SCHWABER 2013).

The author proposes an adequate and promising framework to deploy *Scrum* techniques in the process planning procedures of the automotive industry, however, to the disadvantage of completely restructuring the current way of working and without a tangible proposal for transition. He thus leaves little power of decision to the project managers, whether a hybrid approach is beneficial in a specific situation based on the actual problems a team faces. The APP model is a highly specialized approach supplementing the well-established matrix-organizational structure and procedural models in the automotive industry providing, however, an excellent sample for agile project management in the manufacturing domain. (ROIDER 2018)

3.3.3 *Agile Engineering*

KLEIN (2017) compiled an agile methodology for the project management in the engineering domain of mechatronic systems systematizing the continuous adaption to changing requirements by the customer. Analogous to the APP, the author created a hybrid process framework by primarily integrating *Scrum* elements into established standard development procedures from the mechanical and plant engineering domain (see figure 3.6).

Strategic planning evolves by translating *User Stories* (features demanded and formulated by the customer) into the *Product Backlog* (items that need to be developed to create these features) (cf. GLOGER & SCHWABER 2013). During the subsequent tactical planning, the team selects items from the *Backlog* list, transforms them into tasks and schedules sprints to compile them to *Product Increments*. KLEIN (2017) supplements this basic *Scrum* procedure with a decision tool for giving a project manager the choice on how many agile elements they want to apply in their engineering project. Therefore, each activity designated to the development of machinery parts is linked to specific agile techniques by systematically evaluating the potential of increasing their performance. As a result, the provided model links the elements of two worlds (mechanical engineering process and agile framework) based on expert evaluation captured in a domain mapping matrix. The project manager individually selects activities from the provided development process for mechatronic systems at the beginning of an engineering project. Any combinations and sequence of activities are allowed. Based on this input, the developed matrix model proposes applicable

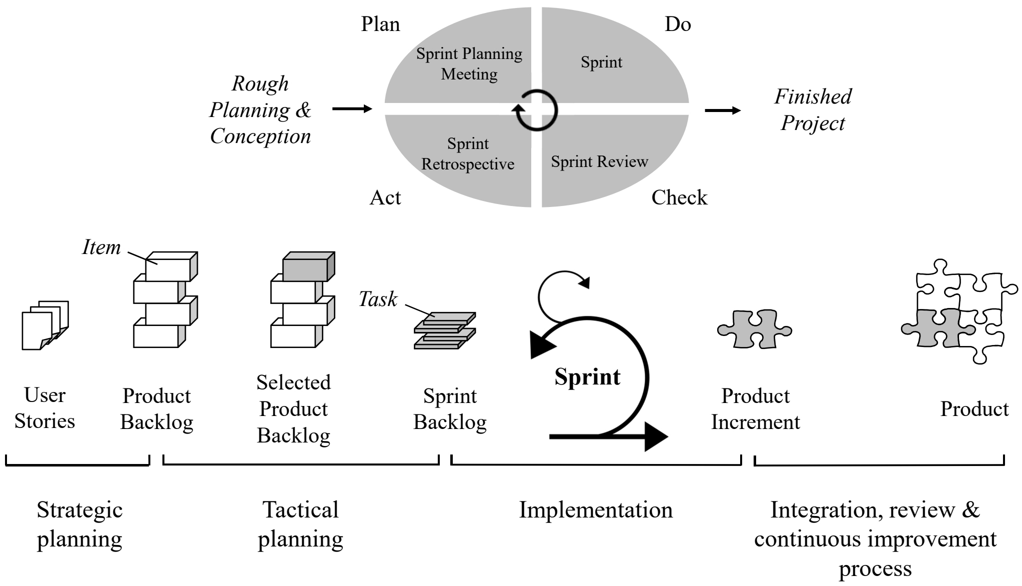

Figure 3.6: Agile engineering framework according to KLEIN *(2017) adopting the short-cycle sprint iterations from the Scrum framework to create an incremental planning routine for the engineering of mechatronic systems.*

agile artifacts. The author recommends at this point, that in order to successfully deploy these selected practices from the *Scrum* framework, individual expertise and experience by, e.g., a dedicated *Scrum Master*, are generally indispensable. (KAGERER 2017b)

In conclusion, KLEIN (2017) proposes a tailorable development process for mechatronic systems that is supplemented with a variable set of agile techniques from the *Scrum* framework. The approach effectively adopts agile project management to the mechatronic domain and provides a linking matrix model for individual tailoring. However, the model is domain-specific to the mechatronic domain due to its underlying input criteria and leaves open space for research in how to gradually deploy the selected agile elements. (KAGERER 2017b)

3.3.4 *Iterative and Visual Project Management 2* (IVPM2)

CONFORTO & AMARAL (2016) developed a workflow-oriented method that refines the general idea of a hybrid project management approach for the application in technology-oriented innovation projects. The *Iterative and Visual Project Management 2* (IVPM2) method also comprises three planning levels, however, facilitates the application with a seven-step iteration cycle, and five visualization tools (see figure 3.7). Similar to COOPER (2016) *Hybrid-Stage-Gate*, a macro planning level determines the phases, milestones, and macro deliverables of the entire project (step 1). On the integration level, managers specify the goals to smaller units and prioritize tangible goals into a processing sequence by applying planning tools from the *Scrum* framework (step 2) and by updating a central coordination data base (step 3). Team members on the operational, micro planning level, achieve results by defining (step 4) and completing individual tasks in sprints (step 5). Based on an automated performance report (step 6), the project team then plans the next iteration (step 7). (RIDOLFI 2020; ROIDER 2018)

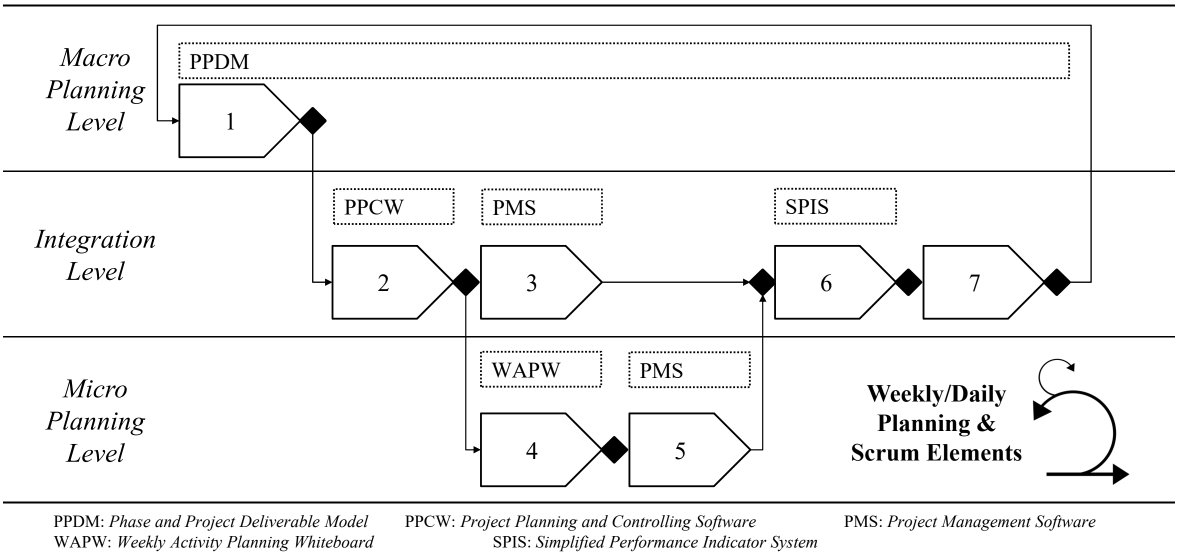

Figure 3.7: Iterative and Visual Project Management 2 (IVPM2) framework according to CONFORTO & AMARAL *(2016) adopting the short-cycle sprint iterations from the Scrum framework to create a workflow-oriented, incremental planning routine for the application in technology-oriented innovation projects. Illustration developed by* ROIDER *(2018).*

This seven-step, iterative routine helps the team to proceed in a project, while the proposed five visualization tools best-practices to visualize and coordinate the project structure, deliverables, performance, and progress. For a successful application, the authors suggest to consider the individual team characteristics, employee competencies, corporate culture and structure, available resources, technological uncertainty, and the current market situation as critical factors in the application of the IVPM2 method. However, they underline the challenge of analyzing these critical factors before and during projects. The IVPM2 method does not provide a structured decision support on whether an actual problem situation is suitable for an iterative progress strategy. (RIDOLFI 2020; ROIDER 2018)

Conclusion

The investigated Hybrid Project Management approaches altogether provide an archetype for coping with project complexity. The authors propose reasonable and promising frameworks constituting a reference for more project agility. Apart from the APP framework, all models suggest a three-layer model separating strategic (macro) from tactic (integration) and operative (micro) planning activities. All authors include iterative feedback loops (mostly complying with the sprint logic from the *Scrum* framework) to coordinate project progress.

With the *Hybrid-Stage-Gate* the authors put emphasis on sustaining a generic organizational meta-structure by relying on quality-gates. APP and *Agile Engineering* are two attempts primarily integrating *Scrum* elements into very specific planning use cases in the automotive and mechatronic industry. The IVPM2, by contrast, is a generic, workflow-based methodology with a strong focus on information gathering and visualization.

Summarizing the author's statements, a successful application of their models requires specific employee competencies, a corresponding corporate culture, and additional expert resources. This leads to the assumption that Hybrid Project Management can only work successfully as a holistic approach that demands initial skill adaption training. However, the authors do not consider the effort to change the current way of working adequately nor do they provide a transformation guidance for project managers. Additionally, the approaches leave little intelligence and authority to project managers to decide, whether an agile or hybrid organization is actually beneficial in a specific situation.

3.4 *Explorative Validated Learning* (EVL)

The organizational and structural aspects of Agile and Hybrid Project Management reflect a novel philosophy for coping with project complexity. Their roots however, are deep-seated in the Japanese manufacturing industry (see subsection 2.4.3). NONAKA (2007) outlined how Japanese managers use challenges, routines and coaching to generate innovation through Explorative Validated Learning. Based on structured experiments in a closed loop, incremental learning achieves results in a complex problem situation. In this section, three related concepts for systematic knowledge creation based on experimental validation are presented. *The Lean Startup* method is a project progress routine for new business ideas through validated knowledge creation using direct customer feedback (3.4.1). It therefore uses an auxiliary tool called *Minimum Viable Product* (MVP) representing the latest viable version of the business idea (cf. RIES 2019). Building on this approach, SCHMITT & SCHUH (2019) propose a corresponding *Minimum Viable Production System* (MVPS) allowing a similar internal feedback between the concurrent product development and planning of a production system (3.4.2). The section then provides a deeper insight into the *Toyota Kata Management Philosophy* (see section 2.4.3) as a holistic institutionalization of Explorative Validated Learning (3.4.3).

3.4.1 *The Lean Startup & Minimum Viable Product* (MVP)

Eric Ries, a successful entrepreneur, wrote a book called *The Lean Startup* describing a method on how to quickly and successfully start and grow ventures by systematically reducing risks for failure (see RIES 2019). The book gained broad publicity outside the scientific community. Apart from that, the suggested methodology captures the author's personal several experiences and is widely acknowledged for arsing from the ideas and tools of *Lean Management*, as well as being compliant with the values and principles of the *Agile Manifesto*. *The Lean Startup* method is a fundamental approach to innovative product development processes, which enables entrepreneurs to increase the chances of success of their company by using targeted procedures and techniques. RIES (2019) defines an entrepreneur as a person who develops a new idea within an uncertain or complex context and recommends his approach for enabling continuous innovation not only in startups but also in organizations of any size and from any industry. He argues, that the latter equally dependent on successfully implementing innovations, as these enable indispensable growth and thus ensure their future existence. (cf. RIES 2019)

The Lean Startup method transports the idea of “waste reducing” through iterative “validated learning” to the management of a startup company[6]. In such an enterprise, the validated learning process marks the significant performance indicator for progress and comprises activities that enable systematic learning about customer needs. The model, for this purpose, suggests to perform experiments by following the basic scientific procedure: formulate a hypothesis, build an experiment, and then verify it by collecting data. A startup company, collects data by observing a customer’s feedback when interacting with preliminary product versions. RIES (2019) calls these “MVPs”. (RIDOLFI 2020)

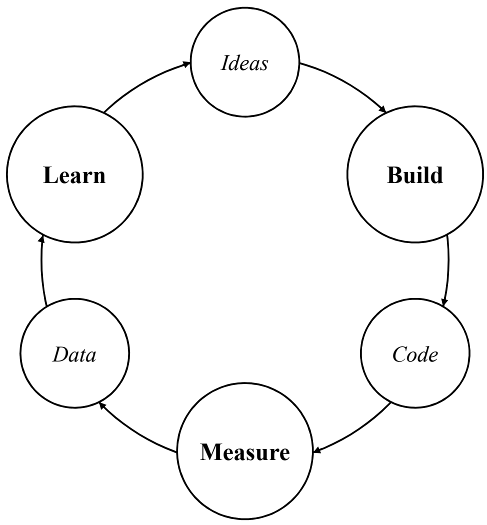

Figure 3.8: The Build-Measure-Learn (BML) cycle represents the core of The Lean Startup methodology by applying a basic scientific procedure (in accordance with RIES *2019).*

[6] A startup is a form of human organization that develops new and innovative products or services within uncertain and insecure environments (RIES 2019)

The MVP marks the starting point for the initiation of an iterative *Build-Measure-Learn* (BML) feedback loop building the central model of *The Lean Startup* method (see figure 3.8). It facilitates developing a sustainable business model through experiments and organized learning. RIES (2019) explains, that the MVP is not necessarily the smallest or cheapest version of a product, but the next one that allows a complete run through the BML feedback loop. The complexity and nature of a MVP can vary on various factors like the company or industry. Since the prototype is meant for testing basic hypotheses during one iteration, any functions and components not essential to the learning cycle should be omitted. To make innovation accountable in a disruptive environment, RIES (2019) proposes a specific "innovation accounting" method to find out whether real progress is being made through validated learning. It involves creating and testing a MVP for data collection, refining, and improving it through micro-modifications, and deciding on maintaining or changing the current course. By continuously running through this BML feedback loop, startups can react quickly to changes and manage adaptations, so that these rapid learning processes lead to successful innovations and sustainable competitive advantages. (RIDOLFI 2020)

Conclusion

The Lean Startup method is a project progress routine for new business ideas based on validated knowledge creation through constant customer feedback. It therefore uses a *Minimum Viable Product* (MVP) as the most recent successful cycle of a *Build-Measure-Learn* (BML) routine for creating something to utilize that allows customer feedback. In contrast to the hybrid project management approaches presented in section 3.3, *The Lean Startup* methods shows its strength in moments when no conventional phases and quality gates provide a general ”backbone”. In manufacturing companies, the superordinate management or in SMEs the proprietors usually provide a strong organizational frame. However, if the project complexity impedes a careful top-down planning of milestones upfront, for example in early phases, the BML routine might serve as a promising reference for project teams. COOPER (2017) proposes a similar approach within the hybrid *Stage-Gate* model for product innovation, the *Build-Test-Feedback-Revise* (BTFR) cycle. FURR & DYER (2014) describe in their work *The Innovator‘s Method* a related *Hypothesis-Test-Learn* (HTL) loop for the successful implementation of innovation ventures and effective management of problems characterized by high uncertainty. While the pattern have a diverging focus (product prototype development and testing of business hypothesis), the underlying ideas coincide. *Build-Measure-Learn* (BML) loop conforms the *Probe-Sense-Respond* cycle implementing *Explorative Practice* for solving complex problems (see *Cynefin* framework in figure 2.5). (RIDOLFI 2020)

3.4.2 *Minimum Viable Production System* (MVPS)

The *Minimum Viable Production System* (MVPS) is a concept for extending Ries' idea of the MVP to an integrated agile planning method for products and production systems (cf. SCHMITT & SCHUH 2019). The authors state, that to achieve rapid-response capabilities for customer needs during the development of automobiles, modern project management models involve highly iterative feedback loops and short cycles. The resulting product characteristics, however, stress the factory planning procedures with continuous new input in order to ensure a synchronization between product and factory development. As a consequence, production systems need to be designed in such a way that they allow rapid adaptability of characteristics and flexibility of production quantities. On this premise, SCHMITT & SCHUH (2019) propose a MVPS to allow early testing and obtaining customer feedback on the production system. (RIDOLFI 2020)
Similar to Ries' concept of the MVP, they argue, that their approach enables the determination of added value for the customer through the product ("benefit hypothesis") as well as the potential possibility to generate growth through the product ("growth hypothesis") (SCHMITT & SCHUH 2019). According to their proposal, the MVP is constantly being further detailed by the sub-sequential, cyclical feedback of the customer and completed by the addition of functions and components. Since changes of the product during its development cause further changes in the production system, the authors recommend the MVPS model to ensure a fast validation of the production processes and to facilitate feedback on the manufacturability and costs. The authors make clear, that the MVPS is a production system with a reduced degree of automation and a limited scope. SCHMITT & SCHUH conclude, that a MVPS should allow producing actual parts with processes close to production series and feedback to the product development. The approach is meant to facilitate the coordination of factory planning and product development. Their interplay with the MVPS and the MVP is depicted in figure 3.9. (RIDOLFI 2020)

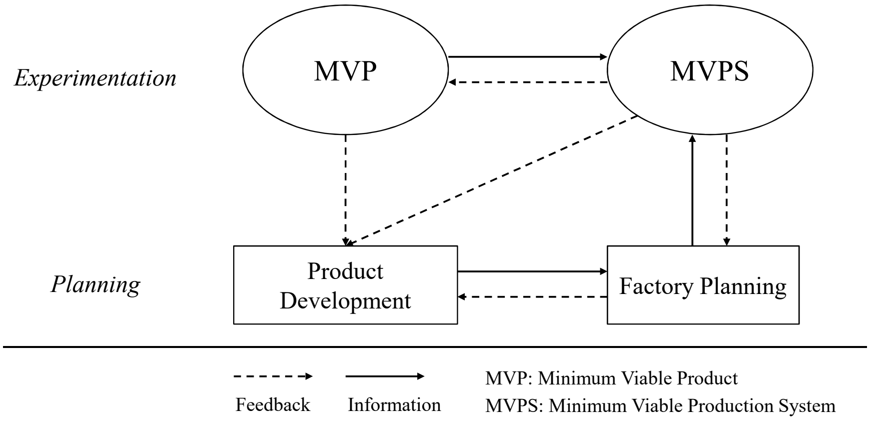

Figure 3.9: The interplay between the MVPS and the MVP within the concurrent engineering of products and production systems (in accordance with SCHMITT *&* SCHUH *2019). Illustration developed with* RIDOLFI *(2020).*

Conclusion

The MVPS approach consequently extends the concept of the MVP to a broader scope especially in manufacturing companies. The primary focus is set on the innovation of product technologies or as mentioned by the authors, the development of new automobiles with innovative technologies. During the design process, new product requirements emerge continuously and become input-planning parameters for the factory planning team. As a promising solution, the authors strive for an agile manufacturing system and a corresponding agile factory planning approach. With regard to a complex BPI project, what remains unresolved is the actual progress strategy of experimental, validated learning embedded in a hybrid project management structure. (RIDOLFI 2020)

3.4.3 *Toyota Kata Management Philosophy*

As presented in section 2.4.3, many methods and tools for efficiency and quality management in manufacturing companies are related to the *Lean Philosophy*. WOMACK et al. (2007) and other authors underlined that these approaches arise from an underlying corporate mindset with an emphasis on people and their routines of continuous organized learning through scientific experimentation (see e.g. AULINGER & ROTHER 2017; BENDER-MINEGISHI 2018; LIKER 2004; ROTHER 2010). As mentioned before, the *Toyota Kata Management Philosophy* constitutes a central element in practicing this mindset with its two essential routines: the *Improvement Kata* and the *Coaching Kata* (cf. section 2.4.3). The *Improvement Kata* implements the problem solving, whereas the *Coaching Kata* applies the concept of on-the-job training (AULINGER & ROTHER 2017). Both are generally neutral content-wise and can be applied by any person in any position in a company (ROTHER 2010).

Improvement Kata

According to the observations by ROTHER (2010) at the *Toyota Motor Corp.*, the *Improvement Kata* is a progress routine for solving complex problems on various corporate levels. Achieving sustainable innovation needs the management and the operational teams to steadily apply the following pattern (see also figure 3.10).

1. Provide a vision and a direction; understand the direction and the underlying challenge.
2. Analyze and assess the current state.
3. Determine and define a next target state.
4. Eliminate or solve occurring problems and obstacles during the pursuit of the next target state by applying fast, iterative PDCA-cycles.

According to ROTHER (2010), steps 1 to 3 are defined as the planning phase, with step 4 characterizing the implementation. The senior management provides a strategic vision to set a direction for all innovation activities and projects in a company (step 1). The corporate vision is not just a quantitative goal, but rather a description of a state that the company wants to achieve in the future, or an ideal picture of it. The challenges emerging while heading in the direction of the vision then need to be formulated as next target states (step 3). Analyzing the current state beforehand (step 2) is what makes these target states tangible. During step 4 of the *Improvement Kata*, people perform the Plan-Do-Check-Act (PDCA) cycle to achieve daily progress by eliminating obstacles and learn through experimenting. (ROTHER 2010)
What ROTHER described to be key to success in this management model at Toyota, was a consistent down-cascading of the superordinate challenge into tangible target states, a three-month scope for the iterative-progressive planning of steps 2 to 3, and

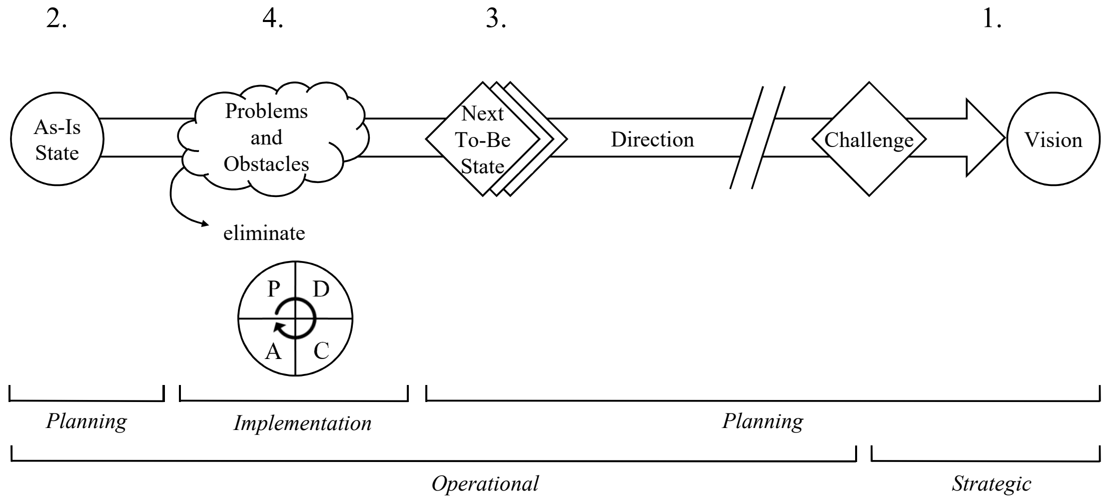

Figure 3.10: The Improvement Kata in accordance with AULINGER & ROTHER *(2017).*

the daily experimentation in small steps. Becoming effective as a company complying to this management philosophy, requires contentious training by coaching. (LOHNER 2018; RIDOLFI 2020)

Coaching Kata

ROTHER (2010) further elucidates, that the *Coaching Kata* is a structured mentor/mentee dialogue ensuring a constant teaching and training of the *Improvement Kata*. It is practiced in all areas and on all levels across all hierarchies within the *Toyota Motor Corp.* The mentee is supposed to find solutions through self-awareness with the mentor's methodological guidance and, if necessary, a directive decision support. The dialogue is structured with another routine of five standard questions asked by the mentor basically to facilitate the mentee's to application of the PDCA experiments.

1. *What is the next target state?*
   Create awareness of the problem.
2. *What is the current state?*
   Capture the actual situation.
3. *What are the current obstacles that prevent you from achieving the next target state? Which of these obstacles will you tackle next?*
   Examine the causes for the current situation and the mentee's thought process.

4. *What is your next step? What do you expect to learn from it?*
   Stimulate developing and testing.
5. *When can we look at the learning outcomes of this step?*
   Agree on a follow-up.

In case the mentee struggles in answering the third question, the mentor can interpose four additional reflective questions on the previous step: *What was your previous step? What did you expect? What actually happened? What did you learn from it?* The dialogue does not push the mentee in a certain direction, but helps the mentor to understand the mentee's thought processes and thereby align the coaching[7]. The interplay of routines substantiates the *Toyota Kata* for being a *Practical Problem Solving* approach[8] with a bidirectional information flow. (LOHNER 2018; RIDOLFI 2020)

Conclusion

The *Toyota Kata Management Philosophy* can be characterized as a set of scalable routines for managing innovative organizations (AULINGER & ROTHER 2017). With cultural development and coaching-backed exercises, an explorative mind-set can be achieved, building the foundation of a learning organization or knowledge-creating company. The approach demands a company-wide commitment and alignment of all people, managers, and operators likewise. For most manufacturing companies, this implies a profound cultural transformation. However, such a shift in values and principles in the modus operandi can start with two persons, a mentor and a mentee, performing the *Coaching Kata*. The mentor avoids the role of a job scheduler and supervisor, but rather acts as a methodical supporter to get the best out of each mentee. As a result, by applying the *Improvement Kata* routine, project teams can overcome phases of instability and complexity (cf. section 2.2) in a self-organized, yet systematic progress. (LOHNER 2018; RIDOLFI 2020)

[7] For more detailed information on the Toyota Kata Management Philosophy and the *Improvement* and *Coaching Kata* in particular, ROTHER 2010 or AULINGER & ROTHER 2017 should be considered.

[8] *Practical Problem Solving* is a capability to deal with problems in a practical and logical approach, with decisions being made on the basis of profound considerations (MALTBY et al. 2011).

3.5 Synopsis

The conclusions in the first two sections (3.1 & 3.2) suggest, that the presented BPR- and OCM-based approaches build the historical and methodological foundation for any BPI projects in manufacturing companies. Designing new business processes demands analytical understanding of the status quo, the creativity to envision an ideal state, technical capabilities for an in-depth comprehension, and the social skills for changing and improving an organization effectively. Lewin's three phases *Unfreezing*, *Moving*, *Refreezing* describe the essential steps any person, group, and organization need to surpass for successful innovation. Therefrom it should be concluded that a BPI procedural reference model should combine and refine these two fields in operational science, considering complexity, organizational agility, an explorative learning (see figure 3.11).

Related Approaches for Managing BPI Projects in Manufacturing Companies

	BPR	OCM	Hybrid Project Management				Explorative Validated Learning		
	(Khan 2018)	(Rosenbaum 2018)	**Hybrid-Stage-Gate** (Sommer 2015, Cooper 2018)	**Agile Process Planning** (Schneider 2015)	**Agile Engineering** (Klein 2017)	**IVPM2** (Conforto 2016)	**Lean Startup & MVP** (Ries 2019)	**MVPS** (Schmitt 2019)	**Toyota Kata** (Rother 2010, Aulinger 2017)
Analysis of Complex BPI Projects in the Industry	○	○	○	○	○	○	○	○	○
Practical Guidance to Address Complexity	○	○	○	○	○	○	○	○	○
Procedural Reference Model	◑	◑	◑	◑	◑	◑	◑	◑	◑
Organizational Agility	○	○	●	●	●	●	◑	◑	◑
Explorative Learning/Problem-Solving	○	○	○	◑	○	◑	●	●	●
Guidance/Convenience of Implementation	○	○	○	○	○	○	○	○	◑

Legend: ● *Fulfilled* ◑ *Partly Fulfilled* ○ *Not Fulfilled or Considered*

Figure 3.11: Overview on the literature of related approaches for managing BPI projects in manufacturing companies.

The subsequent review of Hybrid Project Management approaches, first, serves as an indicator for the benefits and drawbacks of establishing agile elements in the structures and conventions of manufacturing companies. The results e.g. show that a consistently proposed three-layer planning model constitutes a promising frame for creating organizational agility in manufacturing companies and the in-depth analysis of the four reviewed frameworks reveals indications for a procedural reference model and opportunities for explorative learning in technical projects (see figure 3.11).

The review exposes the disadvantages of theses hybrid models, as they require a pre-restructuring of the project. An obligatory paradigm-shift is another central aspect of developing an agile, customer-oriented work culture within the structures and habits of a manufacturing company. These are used to upfront-planning and performance assessment based on pre-defined objectives (NONAKA 2007). The reviewed hybrid models leave little room for maneuver to the project managers, whether such an approach is beneficial in a specific situation[9]. The reviewed hybrid approaches provide only basic information and guidance for project managers to motivate for and accomplish such a change (guidance for implementation). This requires great effort and convincing arguments, if the expected benefits are not tangible nor linked to current problems a project that managers and their teams are facing. This could lead to the paradoxical situation, that in cases a paradigm-shift might be advantageous, there are not enough resources nor time for it.

In the last section (3.4) three approaches are outlined under the caption *Explorative Validated Learning (EVL)*. The title suggests that these models are rooted in the idea of experimental learning in organizations. The models do not particularly provide procedural reference for managing complex BPI projects nor do they address complexity (see figure 3.11). *The Lean Startup* adopts ideas and problem-solving concepts from the *Lean Management Philosophy* and has, like *Agile Project Management*, its ideological origin in the Japanese manufacturing industry[10]. For Eric Ries, the author of *The Lean Startup*, in complex problem situations, progress is accomplished by *Explorative Validated Learning*. This concept builds on rapid scientific experimentation and is identical to the idea behind the *Knowledge-Creating Company*. As outlined in the conclusion of the respective section (see section 2.4.3), the *Toyota Kata*

[9] Not least, the *Scrum* framework, which is usually adopted as an operational planning and implementation routine, is originally intended to develop a software product and, therefore, uses IT-specific language and roles. Hence, it does not per se provide sufficient domain-specific guidance for BPI projects.

[10] Takeuchi & Nonaka coined the first ideas for *Scrum* in their publication *The New New Product Development Game* in 1986 (TAKEUCHI & NONAKA 1986).

Management Philosophy constitutes an integrated management approach that focuses on the continuous innovation of business processes with a strong emphasis on the individual learning of persons. The concept achieves good results, when there is an existing process to be improved. In the typical BPI project, however, there is none or a significantly different *As-Is* state. In this gap, the MVP model from the *The Lean Startup* can be placed, since it is designed for creating something novel. The integration of *Improvement* & *Coaching Kata* from the *Toyota Kata Management Philosophy* with the MVP, respectively the MVPS, concept provide promising opportunities to create problem-solving capabilities based on explorative validated learning in complex BPI projects.

As a conclusion, the models and approaches in the reviewed literature do not provide a comprehensive method for managing complex BPI projects. The following shortcomings guide the subsequent analysis of actual cases in the industrial practice.

Shortcomings from the literature

Shortcoming 1: No analysis of actual complex BPI projects in the industry
The reviewed literature does not provide insights in actual complex BPI projects in the industrial practice.

Shortcoming 2: No practical guidance to address complexity
None of the reviewed approaches provides sufficient guidance to address project complexity.

Shortcoming 3: No applicable procedural reference model particularly for complex BPI projects in manufacturing companies
Neither Hybrid Project Management models nor approaches from the subject area Explorative Validated Learning provide sufficient procedural reference for practitioners to manage complex BPI projects in manufacturing companies.

Shortcoming 4: Insufficient guidance for an implementation of a novel BPI approach
As the only approach in the regarded line-up, the *Toyota Kata Management Philosophy* offers a promising implementation concept for a novel BPI method in manufacturing companies.

From the aggregated shortcomings results a research gap that entails a merge of these different concepts into an integrated methodology for managing complex BPI projects through explorative problem-solving based on validated learning. In the following chapter, these shortcomings are reflected with a more in-depth insight into the actual practice of managing complex BPI projects in manufacturing companies.

4 Best Practice & Actual Needs in the Industry

Within the *Descriptive Study I* of the DRM, Blessing & Chakrabarti (2009) suggest to gather empirical data from current practice in industry in addition to the literature analysis. This insight into actual BPI projects and expert experiences underlines the relevance of supporting manufacturing companies, or more specifically their project managers and teams, in coping with complex BPI projects. Besides, it also offers a more precise understanding of the motivation and goals addressed in the introduction (*Research Clarification* in chapter 1). As a result, the documented experiences and cases in this chapter address the first research question (see section 1.3) and provide empirical data for the design of a new methodology (*Prescriptive Study*).

The following analysis of industry practice is guided by the impression that in manufacturing companies of any size and production type[1] BPI is encountered in various facets, at different stages, to several extents, and at many complexity levels. Within this chapter, exemplary public information of failed BPI projects is gathered (4.1), followed by an online survey on the broader conceptions of innovation, agility, and modern project management in the manufacturing industry (4.2). Thereafter, a case study covering two diverse BPI projects in two different manufacturing companies (I & II) delivers better understanding of the current practice in industry in coping with complex BPI projects (4.3). Finally, a series of more in-depth interviews with selected experts portrays firsthand account on this topic (4.4). The chapter concludes with refined shortcomings for the intended methodology on supporting manufacturing companies in managing complex BPI projects.

[1] Ranging from SMEs to international corporations, with manufacturing products in small, medium or large series.

4.1 Reports from failed ERP Implementation Projects

Implementing a new ERP system was a typical, efficiency-motivated BPI project in the 90's and 2000's to reduce operating costs, increase productivity, and improve customer service quality (BEOR & MANDAL 2000). Apart from these, strong incentive for starting a ERP project arises from a company's necessity to harmonize and integrate various data, IT systems, and processes which have grown over the years at different locations (BARKER & FROLICK 2003). These factors make such an implementation a company-wide project where the adequate management of the involved complexity and emerging technical and organizational problems has significant influence on its success (CHEN et al. 2009; FRANCALANCI 2001).
In the industry study from 2018 already mentioned in the introduction (see chapter 1), KROKER (2018) reports on the unsuccessful SAP implementation project "Magellan", intended to integrate system infrastructures of *Deutsche Bank* and *Postbank*. The project was abrupt in 2015 and commented in the news to have suffered from obvious inconsistencies in a uniform project vision (REXER 2016). The study by KROKER (2018) identifies similar settings in other failed ERP implementation projects, like *Otto Group* (2009), *Deutsche Post* (2015), and *Lidl* (2018). The portrayed issues in these projects coincident with earlier findings by BARKER & FROLICK (2003) & CHEN et al. (2009): a lack of a clear project structure and well defined objectives, improper planning and organization of the project phases, poor, insufficient, or unstructured communication within the project team , as well as a misconception of and lacking sympathy for BPI and change in general.
These reported cases underline the complexity of certain BPI projects, like implementing an ERP system in a company. Apart from these rare examples, the only available information is accessible by interviewing experts and documenting industry cases.

4.2 Industry Survey

Complex innovation projects in manufacturing demand a project management with high responsiveness to changing conditions. This section is intended to present results from an online survey conducted mainly in Germany, Austria and Italy (88%) in 2018/2019 (see BRANDL et al. 2019). The questionnaire was targeted at top-management experts responsible for innovation projects in manufacturing companies, predominantly with a background in *Automotive*, (42%), *Consulting* (21%), or *Machine & Plant Manufacturing* (9%). In total, 74 participants of which 68% have been holding a leadership position for two ore more years helped to capture a quantitative picture of complex innovation and the relevance of agile and hybrid project management methods in the manufacturing industry. (cf. BRANDL et al. 2019)

Main findings
77% of the experts (n=62) observed an increasing complexity in innovation projects over the previous years, with *changing requirements* ranked the highest impact driver. According to their experience, innovation is most likely triggered by *customers & market trends*, *technology improvements*, or *competitors* and it targets *products* (67%), *production systems* (59%) and *IT-systems* (48%) (n=62). More than half of the experts noticed a gain in importance of agile or hybrid project management approaches, of whom 60% already applied them in their innovation projects. However, an industry split reveals that companies with a *Software & IT* background or *Consulting* firms are more experienced with agile project management (in average more than two years) than companies from the *Automotive* (less than two years) or *Machine & Plant Manufacturing* (less than one year) sectors (n=41). (cf. BRANDL et al. 2019)

Discussion
This survey affirms the impression that a lot of manufacturing companies are currently trying to extend their project management portfolio with agile or hybrid models. The captured high interest in those concepts shows the status quo at the time of the survey in 2018/2019. However, considering individual feedback by the experts, the interest in agile techniques might just have traversed the *Hype* phase in *Gartner's Hype Cycle*[2]. Nevertheless, the survey also showed a lack of experience by *Machine & Plant Manufacturing* companies that usually are more smaller in size.

4.3 Case Study

For this industrial case study, two BPI projects in two different manufacturing companies (*Company I* & *Company II*) were accompanied over an aggregated time period of

[2] See section 3.3

24 months in close collaboration with ROIDER (2018), KAGERER (2017a), and BEUL (2018). The data was collected on the basis of an accurate and systematic observational study[3] as part of assistive and advisory activities for the planning and implementation of these innovation projects. The collected data is drawn from personal observations, expert discussions, and internal project documentation. The gathered insights were subsequently processed and are presented in the following.

4.3.1 Company I

Company I is an established premium car manufacturer and, at the time of this case study, was coping with complexity in designing novel business processes for the production of electric motors.

Case background
As a disruptive high-technology, the electric drive is said to have the potential to “destroy existing market conditions” in the automotive industry (JANKE & BURKHARDT 2018). Like already anticipated in 2013, the market of electromobility was facing a highly uncertain future, strongly influenced by the general economy, global and local politics, progress in society, and advancing technologies, making the design of production processes and infrastructure highly complex (cf. e.g. KAMPKER 2014; WIETSCHEL et al. 2013).

Project complexity
The external factors mentioned above framed the highly complex environment challenging not only the corporate identity of *Company I*, but also its technological and methodological core competencies. The situation forced the company to fundamentally new product designs and innovative production concepts. They needed to build up novel expertise while new competitors and component manufacturers entered the market and threatened their current value chains and in-house production depth. The company was forced to leave some successful paths and abandon several proven habits to explore new ways while concurrently improving and further exploiting existing

[3] In this context, an observational study can be understood as the gathering of empirical data based on the observation and documentation of challenges, practices, and effects of new approaches in one company over a longer period of time (cf. e.g. ALBERS et al. op. 2009; CONRADI & WANG 2003).

ones. A project manager in *Company I* pointed out: “We are excellent at making good things near to perfect. We struggle in creating something new and in adapting to constantly changing requirements.” This statement reflects the situation project teams in the process planning division of this company found themselves at the beginning of this case study in 2018. They were facing the challenge of designing new value creation processes for a novel technology that generated requirements gradually emerging during the project. At the same time, since software, e.g., for autonomous driving and assisting systems, became an increasingly decisive part in the new cars, development cycles shortened drastically and customer feedback was more direct. As a result, project managers and process engineers became interested in novel, explorative approaches shifting the working culture in *Company I* more towards agile project management.

Project management

In *Company I*, BPD projects related to production follow the procedural *Stage-Gate* pattern (cf. COOPER 1990) and are based on conventional project management structures in the automobile industry (cf. e.g. FELKAI & BEIDERWIEDEN 2015; HAB & WAGNER 2017; SCHNEIDER 2015). According to the interviewed team members, external supplier contracting, design releases and preliminary inspections, and approvals are important milestones. Project managers take responsibility for the project’s success and coordinate process engineers organized in a matrix organizational structure. In *Company I*, a project manager had technical leadership over a full-time operational core team, while the disciplinary assignment of the individuals stays within the functional administrations. The team collaborates with several internal support teams (e.g. product development, technology planning, quality management) and external partners (e.g. engineering service providers, technical or organizational consultants). The internal support teams are part-time involved and usually assist several projects. This large number of people involved in BPD projects requires a high degree of coordination. The teams, therefore, regularly report on their project status during fixed meetings using a *List of Open Points* (LOP)[4] to document the progress of knowledge and the current need for action. In turn, the project manager answers to a superior management board controlling quality, deadlines and budgets.

4 See, e.g., HAB & WAGNER (2017)

Solving technical problems

In *Company I*, the novelty of the product and process technologies required for the manufacturing of electric drives, constituted a major technical challenge due to lack of experience and references from practice and science. The teams realized during the course of building up know-how, that potential solutions later in the project turned out to be inefficient and line concepts or even the entire production system could not be implemented. A project manager confirmed the known perception: "The later we identified technical problems in the project, the more likely we failed to achieve our objectives." The BPI in *Company I* also underlined the importance of problem-solving capabilities to bridge the discrepancy between the first concepts based on early knowledge and constantly emerging new requirements during the planning.

Observations

Observation 1: Unforeseen changes lead to urgency

If a concept did not reach the level of maturity required at a certain quality gate of the project, unforeseen changes were inevitable. These then became a challenge of urgency. The project team was not trained sufficiently to react in such a situation.

Observation 2: Team availability and skills

Many part-time team members had regular tasks, so that when problems arise, there is not enough capacity to deal with the subject in depth. When developing innovative value creation processes and production technologies, existing know-how alone was not sufficient to solve the numerous emerging technical problems. Technology-specific expertise needed to be developed during the project.

Observation 3: Communication & transparency

Due to the large number of technical challenges and people involved, the project managers struggled to coordinate and prioritize open tasks across all levels. As a result, communication channels between top-level management and operational teams (vertical) were not working sufficiently to create the necessary transparency.

Observation 4: Variety & dependency cause uncertainty

The unforeseen changes throughout the project emerged in great variety and in mutual interaction between process design and product development. The difficulty of estimating the actual effects and dependencies of individual decisions resulted in uncertainty about the further course of action.

4.3.2 Company II

Company II is an international manufacturer of rail track maintenance machines and was radically redesigning business processes, organizational structures, and IT-systems.

Company background & setting

Company II, employing around three thousand people worldwide, is both a technology and a market leader in its sector. The company's headquarters and main production sites are located at a high-wage location within the European Union, developing and producing enormous, technically extensive, and sophisticated products. Due to a growing competitive pressure from the Asian market, the company, in order to remain competitive, decided to undertake a radical innovation by redesigning its central business processes and introducing a novel ERP system. The main focus was laid on the company's engineer-to-order process that organizes all activities between the first customer contact to the product's final delivery and approval. *Company II* formulated a vision and a challenge to provide a clear direction from the beginning of the transition project:
Vision: "Staying competitive without leaving the current location."
Challenge: "Reduce the lead time for a customer specific project to twelve months."[5]

Project complexity

Right from the start of the project, *Company II* was concerned that the intended transformation would become a very complex challenge. One reason for this was the lack of clarity about what the company would have to look like after the change. A first analysis brought forth that the challenge would require a new integrated ERP structure and a radical shift in the corporate culture. In addition, the products comprise a high level of technical complexity and the corresponding expertise was historically fragmented in various departments. For these reasons, the initiative was seen from the very beginning as an ambitious, pioneering project that would affect all areas within the company. Initial analyses also showed that this major task could not be accomplished top-down and overnight, but would require the commitment of all employees and a gradual change from the inside. This is why the company decided to create a core

[5] Free translations and anonymization by the author.

team that would start developing a small-scale core business process for the future, which the team would test on several prototypes until finally rolling it out to the whole company.

Project approach

The core team consisted of seven sub-groups, each of which was led by a sub-project manager. The project was functionally and operationally shaped with compliance to the classic organizational structure of a manufacturing company. The members of a core team were all full-time contributors to the project, while supporting staff from other departments spent part of their resource on project tasks, depending on the current phase and specific requirements. Besides, the project manager (*Expert H*[6]) always stressed the value of an interdisciplinary team, combining staff from several departments with external experts within the project. He[7] mentioned that this "enabled the application of different approaches and procedures" and thus "provided better results". As a consequence of this setting, the steadily growing team considered itself in an internal startup which developed and continuously improved its own organization and work processes through constant collective learning.

Project management

At the beginning of the project, the company's CEO together with the core team agreed on high level stages and gates, giving each a detectable quality criteria. The team together with the project manager divided the stages into smaller phases of three months each, again marked with a sub-milestone. To manage progress, the core team held weekly meetings applying a rolling planning logic: based on the achieved results, upcoming goals were specified more precisely and new tasks were defined. In the early phase of the project, an open and regular exchange of the core team within these weekly meetings guaranteed the coordination of individual goals and tasks sufficiently. Later however, when the project became bigger the several sub-teams needed a structured coordination without restricting their autonomy.

[6] A detailed overview of each expert's background and contribution to this thesis can be found in table A.4 in the appendix.

[7] In the following, the project manager is referred to with *he*, *him* or *his*, since it is a male person.

Observations

Observation 1: Formulating a vision & providing a direction

A clear vision provided a direction for all team members to head in during the project and was the center of motivation. The formulation process was also created an early debate on different interests and concerns. Accepting the vision was the first step into the project.

Observation 2: Organization & knowledge exchange

Despite the early enthusiasm and success of the quite manageable small team in early phases of the project, coordination of tasks and knowledge exchange between the sub-groups became a major challenge and required a systematic routine of coordination and unambiguous lines of communication.

Observation 3: Targets & planning

The Project sponsor and manager had successfully formulated a clear vision and quantifiable challenge to achieve after three years. What turned out to be difficult, was the structured breakdown of the superordinate challenge into tangible target states on a regular basis during the project. Formulating a next target or sub-milestone based gathered knowledge in the prior phases needed a more precise guidance.

Observation 4: Personal coaching

The project manager of this BPI project in *Company II* from the outset decided to establish a management style that is based on the individual development of people as a learning organization [8]. He succeeded to coach his personal sub-project managers as long as the group was of small size.

4.3.3 Cross-case analysis & findings

To provide a more profound insight, the following cross-case analysis highlights differences and similarities between the two observed BPI projects. Although the backgrounds, settings, and project goals vary, common general challenges and strategies to cope with complexity were identified.

[8] See the *Knowledge-Creating Company* in section 2.4.3.

Project complexity

From an external perspective, the teams in *Company I & II* were likewise confronted with various aspects of complexity (cf. figure 2.6 in section 2.3). For example, *Company I* faced a high *volatility* in goals and requirements, as well as *urgency* directly resulting from the dynamic market of electric cars. Many of the involved technologies for producing the novel engines entailed known unknowns, such as production quantities, creating *uncertainty* for the conception and design of value chains. In addition, the teams in *Company I* were facing numerous emerging unknown unknowns during early phases as well as throughout the project creating several periods of *emergency* that temporarily required more focused task forces and specialized expertise. The sub-groups occasionally suffered from conflicting goals arising out of the numerous project participants and stakeholders, creating *ambiguity*.

In *Company II*, the observed project complexity primarily resulted from the extensive scope of the venture including the concurrent total redesign of all core business processes, the adaption and introduction of a novel, company-wide ERP system, and the total reorganization of corporate departments and management structures. In combination with the technical aspects of the product, these factors created a vast *variety* of challenges to solve. As a consequence, numerous known and emerging unknown unknowns created *uncertainty* in goal-setting and multiple moments of *emergency* to respond fast.

In both companies, the awareness for the involved complexity was observed as a very vague and nebulous sensation by the responsible managers and team members leading to question, how it could be measured more effectively.

Project organization

In both projects, the project management adopted a conventional matrix project organization, in which the expertise and accountability by the team members were reflecting a combination of functional and project-oriented criteria (see e.g. GRAU & WAGNER 2014). Figure 4.1 is a simplified visualization of the observed organizational structures in the presented cases in *Company I & II*. The project managers coordinated and led the collaboration of the operational teams, internal departments and external partners while directly reporting to a superior management. The boards were company and project specific and particularly *Company II* benefited from an internal sponsor who represented and personified the project's vision as a central role in the supervisory board.

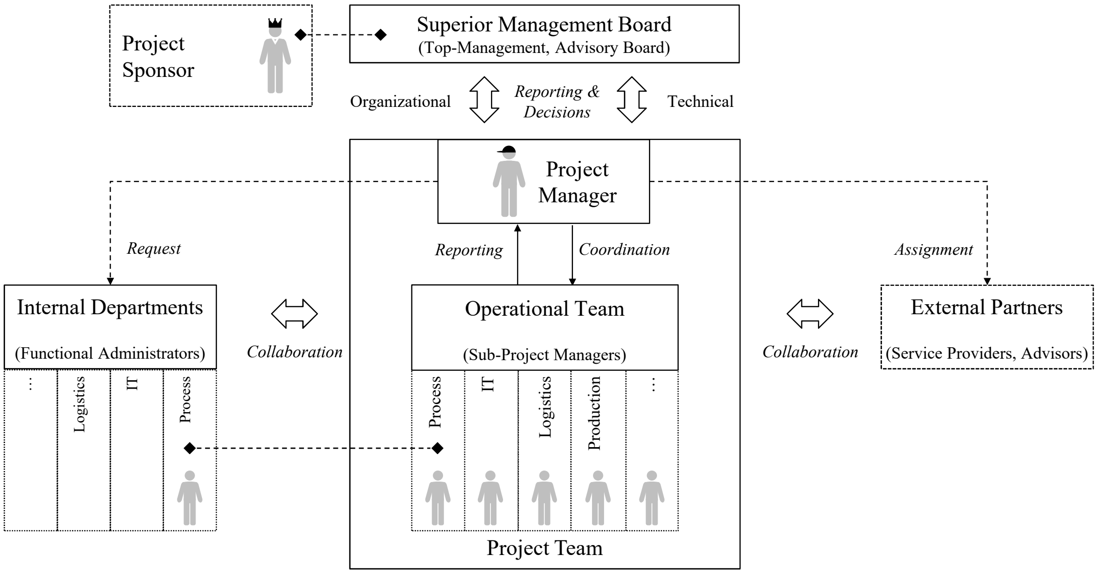

Figure 4.1: Simplified visualization of the observed organizational structures in the presented cases in Company I & II. Illustration developed with ROIDER *(2018) based on* HAB & WAGNER *(2017).*

Project management & problem-solving capabilities

Conventional project management played a central role for managing the involved risks during the accompanied projects in both companies. Therefore, several quality gates were set at the beginning of the projects in order to roughly coordinate development activities with internal and external suppliers, schedule design releases as well as to perform pre-SOP tests for the preliminary approval of new business processes.

Both cases revealed that certain milestone decisions had to be made based on technical immature ideas and concepts. As a consequence, adaptions were made regularly when new insight emerged later in the project. This put more emphasis on developing fast-reactive, agile problem-solving capabilities within the project team and less priority to detailed planning upfront.

The project settings in both companies, however, did not allow a total adoption of an agile project management approach, e.g. by introducing *Scrum*. Instead, the premises lead to an orientation towards a hybrid model (see section 3.3), to which the previously defined superordinate milestones constituted a strategic planning level.

Transformation & empowerment
Apart from the organizational restrictions, *Company I* already had experienced lessons-learned from introducing APM methods to their BPI project and subsequently decided to focus on creating "temporal and local agility", if and when it would likely achieve better performance. *Company II* headed for a rather radical path by following the archetype of *The Lean Startup* (see section 3.4.1) and by creating project agility through incremental, collective learning as practiced in the *Knowledge-Creating Company* (see section 2.4.3). In both cases, the actual transformation towards a more agile project modus operandi was directly related to the individual empowerment of the project teams. *Company I* already was offering and promoting a broad variety of methods and practices to support the project management. Attentions were, therefore, targeted towards systematic ways of selecting and introducing methods and practices especially to newly composed teams with less experience. *Company II* likewise stressed the importance of quick, collective learning. However, in contrast to *Company I*, their approach put more emphasis on coaching and experimentation. As a first step for the transformation and as a motivation for introducing novel ways of collaboration, both companies successfully pursued the goal of creating awareness by all internal and external stakeholders for the involved project complexity. This reduced barriers and increased the motivation for implementing novel practices drastically.

4.4 Expert Interviews

Several series of expert interviews[9] and workshops contributed to a more profound qualitative database for the understanding of BPI and agile organizations in the industry. Some of the interviews resulted directly of the case study in *Company I & II* (see section 4.3), while a few contacts came about from the online survey (see section 4.2).

[9] As outlined in chapter 1.3, expert interviews are an essential contribution in manufacturing operations science to create qualitative data on the mechanics and dynamics of organizations. Interviewing experts is a standard method and outlined in depth, e.g., by BOGNER et al. (2009).

4.4.1 Experts background & interview setting

Experts background

The eight consulted experts from Germany and Austria have an economic-technical background in common and are professionally dedicated to complex innovation projects and modern project management approaches in mainly manufacturing companies, however, serving different roles and providing various perspectives. While *Experts A-C* consult companies in adopting agile approaches and gained methodological knowledge, *Experts D-G* work for *Company I* and provide different perspectives from various departments on agile practices and BPI. *Expert H* leads a substantial BPI project in *Company II* experiencing the benefits and challenges of modern project management. A detailed overview on each expert's background can be found in table A.4 in the appendix.

Interview setting

The meetings took place in the time period from 2016 to 2019. Interview series 1 consists of three individual meetings with *Experts A-C* one at a time. These initial interviews in 2016 were intended to gather information on general requirements and levers for organizational agility during innovation projects in a manufacturing company. Interview series 2 took place at *Company I* in 2017 and captures four different internal perspectives (*Experts E-H*) on one specific BPI project. Based on the notions from the first interview series, the questions were more focused on how organizational agility can be achieved in a BPI project. In interview series 3, by meeting with *Expert H* several times between 2017 and 2019, personal experiences and best practices are captured at three different moments throughout a substantial BPI project in *Company II*: during the preparation, in the early phase, and while implementing a new business process.

The individual statements from the three interview series were documented by ROIDER (2018), KAGERER (2017a), and BEUL (2018) and are summarized in the following section.

4.4.2 Main findings

Interview series 1 with experts A-C

General factors for organizational agility in manufacturing companies

Expert A affirms, that the values and principles in the *Agile Manifesto* serve as an orientation for organizational agility in any organization. The expert highlights the underlying fundamental idea of frequently delivering product increments with a high responsiveness to change while establishing a protected zone for task processing (time-boxing). *Expert A* generally endorses *Scrum* as a holistic framework, since it is ”based on a manageable, well understandable set of rules and directives”. However, in his experience it takes up to twelve months of practice for a team to exploit its full potential. On that premise, *Expert A* proposes the adoption of individual team-oriented aspects of the *Agile Manifesto* for creating organizational agility during BPI projects. Putting more emphasis on regular workshop meetings, so the expert's experience, facilitates collective learning and bundles capabilities in working-group, when teams do not cover every skill required to solve a technical problem. An incremental and iterative progress strategy on the operational project level could dissolve the ”horizontal-orientated *Stage-Gate*” and add a ”simultaneous vertical structure”, so the expert. Therefore, *Expert A* encourages project managers to develop a hybrid project management structure.
Expert B describes agility primarily as an ”empowerment of the team”, allowing a self-dependent organization of work. According to the expert, links this central aspect to the definition of an equivalent *Product Increment* in the respective manufacturing context. He elucidates, to not only contemplate actually implemented new versions of business processes as a result, but various other ”media of delivery” such as virtual and haptic models. These would create intermediate added customer value and allow feedback.
During the discussion with *Expert C*, organizational agility emerged as a central theme. Regardless of the professional context (software development or BPI), the expert considers agile approaches beneficial in projects “where no specifications can be written down”. He warns, if planning is carried out despite a lack of information and prevailing uncertainty, the obvious thing to do is to make every effort to protect yourself in all directions, which bears the risk of over-specification. *Expert C* underlines, that agile approaches focus on a rapid development of intermediate results from which a project team can learn step-by-step. To this end, it is important to agree on intermediate goals and to evaluate their achievement in that perspective. Only then, learning progress and a better assessment of realistic objectives is achievable. When setting up new projects, the expert decides on a progress strategy based on the risk of a deviation from the plan. When complexity is involved, the effects of non-conformance are far-reaching throughout the project. Such a situation requires fast decision-making

and quick learning. Therefore he recommends to consider an agile approach. The interviewee considers the essence of agile collaboration in giving people freedom. However, despite this freedom, an effective cooperation requires certain rules and a common attitude towards work. He considers the *Agile Manifesto* as a powerful framework to create a shared set of values and principles, and describes it as the basis for any agile organization. Yet, the expert thinks that discipline is crucial and agile frameworks alone are not enough. He underlines the importance of an overarching goal or vision that provides a direction but does not constrict and suggests an adapted organizational setting to this purpose. In his experience, many companies fail at the attempt or underestimate the effort of adopting an agile organizational structure. For this reason, ”conventional *Stage-Gate* still does better than a poorly organized *Scrum*”. *Expert C* concludes, that for "becoming more responsive" as a team in facing a complex problem, selective agile practices can help to improve the quality of collaboration without changing the setting entirely.

Interview series 2 with experts D-G

Effective ways of adopting agile approaches during BPI projects

Expert D endorses the notion resulting from interview series 1, that an agile organization is beneficial when it is unclear how a specific goal is achievable. In such a situation, a guiding vision and allowing room for learning and feedback loops is essential. *Expert D* adds to to this point, that a key aspect in achieving success through agile project management is to make sense of the work of those involved. If activities are merely being carried out because managers demand them, they are seen primarily as an effort and an obligation. If the employees recognize the sense in their actions, self-motivated and self-organized work happens. The expert notes, that in the *Scrum* framework, 20% of the time is spent on presenting results, reflection, and preparing for upcoming work phases. Agile teams are dedicated 100% and do not have to perform any other tasks. This requires commitment by both the management and the team members.

According to *Expert D*’s experience, these are essential criteria for a successful agile working approach, however, not every environment allows for implementation. He, therefore, recommends an individual assessment of the given circumstances in a department or a project to decide which aspects and elements promise a real benefit. A "blind" adoption of typical agile frameworks such as *Scrum*, entails the risk of rejection. Besides, in many cases insufficient freedom is granted within the organizational

structure to put the underlying agile principles actually into practice.
Expert E confirms that not for every project or topic in the engineering environment agile approaches are beneficial and distinguishes between visionary product development tasks and daily business activities. He suggests an explorative progress strategy "when the *what* is clear, just not the *how*" and competencies from different areas or departments are required. Other essential criteria according to the expert are the level of detail of project requirements and their robustness, dynamics, risks, pace, the need to create new knowledge, as well as the management grants for building and maintaining an agile organizational structure. Disagreeing with *Expert D*'s statement, a 100% dedication by the team might not be essential. Applying agile practices opposes "lone fighter" mentality and helps to "relearn" cooperation and team spirit. The expert points out that establishing an effective agile organization, like *Expert D* describes, will require a gradual approach, discipline, rules, and continuous learning.
Expert F's field of process planning in manufacturing falls into the area of combustion engine production. The motor itself, in contrast to its significance, does not suffer from fundamental change, making process design for a new engine type a complicated but not a complex problem. At the beginning of such a project, ”several hundred pages of specifications” can be formulated in advance. From this environment, *Expert F* provides a perspective where he sees little potential for introducing agile approaches. Nevertheless, he acknowledges the motivation, discipline, openness, and the willingness to embrace new things of agile teams. He suggests to emphasize on these ”soft factors” of agile organizations rather than radically changing existing company structures. He points to the danger of ”burning” agility among employees with pointless applications. Instead, he suggests to gradually achieve more agility when it has a tangible purpose.
Expert G attributes the greatest added value from agile approaches to the fact that requirements, responsibilities and delivery dates can be specified clearly and transparently within the team and with the relevant interfaces. In his opinion, to successfully implement agile approaches in this area, consistent methodical support is essential. He learned that people need to recognize a personal added value for themselves before accepting changes that come with adapting an agile organization. Further, he underlines the importance of motivation and discipline by all participants. The expert reports positive experiences through the integration of agile techniques in his area of process planning in manufacturing. It fosters communication, increases transparency and inexperienced planners are systematically supported. An agile mindset ensures

more commitment when cooperating with internal partners, like the plant operator who is the customer of process planning. From the project manager's perspective, it provides greater transparency of progress, responsibilities, delivery dates and the status. This allows closer coordination loops between the team members.

Interview series 3 with *Expert H*

Fundamental criteria for successfully managing complex BPI projects

During the first interviews with *Expert H*, various fundamental criteria for successful BPI projects were discussed and documented based on the expert's practical experience in his current role as a COO in *Company II* but also during earlier projects. Before conceptualizing this current BPI project, *Expert H* acquired theoretical knowledge by participating in professional training on the ideas of *Design Thinking* (see CUREDALE 2019), the *Lean Start-Up* method (see RIES 2019), and various modern project management approaches (see TIMINGER 2017).

On this personal, heuristic background, *Expert H*, first and foremost, insists on bringing confidence and trust towards employees particularly in heavy-weighted, complex or business-critical projects demanding architectural change. These phases of transition and instability require teams to incrementally pivot their way along a path on which progress sometimes only may result by instantly learning from mistakes. This requires a constructive failure culture and a secure working environment that allows people to overcome their fear. *Expert H* provides an example of handing ”failure cards”, giving each team member the chance to make a certain type of mistake first-time without any consequences. This, so the expert, motivates individuals to learn through failure and creates room for collective entrepreneurial thinking. Other important aspects are to create an interdisciplinary team and facilitate direct communication. The resulting diversity and spatial narrowness, however, create new challenges to overcome. What helped *Expert H* to build coherence and a strong team-spirit in several projects, was to establish a dedicated area where the team is ”protected by daily business”. They greatest challenge that *Expert H* encountered is to bring people in manufacturing companies, that are used to deliver perfect results according to detailed specifications, to recognize value in intermediate results and working prototypes. This includes operators as well as managers.

Cross-interview analysis

The conducted interviews underline the impression from the online survey (see section 4.2) and the case study (see section 4.3) that organizational agility and explorative learning can contribute to a more effective of complex BPI project in manufacturing commonalities. However, as *Expert C* pointed out, well-practiced conventional project management still performs better than a poorly implemented novel approach. The experts agree on the intention to react quicker rather than heavily plan upfront in order to achieve a better performance and quality in complex problem situations. Introducing new roles, structures, and procedures during an already complex BPI project, however, can overburden a team. At many points during the interviews, an impression was indicated that a significant amount of persons with a manufacturing background reacted "repellent" to the IT-specific language used in the *Agile Project Management*. *Expert H* stresses his personal belief that there is no universal way and a key might be a combination of several "soft factors" to individually empower heterogeneous project teams for collective learning.

Overview & reflection with literature

In the literature related to Agile Project Management, the success and benefit from implementing an agile organization depend on various factors (cf. e.g. KIENBAUM 2015; LINDVALL et al. 2002). According to CHOW & CAO (2008), these can be clustered in *Organizational*, *Team-*, *Process-*, and *Project-* related categories. Table 4.1 shows an overview of gathered factors from several studies and domain literature. These results were later complemented with the findings from the expert interviews[10] (see section 4.4 and table A.4).

A first impression confirms the general tenor to be consistent between the literature and the records on the practical experiences. In the literature, there is no uniform differentiation of these factors with regard to their relevance. Some are rarely mentioned, but can represent essential factors according to the first-hand reports. For example, without an *Openness of Mind*, said *Expert F* and *Expert H*, a team's willingness to adapt its working mode is quite limited. On the other hand, a *Dedicated Team Room* may not be mandatory in every project. However, in *Company II*, it had significant, positive effect on the project's success. *Expert H* observed, that the team was given a safe space to experiment with new technologies and new ways of collaboration during their BPI project. In this specific case, the so-called *Lab* shielded the team from the

[10] The questions in the conducted interviews did not specifically refer to this list. The interviewees were asked to name critical factors based on their personal experiences and the documented findings were inserted in table 4.1

Table 4.1: Gathered factors for a reasonable application of agile approaches in a manufacturing company (based on BRANDL *et al. 2021).*

	Cockburn 2002	Lindvall et al. 2002	Goll & Hommel 2015	Kienbaum 2015	Korn 2016	Schröder 2017	Maximini 2018	*Expert A*	*Expert B*	*Expert C*	*Expert D*	*Expert E*	*Expert F*	*Expert G*	*Expert H*
Category/Factor	**Literature**							**Expert interviews**							
Organizational															
Servant Leadership		x	x	x	x	x	x		x		x	x	x		x
Interdisciplinary Team			x			x	x	x			x	x	x		x
Team Size	x	x	x			x		x					x	x	x
Team Availability			x			x	x	x			x	x	x		x
Corporate Culture	x	x			x	x		x		x			x		x
Organizational Structure			x	x	x	x		x			x		x		x
Team Continuity			x				x	x			x	x	x		x
Dedicated Team Room		x				x	x								x
Common Responsibility					x	x	x			x					x
Physical Collocation							x	x		x			x		x
Access to Resources							x		x						x
Team															
Confidence & Trust	x	x	x	x	x		x	x	x	x					x
Self-Organization	x	x	x			x	x				x		x		
Continuous Learning			x		x		x			x			x		x
Self-Motivation			x		x	x	x		x				x	x	
Professional Expertise	x	x	x												
Openness of Mind			x	x									x		x
Innovation Culture				x	x										x
Communication Skills		x			x										x
Social Skills		x													
Process															
Methodological Assistance					x	x	x	x			x	x	x	x	x
Effective Communication		x	x	x	x	x	x	x							x
Discipline							x			x	x	x	x	x	
Reflection/Feedback			x			x		x	x	x			x		x
Transparency						x	x								x
Project															
Complexity	x	x	x				x			x	x	x	x		x
Common Vision			x			x		x	x		x	x	x		x
Customer Orientation		x		x	x			x		x		x			
Tangible Target States									x			x	x		x

structures and habits established in the surrounding company that contradicted the values and principles of an agile organization. The ”right” *Corporate Culture* inside the *Lab* promoted agility. Prerequisites can lay outside the project managers’ room for maneuver or overburden their available resources. *Project Complexity* is considered a prevailing boundary condition, while, e.g., a *Common Vision* and *Continuous Learning* constitute essential prerequisites. Others might be interpreted as instruments to achieve the desired effect more efficiently (like the *Dedicated Team Room*).
This analysis suggests that all aggregated factors somehow affect a successful implementation of an agile organization in BPI projects but their significance will vary from case to case. Furthermore, it becomes evident that the project managers’ available room for maneuver determines the potential degree of complying with these factors. The methodology should, therefore, not just provide guidance in evaluating project complexity but also in assessing critical prerequisites individually.

4.5 Conclusion

In this chapter, exemplary public information of failed BPI projects was gathered (4.1), followed by an online survey on the broader conceptions of innovation, agility and modern project management in the manufacturing industry (4.2). Thereafter, a case study covering two diverse BPI projects in two different manufacturing companies (I & II) delivered better understanding of the current practice in industry in coping with complex BPI projects (4.3). The subsequent three series of more in-depth interviews with selected experts portrayed firsthand account on experiences with complex BPI projects (4.4). The main findings from these previous sections were then matched in an across-interview analysis and consolidated in an literature reflection. The to address and refine the four shortcomings from the literature (see section 3.5).

Addressed & refined shortcomings from the industry
Shortcoming 1 (addressed): No analysis of actual complex BPI projects in the industry
The documentation of two projects in *Company I* & *Company II*, as well as several expert experiences provides insights in actual complex BPI projects in the industrial practice.

Shortcoming 2 (refined): No practical guidance to assess complexity & prerequisites for agility

The project managers and teams generally show vague awareness of project complexity but lack in methodological guidance to evaluate it. Prerequisites for an agile organization are available in the literature and among agile experts. To motivate for an agile organization in a BPI project, more accessible guidance is needed.

Shortcoming 3 (refined): No applicable procedural reference model for implementing an agile approach particularly during complex BPI projects in manufacturing companies
The observed cases in *Company I & II* reveal a demand for instructive reference for the planning of complex BPI implementing explorative problem-solving and validated learning in the daily routine. A combination of the Hybrid Project Management models with approaches from the subject area Explorative Validated Learning might provide sufficient procedural reference for practitioners to manage complex BPI projects in manufacturing companies with an agile approach.

Shortcoming 4 (refined): Insufficient guidance for an implementation of a novel BPI approach
Complex BPI projects are usually staffed with an interdisciplinary group of many experienced as well as inexperienced persons. What showed to be insufficiently considered in practice, is an approach to individually evolve and empower heterogeneous project teams for organizational agility.

5 Integrated Method for Managing a Complex BPI Project

Based on the extended review of literature (chapter 3) and insight into current practice in the industry (chapter 4), an integrated method for managing complex BPI projects was developed. It is composed of three modules and eight elements. The structure of this chapter follows the top-down process followed when designing the method: three basic modules were derived from the requirements and then described in detail as individual elements. These were finally consolidated to an integrated method.
The resulting procedure helps managers to increase the performance during complex BPI projects. This is achieved by creating organizational agility and explorative learning capabilities in a project team. In compliance with the scientific literature on agile approaches outlined in section 2.4, organizational agility in a complex BPI project is interpreted as following the values and principles of the *Agile Manifesto* embedded in a Hybrid Project Management framework. Explorative learning capabilities, in this context, are based on the routines of validated learning and problem-solving approaches outlined in section 3.4.

5.1 Method design

Based on the requirements outlined in the previous chapter 4, the three corresponding modules presented in the following section form a meta-framework for the detailed design of the integrated method.

5.1.1 Requirements & derived modules

The refined shortcomings were reformulated to reflect the identified needs of a manager during a complex BPI and are based on the findings from the literature analysis and expert interviews outlined in the previous chapter.

Requirement 1: Methodical guidance for the initial assessment of a BPI project setting & decision support whether an agile approach is reasonable in a certain situation
The integrated method should help managers in assessing the setting of a BPI project regarding its complexity and critical prerequisites to understand the necessity and its suitability for an agile approach. The outcome of the assessment should support their decision for or against changing the default project management in an upcoming BPI project.

Requirement 2: Structural and procedural reference to provide orientation in managing a complex BPI project with an agile approach.
The integrated method should provide structural and procedural reference for the iterative planning of next target states and the formation of process prototypes that allow experimental, validated learning during complex BPI projects. These aspects were identified during the literature analysis and expert consultations to constitute to a reasonable agile approach in a manufacturing company.

Requirement 3: Methodical support for empowering project teams in adopting an agile approach during a complex BPI project
The integrated method should support project managers in empowering project teams to implement and apply an agile approach during complex BPI projects.

Derived modules

As depicted in figure 5.1, three modules were derived from the formulated requirements. Moreover, these modules reflect essential perspectives for a successful transformation of an organization: creating *Awareness*, providing *Orientation*, and bringing about a *Change* (see CHRISTA SCHYBOLL n. D.). While the *Initial Assessment* of a BPI project's setting (Module 1) helps managers to create awareness among a team of stakeholders, the *Hybrid Reference Framework* (Module 2) provides structural and procedural orientation. What brings about change is to constantly *Monitor & Adapt* a team's way of working (Module 3).

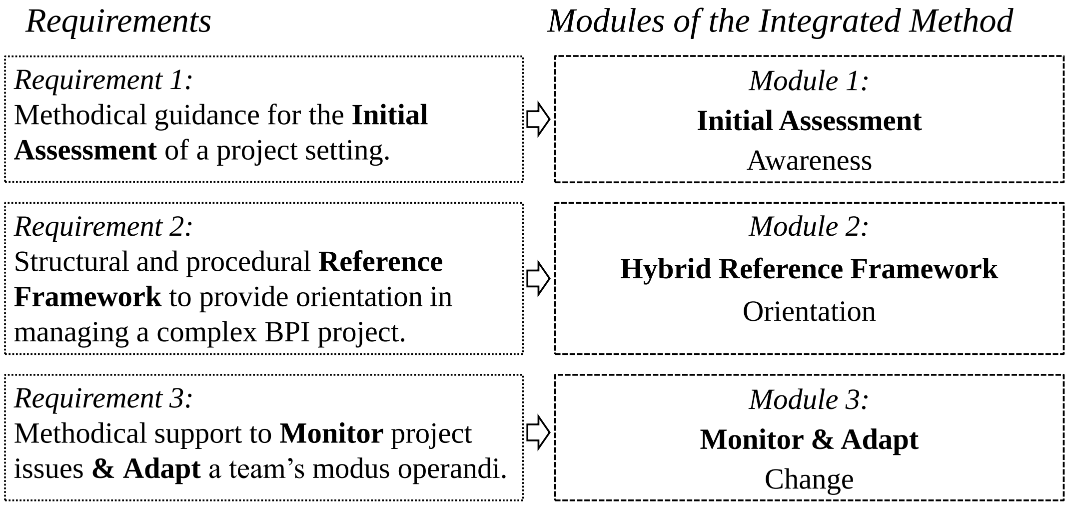

Figure 5.1: The integrated method's modules derived from the three requirements.

5.1.2 Meta-framework & allocation of elements

The method's meta-framework is formed by the three derived modules. Each module represents a coherent unit of elements that are listed in table 5.1 and further explained in the following.

Module 1: Initial Assessment
Module 1 (elaborated in section 5.2) is a methodical guidance for managers of BPI projects to individually assess complexity with *Element 1a: Complexity Assessment* and evaluate critical prerequisites from their perspective *Element 1b: Prerequisites Checklist*. Both elements are usually applied before or at the beginning of BPI projects

Table 5.1: List of modules and elements developed in chapter 5.

Module 1: *Initial Assessment*	**Module 2:** *Hybrid Reference Framework*	**Module 3:** *Monitor & Change*
	Elements	
1a: Complexity assessment	2a: Adapted Target State Cascade for Vision Alignment	3a: Project examination
1b: Prerequisites Checklist	2b: Adapted *Stage-Gate* for Strategic Stability	3b: Project supplementation
	2c: Adapted *Toyota Kata* for Operative Agility	
	2d: Integrative Planning Routine for Tactical Balance	

to support the decision, whether introducing an agile approach is reasonably justifiable.

Module 2: Hybrid Reference Framework

After having achieved awareness of a BPI project's setting and made this decision, *Module 2* (elaborated in section 5.3) offers managers a structural and procedural reference for operative agility in such a situation. As commented before, operative agility in complex BPI projects needs to be embedded in the existing structures of a manufacturing company ensuring strategic stability with quality gates and budgeting. The proposed Hybrid Reference Framework, therefore, combines elements from BPR, OCM, Hybrid Project Management, and Explorative Validated Learning (all reviewed in chapter 3) to allow operative agility while maintaining strategic stability. This hybrid structure is achieved with four elements allocated on an operative, tactical, and strategic project level (see figure 5.2). The Adapted Target State Cascade (Element 2a) and the Adapted *Stage-Gate* (Element 2b) on the strategic layer interact with the operative Adapted *Toyota Kata* routine (Element 2d). The balance between these two elements is managed on a tactical layer delineated in Integrative Planning Routine (Element 2e).

The definition and cascading of a vision (Element 2a) sets the general direction during a BPI project and motivates the team for activities and actions in the daily work routine. The vision is initially broken down into tangible target states to create strategic stability, manifested in the high-level milestones of the Adapted *Stage-Gate* (Element 2b). The Adapted *Toyota Kata* (Element 2c) guides project teams in explorative, validated learning. The constant operative feedback provided by this routine is captured by the Integrative Planning Routine (Element 2d) to align and adjust the next target states.

Module 3: Monitor & Adapt

A successful deployment of an agile organization in a BPI project team requires a systematic empowerment of the involved members in agile practices. Learning and adopting new techniques consumes capacities and requires additional resources. This will only be accepted by a team when the new practices bring about direct improvements in the project by addressing actual issues. On that premise, *Module 3* (elaborated in section 5.4) constitutes a methodical guidance for managers to select and introduce individual practices from the portfolio of Agile and Lean Management. The decision support is based on a constant monitoring of current project issues (facilitated by *Element 1a: Project Monitoring*) to improve a team's modus operandi (*Element*

1b: Project Adaption). This process is additionally fostered by individual coaching incorporated in the reference model as part of the explorative learning routines derived from *Toyota Kata Management Philosophy*.

Overview of the integrated method with allocated modules and elements

Figure 5.2 indicates the allocation of the eight elements to the three modules of the meta-framework. The three modules, eight elements are explained more in-depth in the following sections, stepwise revealing their interaction as an integrated method to manage complex BPI projects.

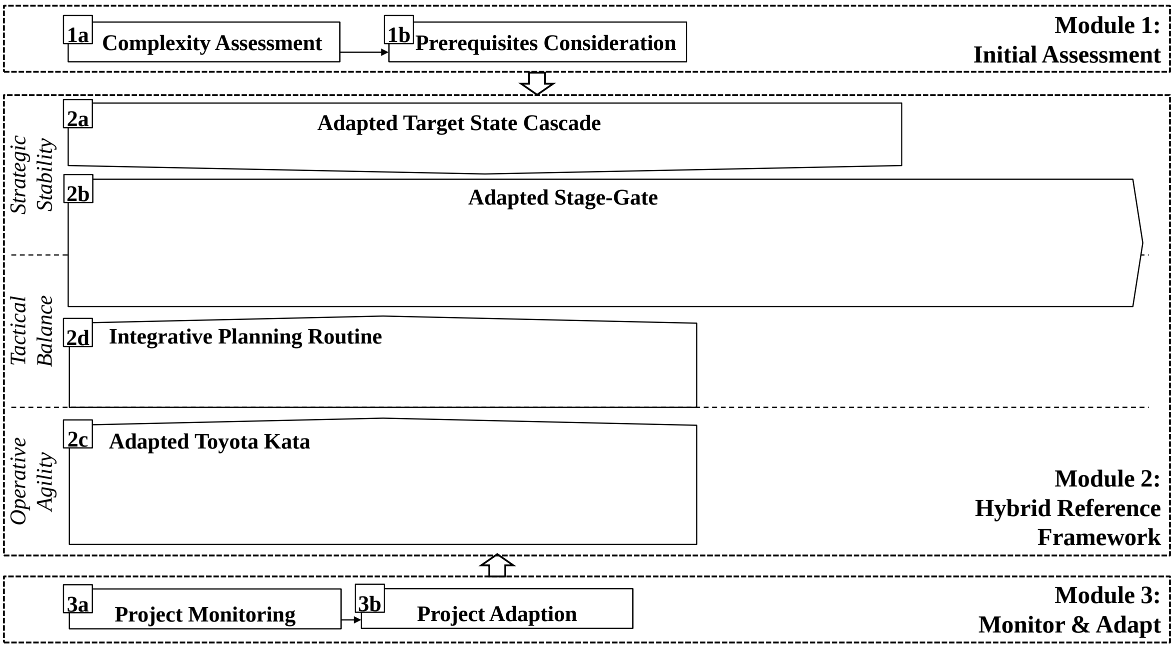

Figure 5.2: Overview of the integrated method for managing complex BPI projects (details of the modules are outlined and added to this visualization in the following sections).

5.2 Module 1: Initial Assessment

Module 1 is a methodical guidance for managers in BPI projects to individually assess complexity and critical prerequisites from their perspective and to achieve awareness of the project setting with *Element 1a: Complexity Assessment* and *Element 1b: Prerequisites Consideration*.

5.2.1 Element 1a: Complexity Assessment

The first review of complexity theory in section 2.3 revealed that the determinative degree of complexity depends on the individual perception by the observer (SCHÖTTL 2016) and what may be regarded as complex by one project manager may ”only” be complicated for another (W. ELMARAGHY et al. 2012). The initial complexity assessment developed for this integrated method, therefore, is designed as a self-evaluation for project managers to reflect on their individually perceived situation. Evaluating complexity at the beginning of a BPI project is intended as a justified motivation for leaving the path of proven practice (see figure 2.4) and up-front planning for establishing an agile project approach.

Synopsis of the relevant literature

According to the displayed *Cynefin* framework (see figure 2.5), in a complex context, *unknown unknowns* are yet to be discovered. On this insight, it was concluded that only retrospective comprehension of the correlations and dynamics is achievable. Complicated problems, on the other hand, tend to allow sufficient understanding by analyzing the *known unknowns* by applying proven pattern and experiences (SNOWDEN & BOONE 2007).

VOGEL & LASCH (2016) provide a deeper insight to the various sources of complexity in manufacturing companies by reviewing 235 scientific publications from several domains. This immense range of literature dedicated to the identification and categorization of complexity *drivers*[1] represents a vast choice for project managers in practice. The authors conclude their analysis with a classification of the drivers in categories of complexity that portray the constitutive elements in a manufacturing company (e.g. product, process, market, technology, logistics). These describe potential sources or areas that generate or involve complexity (cf. VOGEL & LASCH 2016) and facilitate

[1] According to VOGEL & LASCH (2016), “complexity drivers [...] are responsible for increasing a system’s complexity level and help to define the characteristics or the phenomenon of a system’s complexity”. Further, the term is synonymously used to ”indicator”, ”parameter”, ”variable”, ”source”, ”factor” or ”dimension”.

a reduction. By contrast, the literature presented in section 2.3 puts more emphasis on providing a precise differentiation of complexity *types* (e.g. uncertainty, dynamics, pace) for a better understanding without specifying where these emerge or manifest in an organization (see GERALDI et al. 2011). SNOWDEN & BOONE (2007) or SUH (2005) on the other hand, itemize empirically observable *effects* of complexity (e.g. emerging insight, unknown unknowns).

Rationale behind the complexity assessment approach

A complexity assessment as a decision-making basis should guide a manager to reflect on a current project situation systematically. Assessing complexity at the beginning or during a BPI project is essential for managers but not trivial (BRANDL et al. 2021). As SNOWDEN & BOONE (2007) stated, complex situations hide unknowns, allowing only retrospective understanding of correlations and dynamics. Therefore, a complexity score could be misleading when evaluating a project during an early phase.

The approach of this assessment is therefore, to give managers a sensation for the complexity of a BPI project by letting them reflect on typical drivers. This self-reflection is guided by a list of project-related questions composed as a questionnaire. By trying to find answers to these questions, they are supported in analyzing a current problem situation. If they can recognize and eliminate typical unknowns by giving sufficient answers to these questions, the complexity should be manageable with conventional plan-driven project approaches. The more a project manager struggles with the questionnaire, the higher tends to be risk of being confronted with emerging unknowns during a project, and therefore, a high level of complexity.

Result: Complexity Assessment questionnaire

The developed questionnaire visualized in table 5.2 is clustered in six categories of questions that address a project complexity and is developed with the consulted experts from the industry (see table A.4). To reduce the effort for managers, the list is limited to 24 questions and has a strong focus on potential complexity drivers tending not to be self-evident to them. Discussions with the experts revealed that managers usually focus on product- and process-related complexity which have primarily a structural nature (variety). In their experience however, in BPI projects, many unknowns emerge from confusion in stakeholder participation (internal and external), inexperience with involved technologies (product- or process-related), unstable market conditions, an unpredictable or unreliable project plan, fragile accountability scopes, or insufficient team competences.

*Table 5.2: 24 guiding questions for the individual complexity assessment of BPI projects (*BRANDL *et al. 2021).*

Questionnaire for an Individual Complexity Assessment
Stakeholder Participation Who contributes to the project? How many and which departments participate? How many and which persons participate? How many and which external stakeholders participate?
Involved Technologies Which technologies are involved now and throughout the project? How ranks the maturity level of these technologies? How can my team cope with the requirements of these technologies? Do the involved persons have knowledge about these technologies? Are the involved persons experienced in practice with these technologies?
Market Conditions Is the relevant market stable and predictable? How does a market change affect the project? What tangible project requirements do I know? Are they solid?
Project Plan How can I guarantee transparency? How can I coordinate the project? How does the superordinate project plan look like? Do I know all essential milestones and their deadline? Is the project plan reliable?
Accountability Scopes What is my scope of accountability? What are my direct interfaces' scope of accountability? Are the scopes arranged among the project partners? Are the arrangements solid?
Team Competences Which competencies do I need in my team to achieve the project goal? Do I know all the necessary competences? Are all required competencies available in the project team?
Can I give satisfying answers to all questions?

The questions force project managers to self-reflect on a project's involved complexity. A good indication for a high level is when they cannot answer the questionnaire with ease, have an uncomfortable feeling, or feel unsatisfied with the quality of their answers. The self-reflection on these helps them to decide whether an agile project approach should be considered.

5.2.2 Element 1b: Prerequisites Consideration

Complexity can be regarded as a necessary condition for introducing agile approaches, but not a sufficient one. Transforming a project organization to be more agile in a non-agile environment consumes additional resources before achieving a beneficial outcome. On that premise, essential prerequisites for increasing agility in a BPI project team are elaborated in this section. The prerequisites are derived from the general success factors for a reasonable application of agile approaches in a manufacturing company gathered from the literature (visualized in table 4.1 on page 83). The full list of success factors was aggregated to a practicable checklist of 14 essential prerequisites that project managers can reflect on when considering to confront their teams with an agile approach during a complex BPI project.

Synopsis of the relevant literature
The literature review and expert interviews in the previous chapters 3 and 4 revealed that the success factors for implementing organizational agility in an organization may differ from case to case (BATRA et al. 2010). Authors like COCKBURN (2002), LINDVALL et al. (2002), GOLL & HOMMEL (2015), KIENBAUM (2015), KORN (2016), SCHRÖDER (2017), and MAXIMINI (2018) identified organizational, team-, team-, and project-related factors as relevant (see table 4.1). These factors were also confirmed by the interviewed experts of this research project (see table A.4).
Some factors were consistently stated by almost all of the authors, like a *Servant Leadership* style or to show *Confidence & Trust* to the project team. Other factors were mentioned barely in the literature, like an *Openness of Mind* (GOLL & HOMMEL 2015; KIENBAUM 2015) or *Social Skills* of the team members (LINDVALL et al. 2002). According to the experiences of *Expert H* and *Expert F*, however, without an *Openness of Mind*, new techniques and practices were hardly adopted by their teams.
In the following, the process of translating the gathered success factors to a practicable checklist of essential prerequisites is explained.

Rationale behind the selection of prerequisites
Similar to the approach of developing the complexity assessment questionnaire outlined in the previous section, the essential prerequisites have been selected from the perspective of a manager wanting to understand, whether a certain BPI project is suitable for introducing agile techniques. Observations in the filed confirmed the impression that forced a implementation of agile organizations will fail or can create

"false front-end agility" (see expert interviews in section 4.4). Only managers and teams expecting a benefit from an agile project approach will accept and actively support such a transition.
On this premise, a checklist of 14 essential prerequisites was created based on the gathered factors for a reasonable application of agile approaches in a manufacturing environment depicted in table 4.1. The rationale behind selecting the essential prerequisites was to identify and gather potential show stoppers for introducing agile techniques. The checklist was created by logical thinking and was discussed in several iterations with the consulted experts from the industry (see table A.4) reflecting on their experiences with implementing agile project management.

Result: Prerequisites Consideration checklist
The developed checklist shown in table 5.3 is divided in *Project-*, *Team-*, and *Organization*-related aspects. The minimal prerequisite is therefore formulated as a self-reflection for the project manager: *I am the initiator for deploying a hybrid project organization.* This does not imply that the idea or the motivation cannot have an external source, however, the project manager should be the initiator of the final decision. Some of the prerequisites are a matter of personal evaluation (e.g., *Pace plays a significant role in this project.*), others might later be accomplished during the project (e.g., *My core team is fully dedicated.*), or may require a change in the project manager's personal mindset (e.g., *I have trust in my team and I let my team make mistakes to learn from them*). All prerequisites can be assessed from the project manager's perspective.
The combination with the individual assessment of project complexity facilitates a more profound decision on the adaption of the modus operandi. The remaining success factors gathered in table 4.1 are incorporated in the following procedural reference model and empowerment routine.

5.3 Module 2: Hybrid Reference Framework

Module 2 supports the overall goal to create more agility in BPI projects embedded in a *Hybrid Project Management* structure. As captured by the online survey (see section 4.2) and postulated by many authors (see e.g. CONFORTO & AMARAL 2016; COOPER & SOMMER 2018; SOMMER et al. 2015), *Hybrid Project Management* gains in interest

*Table 5.3: Checklist of 14 essential prerequisites for the individual assessment of BPI projects (*BRANDL *et al. 2021).*

Checklist for Critical Prerequisites
Project
I am the initiator for a hybrid project organization.
I know my project's internal or external customer.
The project's customer can test and review partial results.
The project has a clear vision. I understand and support this vision.
To this point, I cannot specify the project's requirements in detail.
The project's requirements are likely to change.
Pace plays a significant role in this project.
Team
The vision requires a collaboration of interdisciplinary competences.
My team welcomes new ideas and changes.
My team appreciates community spirit.
I have trust in my team.
I let my team make mistakes to learn from them.
Organization
The superior management grants the required room for maneuver.
My core project team is fully dedicated.

among manufacturing companies to increase operational agility while maintaining their conventional meta structures. The *Hybrid-Stage-Gate* and the methodological portfolio of the *Agile Software Development* domain with *Scrum* have received the most attention.

As Takeuchi Hirotaka and Nonaka Ikujiro outlined in their essay from 1986, the idea behind fast-iterative problem-solving in the *Scrum* framework (called *Sprints*) is grounded in the Japanese manufacturing industry (cf. TAKEUCHI & NONAKA 1986). Nonaka Ikujiro later added, that the Japanese manufacturers build their innovative venture on corporate learning in which experimentation and individual coaching play a key role (NONAKA 2007).

Since the first studies in the 1980's, the western world's understanding of *Toyota's* success was primarily focused on the visible methods and tools of *Lean Production*, falsely marking the underlying management approach as a concept for reducing costs by the continuous improvement of a production system's efficiency only (ROTHER 2010). ROTHER (2010) and many other authors realized, that "The Toyota Way" of innovation was different to the western tradition as well. According to their observations, *Toyota's* integrated management system of continuous experimental learning and individual coaching is the driving force behind the company's innovation capacity and success (see section 3.4).

The transition from conventional plan-driven project management to an agile approach in a manufacturing environment is a change project by it self. But, companies like *Toyota* demonstrate how complex innovation projects can be managed with proven routines and practices based on Explorative Validated Learning. Following up on the above mentioned observations by TAKEUCHI & SHIBATA (2012), NONAKA (2007), and ROTHER (2010), the Hybrid Reference Framework was developed by combining and adapting the approaches presented in chapter 3: *Organizational Change Management* (OCM), *Business Process Re-engineering* (BPR), *Hybrid Project Management* (HPM), and *Explorative Validated Learning* (EVL). The reference model constitutes an instructive framework for the iterative planning of next target states and the formation of process prototypes that allow Explorative Validated Learning.

Hybrid Reference Framework structure

The first step in developing the Hybrid Reference Framework implied the definition of a general structure that not only takes the involved corporate hierarchical levels into account, but also allows a precise breakdown of individual goals and activities within specific time granularity. In accordance with the requirements for this module, the proposed model facilitates the coordination between the disparate priorities of *operational agility* and *strategic stability*. The structure depicted in figure 5.3 separates a BPI project into a strategic, tactical, and operational level. This is in line with recent published *Hybrid-Stage-Gate* models (see e.g. COOPER & SOMMER 2018). On these levels, the various participants perform distinct tasks and activities.

While a tactical sub-phase should take between two and three months, following suggestions by COOPER & SOMMER (2018) and ROTHER (2013), the daily project work phases, confined by targets states, are limited to two weeks. These operational planning cycles correspond with observations in the *Toyota Motor Corp.* by ROTHER (2013) and with suggestions for *Sprints* by COOPER & SOMMER (2016)[2]. A target state thus contains the results to be delivered every two weeks, which can have various characteristics depending on the phase in a BPI project. Milestones on the strategic level confine phases with a duration from six to twelve months.

[2] It should be mentioned that in some models found in the literature, *Sprints* are rather assigned to the tactical level with a duration of several weeks (see e.g. CONFORTO & AMARAL 2016).

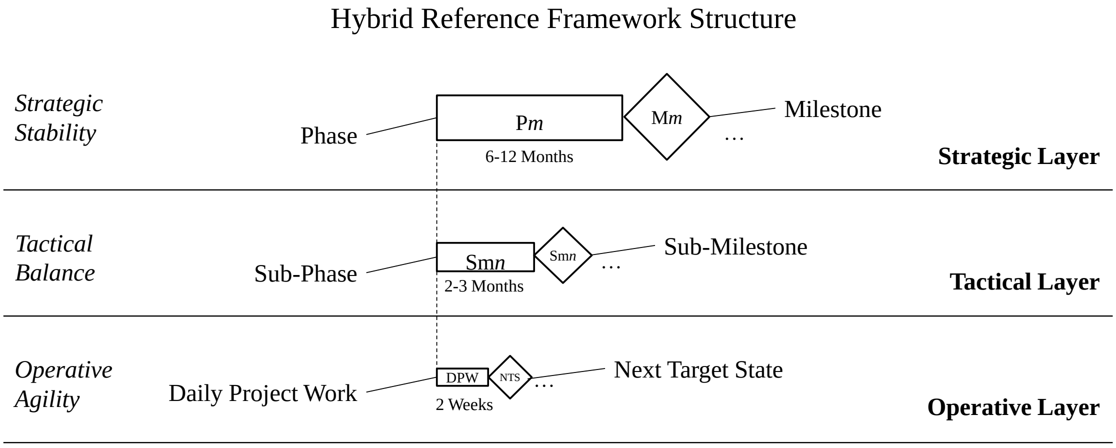

Figure 5.3: The Hybrid Reference Framework structure (module 2) separates a BPI project into a strategic, tactical and operational level, enabling and facilitating coordination between operational agility and strategic stability. Illustration developed with RIDOLFI *(2020) based on* BRANDL *et al. (2020) &* COOPER *&* SOMMER *(2018).*

5.3.1 Element 2a: Vision Alignment & Adapted Target State Cascade

All three levels of a BPI project should be guided by a higher-level vision providing a direction and motivation for activities and actions in the daily work and planning routines.

Vision Alignment

When formulating of a process vision, DAVENPORT (1993) explains that the company vision, customer requirements (internal and external), and bench-marks of other companies' processes help to formulate reasonable process goals and attributes (see figure 5.4). The process goals are later broken down into target states within the hybrid framework and should be quantifiable by using quantitative KPIs like, e.g., the order throughput time (DAVENPORT 1993). Process attributes in contrast, are qualitative details specifying, for example, the technical equipment to be used (DAVENPORT 1993). These goals and attributes correspond with product specifications in the product development process (cf. KLEINSCHMIDT et al. 1996) and also reflect overarching intentions like better planning, standardization, or modularization. It makes sense to specify these higher-level intentions before cementing tangible process objectives.

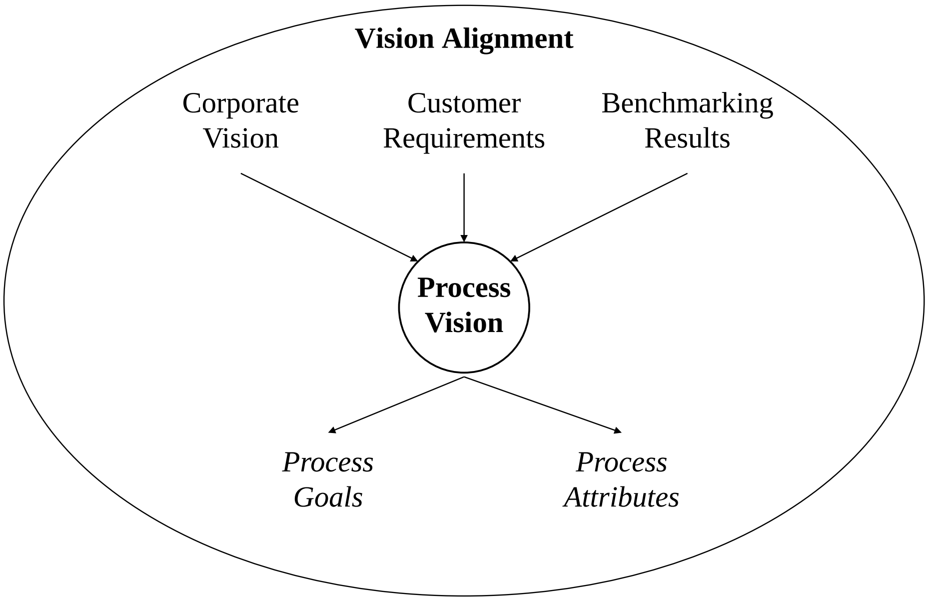

Figure 5.4: Formulation procedure of a process vision at the beginning of BPI project. Illustration developed with RIDOLFI *(2020) in accordance with* BRANDL *et al. (2020)* & DAVENPORT *(1993).*

Adapted Target State Cascade

As outlined in the previous passage, the senior management formulates a process vision before or at the beginning of a BPI project based on the corporate vision, customer requirements, and benchmarks results of comparable processes. To approach this process vision they usually set a strategy (RIES 2019; SCHUH & KAMPKER 2011) . As depicted in figure 5.5, the project team together with the manager try to follow the set course by agreeing on process goals and attributes. To organize the daily project work, however, the process vision and the project challenge are cascaded down into superordinate milestones, sub-milestones, and theoretically, into tangible target states (AULINGER & ROTHER 2017). This cascading approach is closely linked with the *Hoshin Kanri* policy deployment and agile strategy implementation in the production management practiced by the Toyota Motor Corp. (see e.g. KUDERNATSCH 2019). The adapted target state cascade is a top-down planning routine for complex BPI projects that helps the managers and senior management to steer the operational activities top-down. However, it has a continuous, iterative character, since the involved complexity does not allow full up-front-planning. While the superordinate milestones are agreed upon after formulating the process vision, the upcoming interim sub-milestones are periodically re-aligned with the process vision at the beginning of a project phase[3]. The formulation of operational target states is left to the project team, and might only be influenced deliberately. *Element 2d*, the *Integrative Planning Routine*, captures this continuous re-alignment of gained knowledge and setting of next target states is outlined in detail. Before, the strategic (*Element 2b*) and operative (*Element 2c*) layers are explained. Figure 5.6 shows the allocation of the *Adapted Target State Cascade* in the framework.

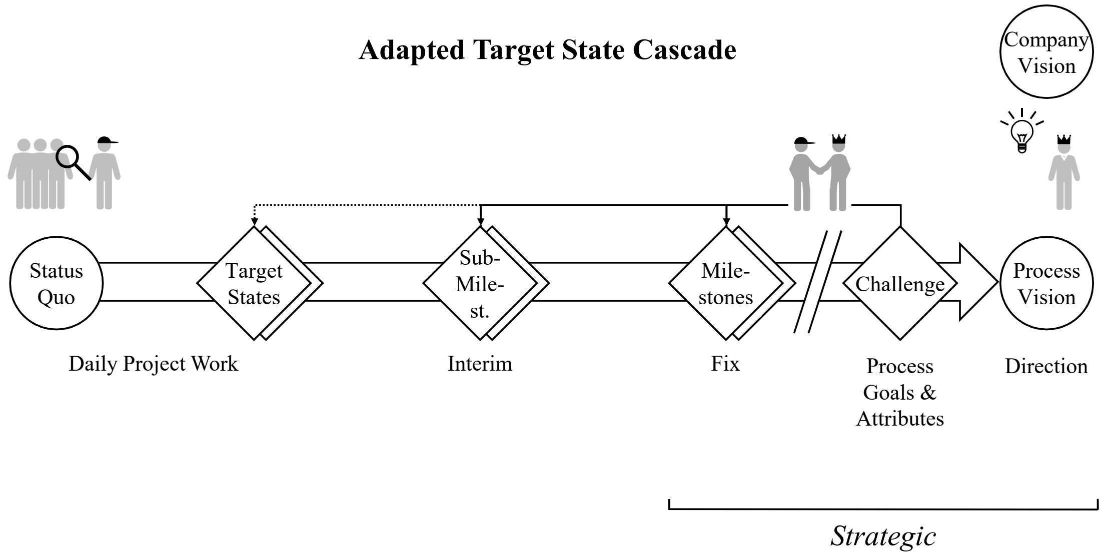

Figure 5.5: The adopted target state cascade to break down the process vision into sub-milestones and target states on the strategic planning level of BPI projects (extended visualization based on depictions by AULINGER & ROTHER *2017).*

5.3.2 Element 2b: Adapted *Stage-Gate* for Strategic Stability

To guarantee stability in a complex BPI project, the proposed strategic level of the procedural reference model is an adaption of Cooper's classical *Stage-Gate* structure

[3] While the sub-milestones might be interim content-wise, their scheduled date should be maintained to keep a steady pace.

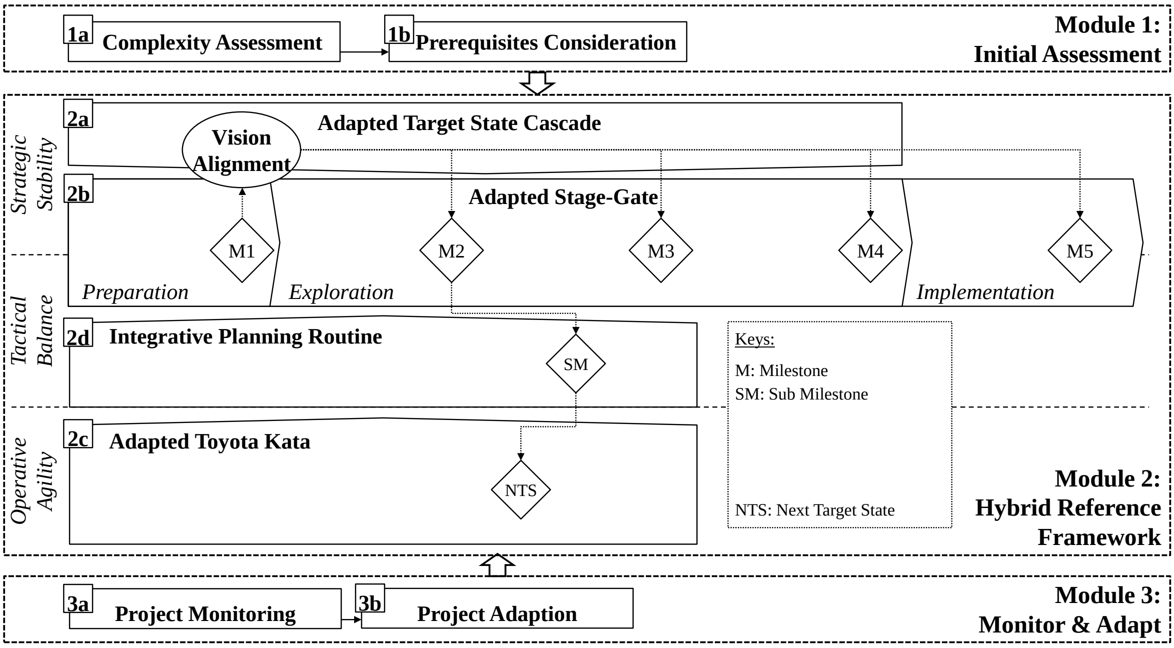

Figure 5.6: Overview of the integrated method for managing complex BPI projects with the incorporated adapted target state cascade

(see COOPER 1990). The phases are modified with regard to the experiences of the consulted experts (see table A.4) and the references from Agile Process Planning (APP) (see subsection 3.3.2).

In a *Stage-Gate*-structured project, the actual work is achieved during the stages (COOPER 1990), while the gates serve as milestones or decision points (KLEINSCHMIDT et al. 1996). Managers together with their teams suggest requirements to be met and results to be achieved at each milestone at the beginning of a project. This proposal is then either approved or rejected by the superordinate management board. Once accepted, the strategic phases and milestone specifications should not be changed during a project (KLEINSCHMIDT et al. 1996).

Adaption of phases & overview

Like many BPR approaches (see section 3.1), the adapted *Stage-Gate* model for BPI opens with an analysis phase (*Phase 1: Analysis*). Instead of focusing on idea screening (see classical *Stage-Gate* in figure 5.7), BPI projects require a deep understanding of their general environment and constraints. Depending on the business process and the manufacturing company, the first phase should last three to six months and, as proposed by DAVENPORT (1993), conclude with a process vision that reflects the company's general vision.

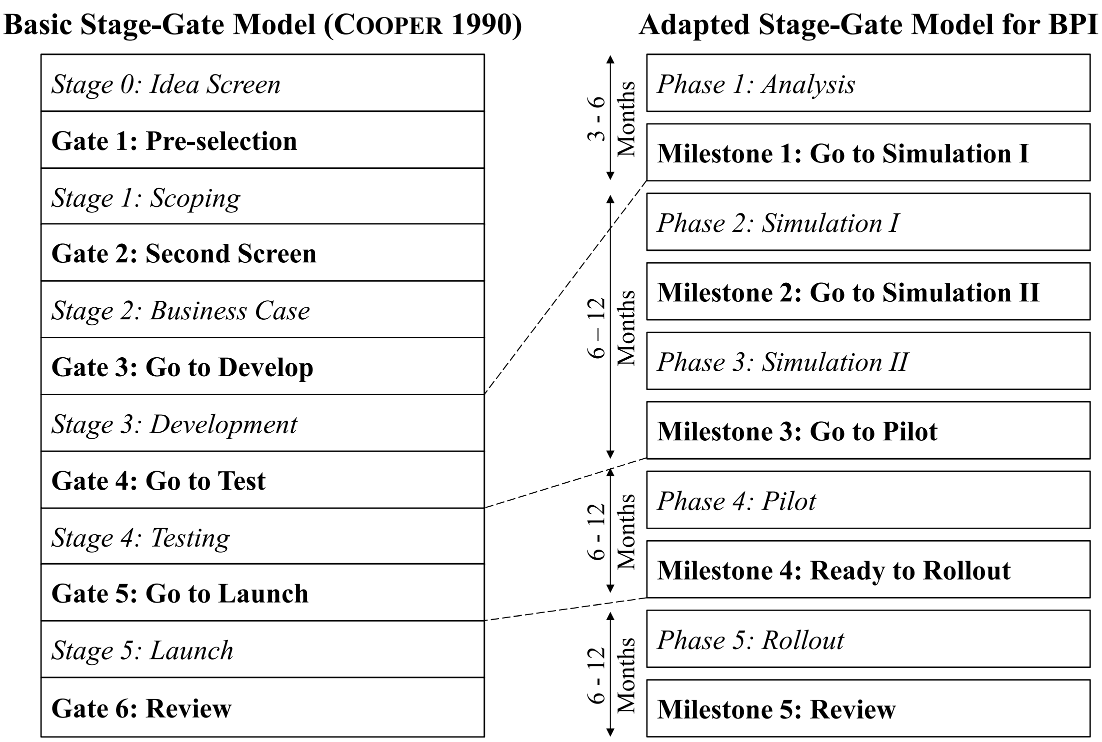

*Figure 5.7: Adaption of the classical Stage-Gate model (*Cooper *1990) to BPI projects, adding elements of BPR approaches (*Davenport *1993;* Hammer & Champy *2006). Illustration developed with* Ridolfi *(2020).*

The BPR approaches postulated by Davenport (1993) and Hammer & Champy (2006) were criticized for their neglect of social and organizational factors in later years (see e.g. Vakola & Rezgui 2000). In particular, it was pointed out that the authors were describing business processes mainly as compiling the correct sequence of activities and leaving out the involved persons (see Lindsay et al. 2003). To address this shortcoming that led to a low success in practice (Gaitanides 2013), the proposed adapted *Stage-Gate* model proceeds with two simulation phases (depicted in figure 5.7). During these phases, the focus is set on collective learning through validated experimentation by the project team using a physical process simulation setup as a ”vehicle”. *Simulation I* is intended to bring forth a validated process idea on

an abstract level. This can be achieved, e.g., with physical cardboard models[4] or in dedicated environments for learning and innovation, like *Learning Factories*, where basic processes can be reproduced and experienced (see ABELE et al. 2019).
Simulation II provides a more technical validation of critical process features. It can be understood as a better equipped and in certain parts more sophisticated version of the prototype setup used during *Simulation I*, e.g., by adding real equipment and actual IT systems to it. The still experimental environment allows configuration, customization, or first training of involved people which helps reducing surprises and resistance during the actual implementation. In contrast to the subsequent pilot phase, *Simulation II* still operates in a protected area outside the daily business. Both simulation phases contribute a significant element to the experiential learning aspect.
The added *Pilot* phase represents the first step into the actual business environment. To do so, the latest version of the developed process prototype is implemented as a fully operational trial in a selected area or section in the company. The result, and the undertaking of achieving it, helps to demonstrate the technical validity and performance of the process, however, at a limited scope. The pilot also marks the starting point for a novel path of continuous improvement (see figure 2.4) and for expanding the results to further business units, sections, or locations.
Once the pilot area has demonstrated technical validity and respectable performance, the *Roll-Out* phase may begin. During the roll-out, the achievements from the pilot area are expanded to all relevant business areas. In accordance with COOPER's *Stage-Gate* (1990), the BPI project should finish with a *Review* milestone comprising a project review, lessons learned, and a final handover to the process owners[5] of the new business process and its sub-processes. For a smooth launch, the process owners should participate in the BPI project playing a central role, e.g., by steering the respective process experimentation and development during the simulation and pilot phases as sub-project managers.

[4] In the German community, *Cardboard Engineering* commonly refers to the practice of experimenting with physical mock-ups using mainly cardboard or generally cheap materials to build a realistic and cost-effective process simulation in which key process stakeholder can participate by taking an active role (BERTAGNOLLI 2018). The technique is considered a basic tool in the TPS (LIKER 2004)

[5] A process owner is a single person accountable for developing, sustaining, and improving a particular process or sub-process to guarantee an adequate process output (cf. *Gabler Wirtschaftslexikon* 2019).

Detailed phase description

Phase 1: Analysis
In the first phase, the actual perimeter of the business process to be innovated is delimited (see table 5.4). According to DAVENPORT (1993), this task consists of enumerating the main process steps or activities, defining their respective perimeters, determining their strategic relevance, analyzing their individual ”pathology”, and evaluating their political and social relevance in the organization (GAITANIDES 2013). As outlined in the previous section, innovation efforts can be channeled with a formulated and aligned process vision, which only succeeds with a common understanding of the current process. The process vision comprises measurable goals and attributes, is aligned with the corporate vision, and provides orientation for process related changes in the organization. The process vision reflects the customer needs in terms of output, performance, stability, and transparency[6] (DAVENPORT 1993). Formulating a process vision marks an essential deliverable during the analysis phase. Other important activities are the specification of the future process goals and attributes, an estimation for the transition budget, and the core team assembling. The first milestone requires a formulated process vision and defined project conditions (see table 5.4).

Phases 2 & 3: Simulations I & II
After successfully passing the first milestone, having defined the project setting and formulated a process vision, the second and third phase are dedicated to develop and build several process prototypes. This early and systematized experimentation facilitates the iterative specification of process characteristics (see DAVENPORT 1993). The separation into a first and a second process simulation phase ensures a better integration of experimental findings. The additional milestone in between these two phases is also intended to facilitate risk mitigation by allowing the senior management to intervene at an early stage if the first results do not provide sufficient references for a promising outcome. The incremental improvement of the process prototype helps to increase the level of common comprehension among all stakeholders, a key factor in redesigning business processes according to DAVENPORT (1993).
Simulation I should start with simple flow diagrams that might be constantly further

[6] This list of customer requirements towards the process corresponds to the specification book in stage 2 of COOPER’s model (1990) (see table A.1).

detailed and extended, always visualizing the latest states. Later, computer simulations and physical mock-ups provide better opportunities to specify the process. They also allow first training and support mutual understanding, for example, by recreating the process vision with simple simulation games[7]. Refining such a simplified, haptic simulation collectively in a project team according to the current process goals and attributes can help to identify critical aspects in a visual manner and therefore creates common understanding. When the process idea is validated on an abstract level (e.g. in a protected area), the second milestone can be passed to *Simulation II*.
As part of *Simulation II*, the prototype can now receive greater attention to detail to bring it closer to a real process. For this purpose, following DAVENPORT's process prototype description (1993), actual work equipment can be installed to carry out individual steps and activities within the process. This may, for example, be achieved by adding PCs and work stations, and by implementing a real ERP system. This procedure helps to identify and define the essential interfaces to corporate information systems or organizational structures (DAVENPORT 1993). The simulation phases end with the technical validation of critical process goals and attributes. *Milestone 3* marks the last quality gate before the actual implementation of a new business process. The insight gained from the simulation is utilized to reflect and specify the planning parameters defined during *Phase 1* in order to achieve better results in the subsequent pilot.

Phase 4: Pilot

During the fourth phase of the adapted *Stage-Gate* model, the novel business process is piloted within a defined area or section of the company to demonstrate its technical validity and performance. This pilot implementation can be characterized as a fully operational business process, however, within a limited scope. This approach of starting the change with a positive example is in line with the successful introductions of the *Lean Management Philosophy* (see e.g. WOMACK & JONES 2003) and some ideas in the OCM models presented in chapter 3, section 3.2.
The phase ends with the fourth milestone *Ready to Roll-Out* which serves as the final feasibility assessment for the entire BPI project and thus corresponds with the

[7] In Lean or Supply Chain Management training, a common simulation game is for example a simplified Manufacture to Order (MTO) design and manufacturing process of classic paper gliders to demonstrate fundamental concepts.

Table 5.4: Adapted Stage-Gate model for Business Process Innovation (BPI) in manufacturing companies developed with RIDOLFI *(2020).*

Adapted Stage-Gate Model for Business Process Innovation (BPI)
Phase 1: Analysis *Identification and perimeter of the business process in focus;* *Detailed analysis of the current process goal, stakeholders, and components;* *Specification of the future process goals and attributes;* *Estimation for the transition budget;* *Core team assembling;* *Formulation of a process vision in compliance with the company vision*
Milestone 1: Go to Simulation I *Process vision formulated and project conditions defined*
Phase 2: Simulation I *Validated experimentation through collective learning using digital and haptic simulation tools (e.g. cardboard engineering, simulation factories, process labs)*
Milestone 2: Go to Simulation II *Validated process idea on an abstract level (e.g. in protected area)*
Phase 3: Simulation II *Validated experimentation on close to reality process simulation (e.g. applying real equipment and software, simulating standard and special process cases); first training*
Milestone 3: Go to Pilot *Technical validation of critical process features (e.g. in protected area with features)*
Phase 4: Pilot *Implementation of a process pilot in a selected area or section in the company to demonstrate the full technical validity and performance at a limited scope; training on the job*
Milestone 4: Ready to Roll-out *Technical and performance validation in a selected area or section in the company*
Phase 5: Roll-out *Expansion of the achievements to all relevant business areas, stabilization, and continuous improvement of the implemented processes, lessons learned*
Milestone 5: Review *Project review; lessons learned; ready to handover*

”decision on market readiness” for product innovations (COOPER 1990). At this point, the parameters set at the beginning of the project are reviewed, finally deciding on the company-wide expanding of the results. The gathered data and experiences from the pilot implementation, for example a record of positive and negative response to the new process, helps to better coordinate and direct the company-wide roll-out.

Phase 5: Roll-out

During the final phase, the business process is extended step-wise to the intended perimeter. In doing so, the established pilot area provides operational learning experiences for other employees, which helps to overcome resistance (BEST & WETH 2003). The course of the roll-out phase strongly depends on the individual situation, however, it should be completed with the last milestone, a *Review*, as proposed by COOPER (1990). During this final analysis, when the project results are evaluated and the project team breaks up, the novel business process finally becomes part of the company's daily operations.

Figure 5.8 shows how the phases of the adapted *Stage-Gate* is incorporated in the integrated method. The analysis phase is of the preparation, while during the simulation and pilot phases the focus is set on exploring the right new processes. During the roll-out phase, the modus switches to implementation of what has been defined before.

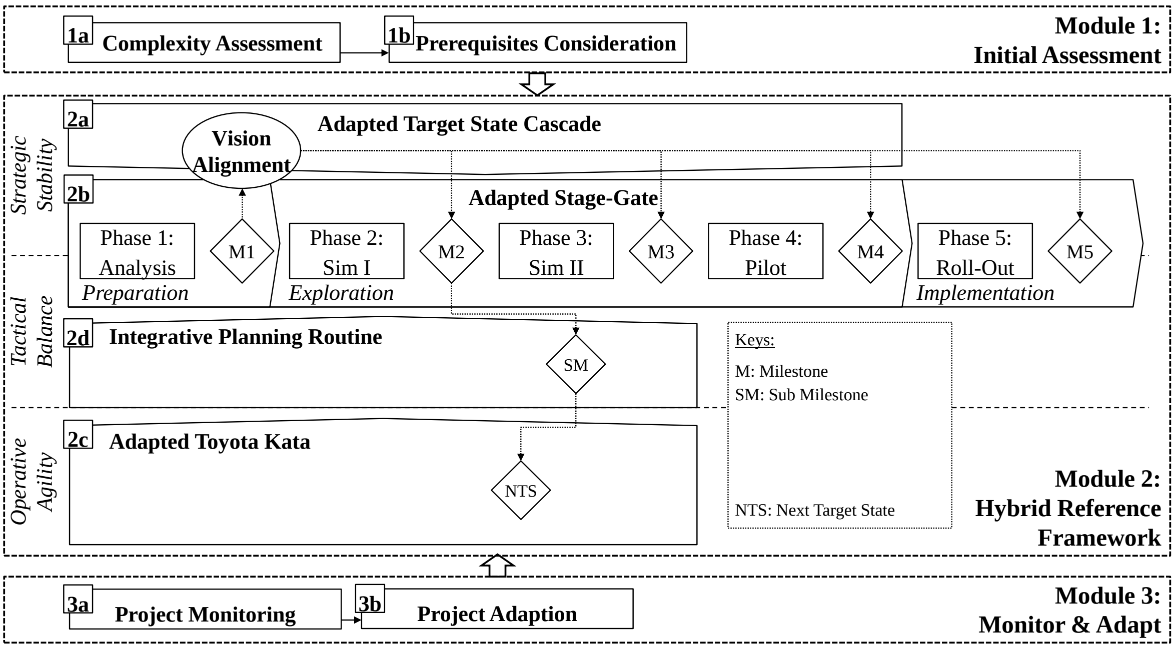

Figure 5.8: Overview of the integrated method for managing complex BPI projects with the incorporated adapted Stage-Gate

5.3.3 Element 2c: Adapted *Toyota Kata* for Operative Agility

In a conventional daily business routine in a non-complex environment, progress is achieved by accomplishing day-to-day goals and by following best practice (see chapter 2, section 2.3). Since the BPI project in focus is characterized as complex, the advancement requires emergent practice based on explorative, validated experimenting to incrementally discover cause-and-effect relations (PFEFFER 2019). The PDCA cycle, which is embedded in the *Improvement Kata* (see chapter 3, section 3.4, figure 3.10), provides a basic scheme for problem-solving under these conditions.

Adapted Improvement Kata
In a BPI project, the initial strategic planning part of the standard *Improvement Kata* (step 1) happens on the strategic level. The senior management formulates a process vision and a challenge by setting process goals and attributes to provide a direction. The strategic stability during such a project is guaranteed with the preset milestones and interim sub-milestones. With the gathered knowledge from the status quo (step 2 of standard *Improvement Kata*), next target states can be formulated and interim sub-milestones can be refined or affirmed (step 3). To reach a next target state, the team overcomes problems and obstacles (step 4). Figure 5.9 summarizes the adapted *Improvement Kata* as an implementation of emergent practice for operative proceeding in a BPI project. The main advancement of the adapted Kata are the introduced milestones and sub-milestones to achieve the hybrid integration with the adapted *Stage-Gate* process.
Problem-solving capabilities play a key role for achieving operative progress in complex environments (BULLINGER 2006). Apart from the PDCA cycle, the *Lean Management* and *Agile Project Management* domains provide a broad choice of practices and techniques to support situation-specific problem-solving. A well-known practice from the TPS is the *Five-Why-Analysis* (see e.g. KING 2019). This approach, which is also suggested by RIES (2019) as part of the *Lean Start-Up* method (see section 3.4), is based on the consideration that apparent problems are usually symptoms of deeper causes. However, several methods and tools are available. Therefore, *Module 3*, which is presented in the subsequent section 5.4, is fully dedicated to the question, how project managers can cultivate their team's operational problem-solving skills systematically. The module elaborates on this by providing a list of hands-on problem-solving practices applicable during complex BPI projects that foster the right mindset.

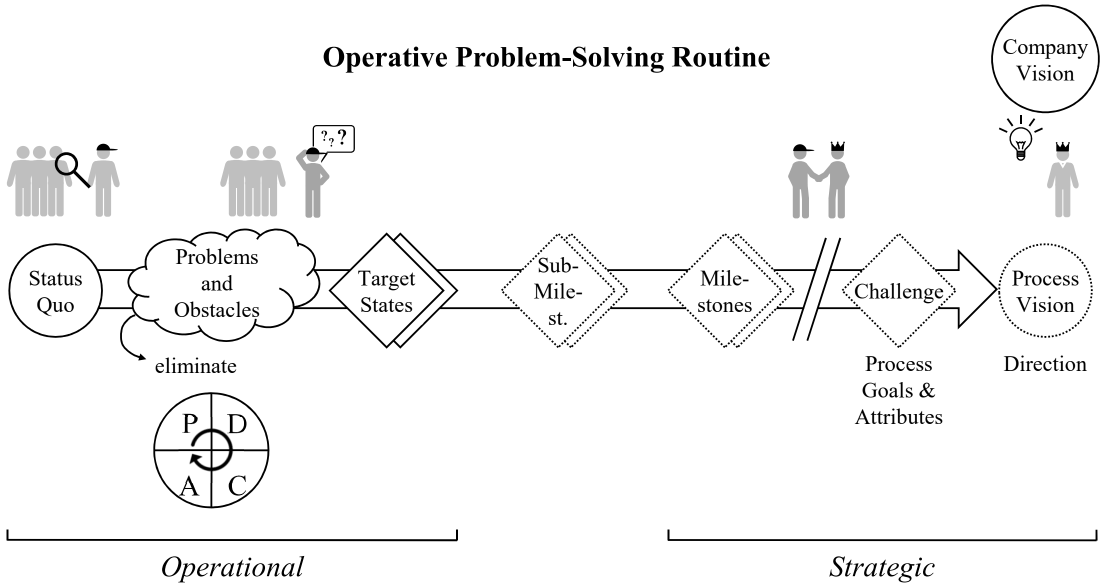

Figure 5.9: Adapted Toyota Kata as an operative problem-solving routine for BPI projects in accordance with AULINGER & ROTHER *(2017) &* BRANDL *et al. (2020).*

Adopted Coaching Kata

Apart from the deployment of practices, achieving operative progress in complex BPI projects requires managers to adopt the idea of systematic coaching. Since the complexity does not allow to provide far-sighted structure and stable tasks, their teams need to develop individual problem-solving and self-organized, validated experimentation skills. Personal coaching generally strengthens self-management capabilities (STOESSER 2019). With *Toyota's Coaching Kata* (see subsection 3.4.3), persons continuously exercise explorative, validated learning under the guidance of a personal mentor (ROTHER 2013).

In BPI projects, the *Coaching Kata* serves as a fundamental structure for short, daily coordination meetings between a mentor and a mentee. While the sub-project leaders serve their team members in this role, the project leader is their mentor in turn[8]. In these meetings, they follow the *Coaching Kata*'s five questions (see subsection 3.4.3) by clarifying the next target state (question 1), describing the status quo (question 2), reflecting on the previous step and its results (reflective questions on the last PDCA

[8] This requires a management style known under the term *Servant Leadership* (see e.g. GREENLEAF et al. 2002) or *People Management* (see e.g. BENDER-MINEGISHI 2018; ROTHER 2013)

cycle), listing the current obstacles and determining the next to tackle (question 3), agreeing on the next step (question 4), and determining a follow-up (question 5).
The *Coaching Kata* fosters interaction and knowledge proliferation between different levels of the project organization and the daily, short exchange meetings (each lasting about 20 minutes) facilitate a common understanding of the upcoming work which channels efforts and resources. The mentor-mentee relations guarantee a structured, vertical exchange of knowledge, like in the daily shop floor meetings between line staff and foremen in production plants. This mechanism leaves operational freedom to the project teams and supports the development and continuous improvement of their self-management and problem-solving skills. Additionally, the routine stipulates standardized ways for communication and creates a clear escalation ladder.

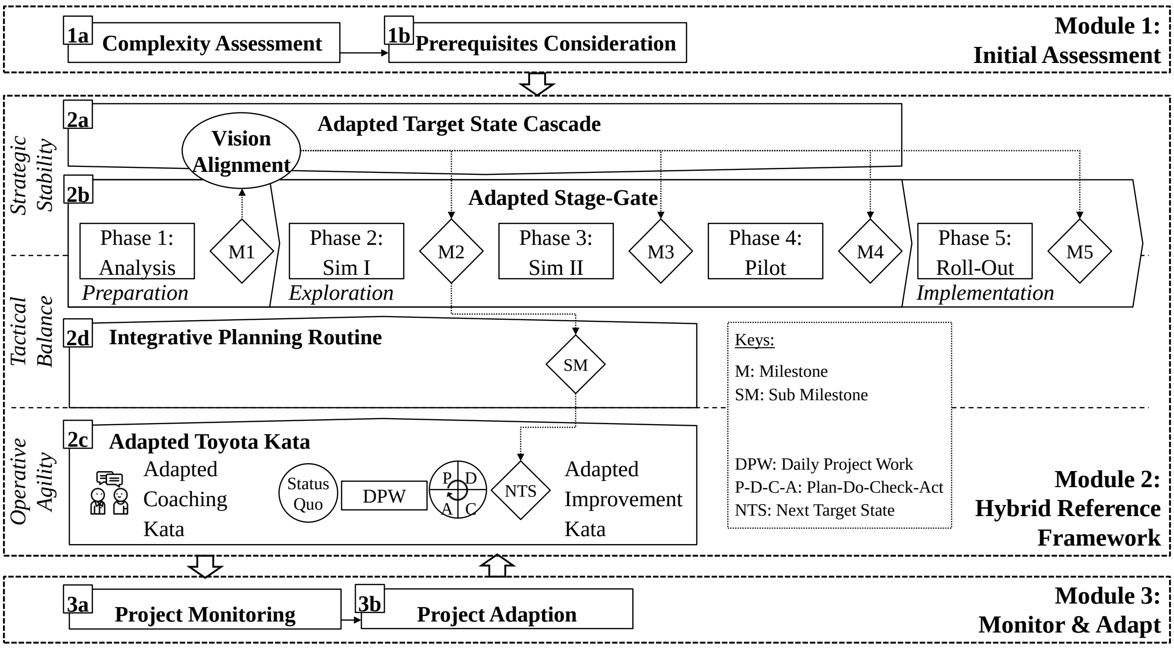

Figure 5.10: Overview of the integrated method for managing complex BPI projects with the incorporated adapted Toyota Kata

Figure 5.10 depicts the integration of the adapted *Toyota Kata* in the method framework. The Coaching-Kata thus replaces the Daily Scrums of the Hybrid Stage-Gate model, where the project team members meet daily to discuss and determine the work activities for the next day (SOMMER et al. 2015, see).

5.3.4 Element 2d: Integrative Planning Routine for Tactical Balance

To achieve the full potential of the adapted *Toyota Kata* as an operative progress routine in BPI projects, the iterative formulation of reasonable and tangible next target states is essential (step 3 of *Improvement Kata*). To be helpful, they need to be aligned with the strategic direction provided by the process vision and milestones captured in the adapted *Stage-Gate*. The integrative planning routine for BPI projects fills the gap in-between the two poles of strategic stability and operative agility, as sketched in the literature (see e.g. COOPER & SOMMER 2018; SOMMER et al. 2015). It builds on a *Build-Simulate-Learn-Align* (BSLA) routine which combines elements from the Build-Measure-Learn (BML), BTFR, and HTL pattern introduced in section 3.4 and ideas from the *Shop Floor Management* in production systems (see e.g. BRUNNER 2017).

Build-Simulate-Learn-Align (BSLA) cycle

The BSLA cycle is designed for receiving feedback and learning by building and testing process prototypes in a BPI project, especially during the simulation and pilot phases (see 5.3.2). The systematic addressing of issues in a project is essential at the moment when defining a more sophisticated next target state. In order to perform PDCA cycles to eliminate problems and obstacles on the operative level in a BPI project, (by definition) a process first needs to be *build* (first step of the BSLA cycle). While building and incrementally improving the current process prototype with several fast PDCA cycles (*simulate*), experimental learning happens and is aggregated (*learn*). The emerging knowledge and experience is then communicated and demonstrated to the project management to decide on better next target states collectively (*align*) (see figure 5.11).

By constantly applying this integrative planning routine, the top-down cascaded preliminary sub-milestones can be affirmed or, if required, adapted within the bi-weekly rhythm of team meetings. If a sub-milestone is achieved, the planning of the following is again carried out by combining the break-down of the process vision (top-down target state cascade) with the emerging new knowledge (bottom-up target state aligning). This procedure depicted in figure 5.12 ensures an adaptive *Rolling-Wave Planning* (see PROJECT MANAGEMENT INSTITUTE 2017) and accomplishes the *Explorative*

Practice for achieving progress in complex BPI projects as generally suggested by the *Cynefin* Framework (see chapter 2, section 2.3).

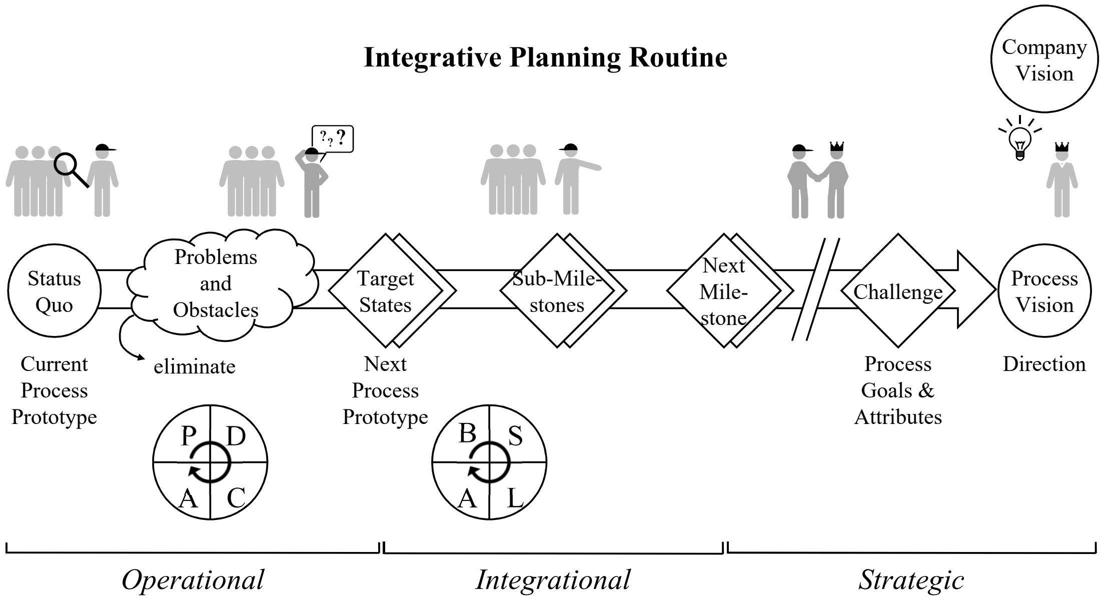

Figure 5.11: Added integrative planning routine to coordinate and control collective problem-solving between the operational and strategic layer of BPI projects (own viualization based on concepts by AULINGER & ROTHER *2017;* BRANDL *et al. 2020;* RIES *2019).*

Structured knowledge transfer

To create genuine operational agility, the project teams need to communicate their recently gathered insights and aggregated experience upwards the management levels in a structured manner. Only a systematic integration of the emerging knowledge allows rapid response to any changes in the complex project environment and, as a result, an effective determination of the respective next operative step. The incremental knowledge gain results from the successively acquired specific customer requirements. In line with *Shop Floor Management* systems, established to coordinate and control collective problem-solving at production lines (see e.g. BRUNNER 2017), specific recurring meetings constitute such a structured knowledge transfer. While the (sub)-teams coordinate work during their 20-minute *Coaching Kata* meetings, through direct communication or situational sessions, bi-weekly team-wide jour-fixes confine the BSLA cycles. Milestone and sub-milestone presentations every three months involve the senior management and other corporate departments, stakeholders or partners as necessary.

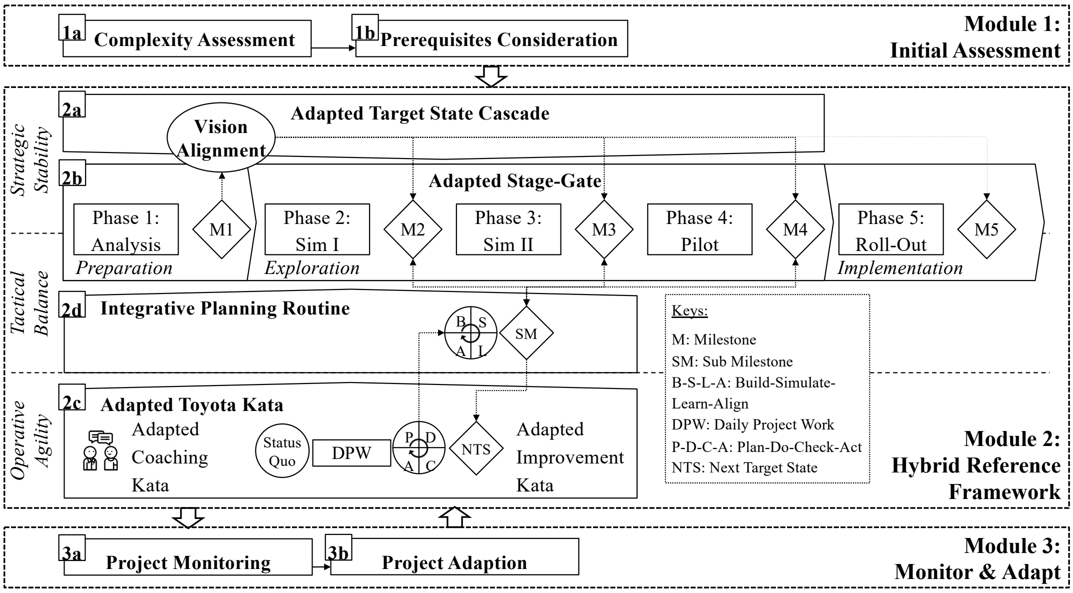

Figure 5.12: Overview of the integrated method for managing complex BPI projects with the incorporated integrative planning routine

Target state formulation as process prototypes

In this procedural reference model for BPI projects, target states should generally be understood as business process prototypes that allow customer engagement and direct feedback. While these prototypes can be abstract in the first phase of the adapted *Stage-Gate* model (*Analysis*), they become more specific and substantial during the simulation phases. COOPER & SOMMER adopt the term "Protocept" (2016) from the *Scrum* framework for that reason and postulate that such target state results should simply embody "something tangible". Target states during the *Roll-Out* phase are highly company-specific, but generally can be characterized as the continuous extension of the pilot business process to other departments or sections.

When formulating target states, it is important to understand that, depending on the project and business process, operational results can either be sub-component or sub-steps, or, in case of self-similarity, fractals of the intended process[9]. Project managers should consider the following three types when formulating target states:

Type 1: Descriptive target states. In the literature there are various definitions for describing business processes (see e.g. SCHWARZ 2018). According to BECKER (2018), a business process is formed by a supplier, a customer, input and output variables, and logically linked sub-processes and has an organizational and operational perspective[10]. Based on this understanding, process prototypes may also be specified by their sub-processes, sequence and the involved stakeholders. The maturity level of a business process prototype increases with the quantity and substance of its sub-processes, their logical connections, as well as the people, departments and organizational structures involved.
Commonly used charts for the visual description of business processes in manufacturing companies are the *Value Stream Map* (VSM) from the TPS (see e.g. OHNO & ROTHER 2013) or *Swimlane Diagrams* (see e.g. BINNER 2010). Any representation should include details on the input, output, sub-processes, involved stakeholders and required equipment or software (DAVENPORT 1993). The visual and later physical target state representations serve as a basis for discussions or meetings implementing the ”go and see” principle[11] in the early phases (*Analysis* and the beginning of *Simulation I*). However, these prototypes should be maintained up-to-date and visible as a single point of truth. During *Simulation I*, the process prototype, and therefore the target states, become more technical and physical.

Type 2: Physical target stages. A physical process prototype is a haptic representation of a descriptive target state. It is intended for experimenting and haptic simulation to foster collective, validated learning. *Cardboard Engineering* is a simple and cost-effective way to build prototypes during early phases of a BPI project. By no later than the beginning of *Simulation II*, technology, actual work equipment, and IT-Systems should constitute the major part of the current prototype. A dedicated space, separated

[9] A target state with fractal characteristics has the same or similar properties as the intended process prototype on a scale level (AULINGER & ROTHER 2017).
[10] The organizational perspective defines a company’s division into units or departments, whereas the operational perspective represents the chaining of (sub)processes (TEUSCHER 2011).
[11] This principle from the TPS suggests that in order to truly understand a problem, people need to observe what is happening with their own eyes at the actual place.

from the daily business of the company, facilitates to build and test process prototypes and use it also a demonstration and training area. The systematic application of simulation games supports learning, mutual understanding, and endorses the acceptance among employees[12].

Type 3: Performance target states. The field of process controlling provides a more in-depth look at business processes and their characteristics. Some of the KPIs used for monitoring processes and ensuring corporate goals (see GADATSCH 2020) also work well for specifying process prototypes, like indicators assessing a process' integration into the corporate landscape (e.g. the ratio of dispatched process workers to total company workers) or relationship indicators (e.g. the ratio of training costs per employee) (cf. GADATSCH 2020). Index metrics that monitor the performance of a business process over a time period are less suitable for evaluating process prototypes during the simulation phases, however, become essential for the pilot.
Dedicated KPIs can serve for the consistent description of the business process prototypes and to provide validated data for the bi-weekly retrospective meetings. Depending on the phase and prototype characteristics, they can highlight critical process steps (error rate at a certain sub-step of a cardboard simulation), allow early conclusions about existing inter-dependencies (required information input at a process-step), and bring forth the need for analyzing a process-step more precisely. These examples show ways, how project managers can achieve what RIES (2019) describes as "validated learning" during a complex BPI project.

Altogether, an ideal target state definition for the step-by-step design of a complex business process innovation comprises a comprehensive, visual representation, a description of process attributes, and performance indicators. By following this recommendation, a target state definition (for the simulation and pilot phases) addresses a precise area of improvement (the process prototype) and is therefore *specific*. Furthermore, it contains *measurable* elements, is *achievable* due to the team's involvement in its definition, can be *realistically* achieved with provided resources, is *time-related*, and can therefore be characterized as a *s.m.a.r.t.* goal (DORAN 1981).

[12] KRUEGER provides a comprehensive guideline for developing and using haptic simulation games to introduce new working systems (KRÜGER 2019).

5.4 Module 3: Monitor & Adapt

The *Hybrid Reference Framework* forms a promising recommendation for coping with complexity in BPI projects by maintaining strategic stability while gaining operative agility. Despite that, the guideline still leaves open how project managers can motivate their teams to follow such a different path. The insights from the industrial practice confirmed the impression from the literature that the potential benefits from integrating organizational agility into conventional approaches require activation effort and endurance. This is largely attributable to the aspect that establishing a novel work culture within the structures and habits of an environment used to assess performance based on achieving pre-defined objectives requires a paradigm shift for most project teams in the manufacturing industry. Contrary to completing predefined tasks, an emergent practice requires more self-organization and intrinsic motivation. These factors lead to the paradoxical situation that in many cases, adapting a more agile working mode might be advantageous, however, there are not enough eager resources nor capacity on hand for a transformation.

The interviewed experts with experiences in creating agility in manufacturing companies (see section 4.4) confirmed that, regardless of the actual project management approach, developing a mindset according to the values and principles of the *Agile Manifesto* (see figure 2.7) might have a beneficial impact on the performance of a complex BPI project. Their statement does not necessarily implicate to switch entirely to an agile model, e.g, by introducing *Scrum*. They rather emphasize to a team's underlying mindset and motivation for "improving their current situation". In their experience, project managers and their teams first need a common understanding and goal for an agile collaboration. Otherwise, an implementation might just create "false front-end agility." (BRANDL et al. 2021)

Based on the previous introduction and the general requirement to establish the right mindset in a project team (see figure 5.1), *Module 3* is designed to support managers in implementing and applying explorative problem-solving based on validated learning. Thus, the this module aims at creating local, operative agility based on the values and principles from the *Agile Manifesto* and expanding it from this point.

In accordance with the design approach of this method, *Module 3* is applicable independently from *Modules 1 & 2*, however, interacts with them beneficially.

5.4.1 Element 3a: Project Monitoring

Learning and internalizing the agile values and principles requires the involved persons to exercise them in practice. Since the motivation to make this individual effort is related to a benefit, the team's awareness towards actual issues and the access to deployable practices in the daily project work build an essential prerequisite.

Assessment of typical issues in BPI projects
To assist project managers in continuously identifying areas of improvement and setting goals for operative agility, BRANDL et al. (2021) provided a list of typical areas of improvement (see table 5.5). The authors gathered these by reviewing literature from various specific scientific domains like process planning in the automotive industry (cf. SCHNEIDER 2015) or innovation and project management in manufacturing companies (cf. BULLINGER 2006; HORSCH 2003), literature providing strategies to minimize risk during technical projects (cf. FELKAI & BEIDERWIEDEN 2015), and various suggestions in dealing with complex situations (cf. DÖRING-SEIPEL & LANTERMANN 2012; SNOWDEN & BOONE 2007). In addition to these insights, the authors also took into account the experiences documented during interviews with experts involved in the project depicted as *Company I* (see case study in section 4.3). The provided aspects for improvement are within a project managers' room of maneuver during BPI projects. In the appendix, a more in-depth version of the list can be found, including indicators for an individual assessment (see table A.2).

Self-reflection on the work maxim
In addition to the self-awareness towards project issues, the manager and team might also evaluate the their current mindset and modus operandi with respect to the principles of the *Agile Manifesto* (see 2.7). For this purpose, table A.3 depicts an interpretation and adaption of these work maxims to the environment of a BPI project in a manufacturing company. For instance, principle seven, *Work for customer-valued results*, in the original version from the software development domain (see e.g. FOWLER & HIGHSMITH 2001), measures the created customer value by the number of working software code lines that have been produced. In the context of hardware or process development, this maxim has been generalized towards customer-valuable results that allow to identify problems at an early stage of development in order to make better decisions in the following steps. The original objective of producing customer-valued

*Table 5.5: General areas of improvement in BPI projects (*BRANDL *et al. 2021).*

	SCHNEIDER 2015	FELKAI & BEIDERWIEDEN 2015	SNOWDEN & BOONE 2007	DÖRING-SEIPEL & LANTERMANN 2012	BULLINGER 2006	HORSCH 2003	Expert interviews in *Company I*
Areas of improvement	**Literature**						
Improve communication	x		x	x		x	x
Clarify project goal and requirements		x			x	x	x
Involve the customer	x				x	x	
Involve internal interfaces	x	x			x		
Expedite early results	x				x		
Foster motivation		x		x	x	x	x
Quick troubleshooting		x			x		x
Encourage self-reflection	x			x			x
Enable self-regulation			x				
Strengthen team spirit and cooperation		x	x		x	x	
Increase willingness to change	x					x	
Increase transparency					x	x	x
Facilitate continuous learning		x	x	x	x		x
Learn from mistakes			x				x

results as an indicator to measure progress is therefore carried over[13]. The residual principles have been adapted in the same manner and are in compliance with their interpretations manifested in various available hybrid approaches in the literature (see 3.3).

[13] This principle, among others, e.g. is behind the concept MVP from *The Lean Startup* (see 3.4)

5.4.2 Element 3b: Project Adaption

In the agile domain, *Scrum*, *Kanban*, and *Xtreme Programming* are the most common agile frameworks that comprise several practices, roles, and artifacts (KLEIN 2017). A framework is designed to create increased agility by providing a holistic set of practices that complement each other and cohere in a big picture (BECKER 2018). On the other hand, PRÖPPER (2012) and later ŽUŽEK et al. (2020) suggested to adopt individual practices and create ”local agility” in cases where companies cannot fully switch to an agile organization. Since *Module 3* is also intended to support project managers in establishing the right mindset for operational agility and to facilitate the implementation of the procedural reference model (see section 5.3), the deployment of individual practices might be a promising way. Considering that adoptable techniques need to be deployable independently and reasonably during a BPI project.

List of deployable practices
On the same criteria, BRANDL et al. (2021) already assessed practices that have evolved in the *Agile* domain and provide a list based on their review. Since the underlying values and principles from the *Agile Manifesto* are related to the *Lean Management Philosophy* (both domains rely on a strong customer orientation and collective problem-solving, see section 2.4.2), this list has later been extended on the same criteria with practices from the *Lean* domain, many of which are already known in manufacturing departments. Table 5.6 depicts the resulting proposal of practices that facilitate customer orientation and collective problem-solving.

Recommendation for the deployment of practices
The project and sub-project managers can use the overview to choose deployable practices whenever the occasion demands an adaption of the current modus operandi. To systematize their gut feeling, they can apply the self-reflection on typical project issues and the assessment of the work maxim introduced in the previous subsection. Additionally to this methodological guidance in formulating goals for organizational agility, the following recommendation for a reasonable deployment of the practices is based on a correlation analysis. The resulting matrix combines expert knowledge from

Table 5.6: Selected practices from Lean Management, the agile frameworks Scrum, Kanban, and Xtreme Programming that are transferable and independently deployable in a BPI project extending a list by Brandl *et al. (2021) with* Neubert *(2019).*

Practice	Key Goal	Origin
5 Why	Find root causes through repeated questioning	Lean
Ishikawa	Visualization of a cause analysis within a problem solving process	Lean
5S	Establishing a lasting clean and tidy workplace	Lean
Value Stream Map	Analysis method to capture and visualize a process chain as a value stream	Lean
8 D/A3 Report	Problem solving document with a predefined workflow	Lean
Gemba Walk	Go to the actual place of the problem to gather impressions first hand and exchange ideas	Lean
Kamishibai Board	Scheduling tool to facilitate recurring tasks	Lean
Shop Floor Board	Visualization of the current status serving as a discussion basis and guideline for shop floor meetings	Lean
Shop Floor Meeting	Regular, structured meetings to solve the problem at the place of occurrence effectively	Lean
Kaizen Journal	Transparent and easy understandable way to show what work still needs to be done	Lean
Definition of Ready	Define acceptance criteria to create a common understanding of new tasks.	Scrum
Definition of Done	Define criteria for tasks to create a common understanding for when tasks are considered completed	Scrum
Daily	Exchange information on the current status	Scrum, Kanban
Impediment Backlog	List of current problems and obstacles to solve or overcome	Scrum
Sit Together	Promote casual exchange of knowledge via osmotic communication	Scrum
Retrospective	Reflect the past and learn from it by implementing improvements	Scrum
Time Boxing	Set fixed time frames to make work more efficient and plannable	Scrum
Task Board	Visualize team tasks, create transparency, identify bottlenecks	Scrum, Kanban
Pair Programming	Learn from each other and avoid mistakes	Xtreme Programming

the *Lean* and *Agile* domains[14] and therefore facilitates the decision-making for project managers without a specific background in both fields[15].
The expert knowledge was captured by systematically applying the *Analytical Hierarchy Process* (AHP) (SAATY 1987). Domain-specific experts evaluated for each single practice to which extend it facilitates the twelve principles from the *Agile Manifesto* in a pairwise comparison[16]. The individual results for each practice were then aggregated and normalized to the correlation matrix, depicted in table 5.7. Darker regions visualize stronger correlations between principles and practices according to the expert's experiences. A project manager that wants to better *satisfy the internal customer* at milestone result presentations (identified as an area of improvement), should therefore consider to deploy the *Definition of Ready* practice. Additionally, to cope with issues relatable to insufficient communication in the team, a project manager might *foster interdisciplinary cooperation* and *facilitate face-to-face conversation* by organizing a *Sit Together*, installing a *Public Task Board*, or propose *Pair Programming* sessions and *Gemba Walks*.

5.5 Method application guide

The following recommendations provide various perspectives on the application of the previously explained modules and elements. As stated before, in combination, they unfold the desired gain in performance during complex BPI projects. The major lever results from the synergy of integrating the three modules, but they can also be deployed individually to achieve benefits.

Organizational perspective
By design, the method with its individual modules can be integrated into typical project

[14] Since the interviewed experts with a software-related background (*Experts A & D*) showed great experience in agile project management approaches, they were able to evaluate to which extend common practices from that domain implement certain agile work principles. The experts with a manufacturing background (*Experts I, J, K, L*) showed expertise in evaluating lean techniques (see table A.4).

[15] An earlier version of this correlation model has been published before (see BRANDL et al. 2021) and later refined and adapted for this thesis.

[16] In compliance with the previously published earlier version of the correlation matrix (see BRANDL et al. 2021), the applied scale ranges from 9/1 to 1/9, with 1 for an equally strong contribution to both principles.

Table 5.7: Correlations between work principles from the agile Manifesto and selected practices from the Lean and Agile domains visualized as a heat map, further developed with NEUBERT *(2019) based on a previously published earlier version by* BRANDL *et al. (2021).*

	Satisfy the customer	Welcome changes	Deliver regularly	Foster interdisciplinary cooperation	Motivate with support and trust	Facilitate face-to-face conversation	Work for customer-valued results	Maintain steady pace	Aspire technical excellence	Value simplicity	Favor self-organization	Reflect and adapt regularly
Selected Practices	**Principles from the Agile Manifesto**											
5 Why	0,13	0,02	0,02	0,08	0,05	0,08	0,17	0,02	0,14	0,09	0,02	0,18
Ishikawa	0,08	0,02	0,02	0,10	0,06	0,06	0,11	0,02	0,19	0,11	0,03	0,19
5S	0,05	0,05	0,03	0,12	0,05	0,05	0,06	0,03	0,03	0,18	0,18	0,18
Value Stream Map	0,11	0,08	0,06	0,14	0,05	0,18	0,05	0,10	0,02	0,08	0,05	0,08
8D/A3 Report	0,16	0,05	0,02	0,09	0,05	0,08	0,14	0,02	0,17	0,05	0,06	0,13
Gemba Walk	0,02	0,04	0,02	0,15	0,15	0,16	0,09	0,02	0,10	0,04	0,08	0,13
Kamishibai Board	0,05	0,02	0,10	0,05	0,07	0,07	0,06	0,20	0,02	0,10	0,21	0,05
Shop Floor Board	0,05	0,02	0,02	0,15	0,09	0,16	0,05	0,05	0,02	0,17	0,08	0,14
Shop Floor Meeting	0,06	0,01	0,01	0,13	0,12	0,14	0,06	0,05	0,07	0,05	0,14	0,14
Kaizen Journal	0,06	0,02	0,07	0,17	0,02	0,02	0,02	0,07	0,11	0,16	0,22	0,06
Definition of Ready	0,19	0,02	0,06	0,13	0,07	0,09	0,11	0,03	0,04	0,04	0,09	0,12
Definition of Done	0,08	0,04	0,05	0,14	0,10	0,12	0,08	0,04	0,04	0,04	0,16	0,10
Daily	0,02	0,09	0,06	0,13	0,11	0,19	0,05	0,04	0,03	0,03	0,15	0,14
Impediment Backlog	0,03	0,07	0,08	0,08	0,22	0,09	0,06	0,05	0,04	0,04	0,09	0,17
Sit Together	0,03	0,05	0,04	0,21	0,08	0,22	0,06	0,04	0,05	0,03	0,12	0,08
Retrospective	0,05	0,09	0,06	0,10	0,11	0,09	0,07	0,05	0,05	0,03	0,08	0,23
Time Boxing	0,04	0,03	0,14	0,04	0,04	0,02	0,10	0,16	0,06	0,09	0,21	0,05
Task Board	0,03	0,04	0,03	0,19	0,09	0,23	0,05	0,05	0,03	0,02	0,17	0,08
Pair Programming	0,03	0,02	0,02	0,17	0,13	0,17	0,10	0,07	0,06	0,06	0,09	0,09

structures in manufacturing companies (see figure 4.1). Established roles with their responsibilities and decision-making authorities can be adopted. The method is built around the perspective and motivation of a project manager to cope with complexity during BPI projects. To be successful, a project manager needs room for maneuver

and the consent of a superior management board[17] for adapting the modus operandi of such projects.
The case study in chapter 4 affirmed that complex BPIs in manufacturing companies require a superordinate project management formulating a vision, controlling risks and overseeing budgets. Larger enterprises guarantee this function for the most part with their corporate structure of steering or senior management boards (see figure 4.1). In SMEs, the executive board or managing partners are usually reported to. In both cases, a complex BPI project profits from an effective strategical planning scheme for directing an innovation project in a manufacturing company successfully. Additionally, a sponsor of a project can operate intercessional and represents the process vision.

Procedural perspective
As depicted in figure 5.2, the adapted *Stage-Gate* (element 2b) spans the temporal scheme of the integrated method. The following sections enlarge upon them. During *Phase 1 Analysis*, the management is focused on *preparation*. They formulate a process vision, assemble a core team, form a leading coalition, and set the general procedural and organizational parameters. After analyzing the setting of a certain BPI project with the complexity assessment (1a) and the prerequisites consideration (1b), their main interest is to foster the team's *exploration* capabilities during the simulation and pilot phases. At this stage, the *Hybrid Reference Framework* enfolds its key advantage by merging strategic stability with operative agility. Then, in the last section, the attention shifts towards the actual *implementation* by extending the practical experiences to the intended perimeter.

5.5.1 Preparation

A project manager together with the management board start with preparing a BPI project by formulating a process vision.

[17] According to COOPER (2017), project managers operate on the intermediate level between the meta-project management and the operative team. On that interface, they are accountable for achieving project goals (see section 3.3).

Formulate a process vision

As outlined in subsection 5.3.1 and visualized in figure 5.4, the process vision is in line with the company vision, portrays customer requirements, and reflects benchmark results from comparable cases. In a perfect world, a designated project team is already guided by this vision when beginning with the analysis phase, all stakeholders agreed on a general procedure and the project organization is settled. In practice however, these early steps in BPI project evolve in several iterative cycles, since the insights gathered during the analysis contribute significantly to the vision statement. For example, the team brings forth first-hand information about detailed customer requirements by talking to the relevant key accounts.

Assemble a core project team

Before agreeing on the general procedural and organizational approach for the BPI project, the management needs to assemble a core team. This can be done before or even during the analysis phase, as soon as the actual requirements for skills and available resources become apparent. An innovative project with disruptive characteristics will confront complexity and individual resistance. Some of the involved technologies might be novel and require collective learning. The core team should therefore consist of experienced specialists and inexperienced ”potentials” with great motivation to learn and evolve. The core team should remain and build a ”leader coalition” together with the project sponsor. Around this group of course, optional expertise and resources expand the project team depending on the respective phase and demand.

Analyze the project setting

The assessment of the project complexity (Element 1a) and and consideration of critical prerequisites (Element 1b) is intended as a self-reflection by the project manager during the analysis phase, as soon as a person is designated. The results serve as a justified motivation for leaving the path of proven practice for establishing a hybrid project structure with increased operative agility. The final decision for a certain way of working must be made or at least brought about by the project manager. In general, the complexity is assumed to be constant throughout a project, however, the assessment can be repeated and adapted at will as soon as a shift of parameters is suspected.

Agree on a project structure and organization

Based on the first analysis and assessment results, the management comes to mutual agreement on a hybrid project structure with reasonable scope for operative agility

and a project organization officially designating the core team, project manager(s), the superior management board, as well as internal and external partners[18].
It is possible to omit the procedural reference model (*Module 2*) based on the *Toyota Kata* as the fundamental project structure and instead introduce an alternative hybrid model due to the method's modular structure[19]. The agreed project organization should not be subject to major changes as the project progresses, as it is fundamental to the consistent progress and achievement of milestone goals.

Define and schedule milestones (analysis phase)
The project manager together with the board agree on superordinate milestones by defining and scheduling them via the adapted target-state-cascade (element 2a). At this early phase, they should not care for operational target states, however, schedule interim sub-milestones. The sub-milestones and target states are then aligned incrementally by the project team through explorative learning. The first milestone is already defined at the beginning of the project, since it always comprises a process idea and the basic project setting.

5.5.2 Exploration

Provide strategic stability with the adapted Stage-Gate
The adapted *Stage-Gate* suggests a high-level project plan for complex BPI projects (Element 2b). With explorative learning at focus during the simulation and pilot phases, the management emphasizes on supporting a self-driven and self-organized work culture based on collective learning instead of prescribing it. What provides the strategic frame of stability essential for innovating business processes through explorative learning, however, is defining and scheduling the phase milestones and scheduling the interim sub-milestones.

Top-down cascade a first sub-milestone and target state
Each project phase contains several two- to three-month sub-phases and two-week work cycles. To formulate a first sub-milestone and target state, the project management

[18] See project organization scheme depicted in figure 4.1.
[19] For example, in case a company has already successfully implemented a hybrid structure in a different area, it can be merged into the method.

initially applies a top-down target state cascade (Element 2a). The effort put in this step should not be overemphasized, since it provides a tangible direction for two weeks of work. The subsequently gathered knowledge and experience from the daily work cycles is then exploited to formulate a more sophisticated next target state and to refine the interim next sub-milestone (see figure 5.13).

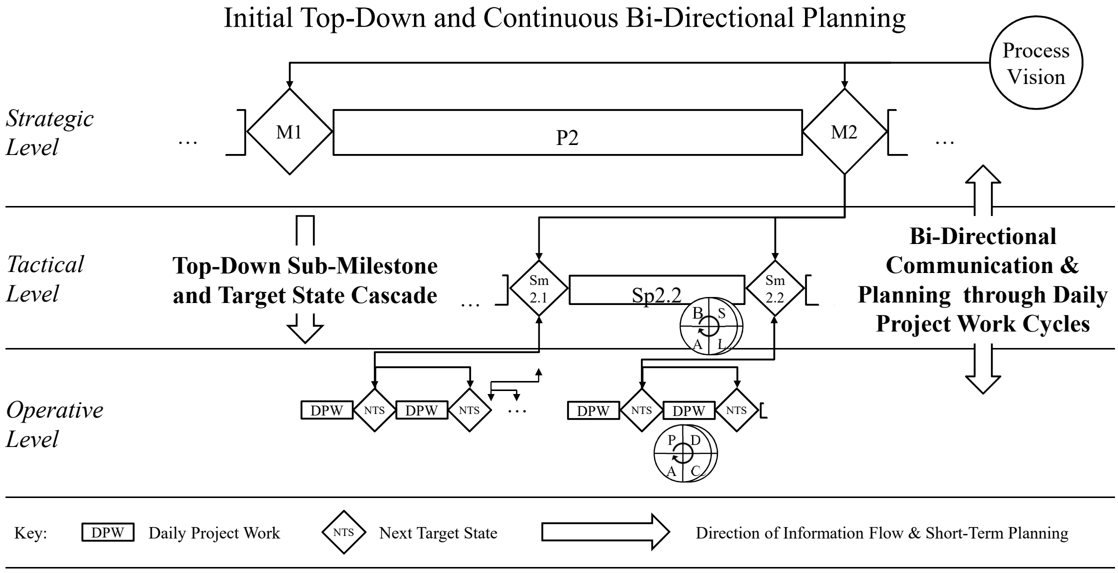

Figure 5.13: Visualization of the initial top-down and continuous bi-directional planning during complex BPI projects (based on BRANDL *et al. (2020)).*

Create continuous bi-directional communication & short-term planning

During the two-week operational work cycles, progress is achieved by carrying out the adapted *Toyota Kata* (element 2d) in combination with the integrative planning routine (element 2d). The team members, each of whom is concerned with a specific sub-problem or sub-obstacle, apply the PDCA scheme to gain knowledge. Each of these cycles is supported by daily, twenty-minute coaching sessions between a mentor and mentee. These individual meetings facilitate to point the daily work effort towards achieving the upcoming target state, guarantee instant feedback, and help to proliferate information across hierarchies and sub-groups.

As stated before, this concept leans heavily on the ideas and mechanics of *Shop Floor Management* in a production environment, where the essential daily bi-directional knowledge flow and short-term planning is concentrated to a single moment during the day (usually a morning routine). The residual time of the working hours are then more focused on actual value creation. In a BPI project, a gain in value is achieved by the team members successfully completing several individual PDCA cycles to reach a target state. The BSLA routine provides the bi-weekly pattern of completed target states in order to successfully achieve the upcoming (sub-)milestone. These target state cycles are confined by bi-weekly jour fixes by the whole project (core) team.

Use a protected space for experimental learning

Building effective process prototypes for collective learning through validated experimenting requires a protected space outside the daily business of a manufacturing company. A process lab is a room or area that provides all necessary resources and equipment to build an test process prototypes. During the simulation phases, the lab becomes a training factory and can be interpreted as a *vehicle* to increase the innovation speed and capacity.

Since a process prototype constantly evolves and changes, the process lab should be designed in accordance with the principles of an easy adaptable system. WIENDAHL & HERNÁNDEZ MORALES (2006), determine a manufacturing system's "transformability" by five categories of "change facilitators" (cf. HAWER 2020) which have been adapted to a process lab:

- **Mobile:** The objects in the process lab can be re-positioned with the least amount of effort, i.e. by using casters.
- **Modular:** The process lab structure subdivides into standardized and autonomous elements.
- **Compatible:** Products, components, processes or equipment can be integrated and removed with minimal effort, i.e. by using standard interfaces.
- **Scalable:** The process lab can grow or shrink in capacity or spatial expansion with little effort.
- **Universal:** The process lab can meet different requirements and can be used for various application cases, i.e. simulation, experimentation, or training.

5.5.3 Implementation

In contrast to the simulation and pilot phases, when experimental learning is in the main focus, during the roll-out phase, target states and sub-milestones should not be formulated as business process prototypes. The roll-out is highly company- and

case-specific but tends to permit more up-front planning, since good practice has already evolved during the pilot. As a result, the project management focus switches to the actual implementation and extension of knowledge. The resulting expansion of the agenda might trigger several follow-up projects of various scope, extend, and complexity. An individual evaluation of each is essential.
During the implementation, the project team dissolves into these follow-up projects or into the daily business. However, a final evaluation of the project brings forth valuable lessons learned.

5.5.4 Continuous evolution and empowerment

The purpose of this last section is to highlight the importance of evolve the current way of working and empower a team's problem-solving skills. The management responsibility for this continuous quest spans the whole BPI project. It creates, however, its major value during the simulation and pilot phases, when collective learning makes the project pace (see figure 5.2). This enormous attention to the development of persons in a complex BPI project justifies itself due to multitude of distinct perceptions existing among these individuals and groups. Each person involved in or affected by such a project, passes trough the typical phases of change (see subsection 2.4.2 or KÜBLER-ROSS 2005). However, they begin their personal journey at distinct moments in the project. While there might be light at the end of the tunnel in the core team's perception, persons becoming involved later during the project, still need to arrive at this point. The lack of being involved as long as others, might be misinterpreted as resistance.

"Successful leadership has always been agile!" (KORN 2016)
This statement by Hans-Peter Korn, a recognized expert for agile project management, expresses a leadership idea that fosters agility at an operational level. The following attributes define *Servant Leadership* in a BPI project reflecting descriptions by KORN (2016), GREENLEAF et al. (2002), BENDER-MINEGISHI (2018), and ROTHER (2013). The list is also in line with the experiences portrayed by *Expert H*.

- **Attention:** Develop result-oriented implementation skills.
- **Appreciation:** Enforce personal growth.
- **Exploration:** Let people learn from mistakes.

- **Fairness:** Facilitate effective communication.
- **Inspiration:** Personify a role model and create trust.
- **Innovation:** Establish an entrepreneurial mindset.
- **Identification:** Motivate through challenges based on values.
- **Experimentation:** Encourage curiosity and explorative problem solving.

Project monitoring

With the results from their complexity assessment (Element 1a) and consideration of critical requirements (Element 1b), project managers can bring forth objective arguments to create a sense of urgency and build a leadership coalition during the analysis phase of a BPI project. The characteristics of successful (agile) leadership help to reflect on their own conduct. Additionally, they should continually identify and address areas of improvement (3a) by introducing new practices (3b). The prospect of solving actual problems in a project situation increases the chances to achieve perceptible quick-wins. These enhance a team's motivation for pivoting along the path through complexity and therefore their capability to design viable business processes. The daily meetings within the adapted *Coaching Kata* build a strong basis for absorbing current issues and obstacles in the project and for displaying leadership characteristics. Apart from these, challenges related to cooperation, communication, or the general team alignment can be examined with the list of typical areas of improvements in BPI projects. A more abstract - but yet significant - insight provides the reflection on the principles from the *Agile Manifesto*.

Project adaption

The constant project adaption by addressing the identified issues with practices is a central key. Deploying a new practice should empower people to generate a personal benefit from it. Thus, project managers need to educate on the mechanics of new practices vividly and relatable, e.g. via dedicated practice workshops (MAXIMINI 2018). BRANDL et al. (2021) recommend to explain and test a new practice before integrating it to the modus operandi. They advise project managers to encourage their team to view the new practices not as an obligation but as an opportunity, e.g., by immediately addressing anxieties and concerns.

An effective way to achieve this is "turning employees from affected to involved" (MAXIMINI 2018) by managing mistrust and personal attitudes. BRANDL et al. (2021) remind to also directly include external stakeholders, like customers or partners, during the introduction of new practices or when evolving the modus operandi.

6 Application & Evaluation

The *Descriptive Study II* of the DRM (see 1.3.3) comprises the application and evaluation of the developed integrated method for managing complex BPI projects in manufacturing companies in *Company I & II* (see 4.3). Similar to the *Descriptive Study I*, the evaluation is an observational study. The following chapter outlines the chosen approach (6.1), the main findings from the case study (6.2), similarities and differences of the observable effects (6.3), as well as benefits and trade-offs from applying the method in practice (6.4).

6.1 Approach

The application and evaluation of a methodical guideline for the management of a complex BPI project in practice is no easy undertaking. Typical projects last several years, are of strategical importance, and companies willing to cooperate at the right moment are rare. However, during the online survey and several expert interviews at the beginning of this thesis project, *Company I* and *Company II* were acquired for an extended case study of 24 months in aggregation.

Both companies agreed on analyzing their current modus operandi (outlined in 4.3) and accepted to implement changes based on recommendations by the developed method. Since *Company I* already relied on an established matrix organization with flexible, cross-functional teams and a versatile set of project management capabilities, the goal for an adaption was moderate: create more space for local agility in existing structures to better cope with complexity (see 6.2.1).

As a result of the project phase (at the beginning of the observational study the analysis phase had just been completed) and the company structures (family-run) as well as the project objective (reorganization of the central business processes), the BPI project in *Company II* offered more scope for modifications through the presented method. In combination, the two cases cover the entire proposed approach and the spectrum of larger to medium-sized companies from different industries.

6.2 Case Study

6.2.1 Company I

As an established manufacturer of premium cars, *Company I* constantly refines and extends its range of project management approaches and techniques to cope with the complexity of innovation in various sectors successfully. The newly developed method for managing complex BPI projects piloted in the general setting introduced in subsection 4.3.1, where the trend towards electric cars confronts process design teams with numerous organizational and technical challenges.

Objectives

At the time of this case study, the observed project already followed a general milestone plan and stood amid the experimental phase. At this stage, requirements for the business process still changed constantly and, at the same time, fundamental process parameters, equipment, and IT-infrastructure needed to be specified[1]. The general phases and milestones determined by the superordinate project management could not be changed at this point. However, a manager in the project perceived an urgent need for adapting the operational modus operandi and, therefore, was receptive and self-motivated for testing new methods and introducing agile practices. This manager of a sub-project and his associated implementation team focused profited from the modular structure of the developed method and put their attention entirely on the focus of applying *Modules 1 & 3*.

The team of six people designed the core value creation process for a component of and electric drive. The team consisted of a project manager[2], a process and control designer, as well as a technology consultant, an operator, and a maintenance technician.

[1] This period actually spans from subcontracting external equipment suppliers to the technical handover and pre-certification

[2] In the following, the project manager is referred to with *he*, *him* or *his*, since in this case it was a male person.

The team was distributed over three locations and within the locations over different buildings, but the team size was suitable for the implementation of agile principles. The interdisciplinary team included all competencies required for the design of a production system.

Assessment of the project complexity

During the observation of this project it became evident that a variety of problems in the daily operational work emerged from the disruptive environment and highly uncertain market development of the electric car technologies. Internally, a large number of interacting stakeholders and dependencies added structural and social complexity. The involved departments were making decisions while pursuing individual goals that competed or even partly contradicted from a big picture perspective. As a consequence, the process design parameters continuously changed throughout the study, prompting a re-consideration of previously defined aspects. A few specific technical issues prompted the team to make fuzzy decisions early in the project prompting severe problems later. The manager noticed that the combination and correlation of these aspects created a complex environment for his team, however, sought for methodical guidance to capture his impression.

The result of the *Questionnaire for an Individual Complexity Assessment* (see table 5.2) underlined the project manager's perception and even allowed a more holistic evaluation[3]. The project manager reported, that the guiding questions prompted him to think about the right things and in the right directions. Not being able to answer several of these points free of doubt or not even having an idea at all helped him to discuss and address complexity more profoundly. This simplified his situation as a project manager and endorsed his sensation to implement a more agile approach.

Consideration of critical prerequisites

Confirmed by the complexity assessment, the project manager pursued the idea of creating more agility to meet the superordinate project goals. He therefore applied the *Checklist for Critical Prerequisites* to better understand the barriers for this plan and to pin his actual room for maneuver. The result of his self-assessment is depicted in

[3] The result of the questionnaire is not provided in this thesis, since many of the personal answers are subject to the non-disclosure agreement as part of the project study. However, since the questionnaire captures a snapshot of the individually perceived complexity, the actual answers are not as relevant as the process of contemplating on them.

Table 6.1: Assessment of essential prerequisites in Company I. Documented by ROIDER *(2018).*

Checklist for Critical Prerequisites *Company I*	
Project	
✓	I am the initiator for a hybrid project organization. *The project manager is self-motivated for introducing operational agility.*
✓	I know my project's internal or external customer. *The designated process owner is the customer.*
✓	The project's customer can test and review partial results. *Process prototypes and partial results are valuable interim results for the customer.*
✓	The project has a clear vision. I understand and support this vision. *The process vision withholds a predefined capacity and a corporate strategy.*
✓	To this point, I cannot specify the project's requirements in detail. *The requirements and standards for the individual process elements are unknown at the beginning of the project.*
✓	The project's requirements are likely to change. *Due to the technological novelty of the entire industry, essential knowledge emerges during the project and process features need to be adapted continuously.*
✓	Pace plays a significant role in this project. *Strategic objectives determine the start of production making the time schedule very tight, as it is based on the planning of processes involving established technologies requiring less time for learning.*
Team	
✓	The vision requires a collaboration of interdisciplinary competences. *The technology and the product require the collaboration of an interdisciplinary team.*
✓	My team welcomes new ideas and changes. *The team is aware of current issues and is therefore willing to explore new ways to help them overcome these difficulties.*
✓	My team appreciates community spirit. *The team recognized the benefits of their cooperation.*
✓	I have trust in my team. *The project manager encourages the team to come up with own ideas by involving them in the planning process.*
✓	I let my team make mistakes to learn from them. *The project requires the team to learn constantly.*
Organization	
✓	The superior management grants the required room for maneuver. *The project manager can shape the operational modus operandi.*
(✓)	My core project team is fully dedicated. *Due to the superordinate organizational matrix structure, the team members are not fully dedicated to this project. However, the management board recognized the situation and promised to grant adequate capacity if required.*

table 6.1. Apart from the last point, the project manager could meet all criteria already. It made him confident to start with the *Project Examination* and *Supplementation* to achieve more agility in the daily project work.

Project monitoring

The manager started the project examination together with his team by informally reflecting on the previous six months. As part of the upcoming sub-milestone, the team had to develop a failure mode strategy for the novel business process. The overall complexity of the project expressed itself in an ambiguity of goals and prevented progress in this period. During their analysis they recognized that many occurring problems are traceable to insufficient communication with internal stakeholders earlier in the project. On that insight, they decided to review their current way of working and find ways for a more transparent collaboration. The assessment of areas for improvement revealed the need to clarify the target state and requirements, increase transparency, improve communication, better involve the process owner, and facilitate continuous learning. The result of the examination is depicted in table 6.2, based on the full list attached in the appendix (see table A.2). These points correspond with the issues that came up during the discussions and, therefore, confirmed the team's impressions.

Project adaption

The team then learned and reflected on the values and principles of the *Agile Manifesto* (see figure 2.7) and the list of selected practices (see table 5.6). Encouraged by these impressions and motivated by the current issues, the team decided to first focus on two principles: better *satisfy the customer* (see table A.3 principle 1) and *facilitate face-to-face conversation* (see table A.3 principle 6).

With the expert knowledge captured in the correlation matrix (see table 5.7), the team chose two practices to start with: *Definition of Ready* and *Pair Programming*.

The *Definition of Ready* practice is a guideline to facilitate that a requirement can be sufficiently defined and explained by the customer, so that the team can work on it (see table ref 5.6). In this case, the team succeeded to consent on what had to be done in the next step, thanks to iterative and cooperative dialogues involving the project manager and the process owner (customer). These meeting were repeated until the sub-milestone was reached.

Pair Programming in its original form suggests two programmers jointly produce code and adopt distinct roles. One person acts and actually creates, while the other thinks

Table 6.2: Assessment snapshot of areas of improvement in Company I. Documented by ROIDER *(2018).*

Problem Category	**Problem Characteristic**	**Consideration**	**Area of Improvement**
Target State	There is uncertainty about the target state.	strongly consider	Clarify project objective and requirements
Alignment	There is a lack common understanding of the target state.	consider	Clarify project objective and requirements
Information Exchange	Persons only know their own tasks and activities.	strongly consider	Increase transparency
	In a regular jour fixe team members personally exchange current information on the project progress (e.g. with a common task board).	consider	Improve communication
Coordination	The current project challenge requires the expertise of the entire project team.	consider	Involve the customer/process owner
Knowledge	The technical knowledge required to solve the problem is available in the team.	consider	Facilitate continuous learning

strategically and constantly challenges the outcome by reviewing whether another solution might supersede it (see table ref 5.6). In *Company I*, the team formed couples of process engineers with different expertise and experience. This helped to foster face-to-face communication and collective learning. As a result, problem-solving became more efficient and effective in the team and the milestone goals could be achieved with less friction.

Since the team did not dedicate 100% of its capacity to the current project, the practices *Sit Together* and *Daily* were considered for a later stage. Both facilitate face-to-face communication among the team members by working closely and discussing problems regularly (see table ref 5.6). Recognizing their spatial separation as a handicap persuaded the team to meet in one room as often as possible. Besides, the project manager looked into the possibility of getting access to a digital solution for the *Task Board* practice. However, a first attempt collided with corporate IT-security regulations. The *Value Stream Map* was already part of the team's repertoire and used to visualize the current state of process planning.

6.2.2 Company II

As outlined in subsection 4.3.2, *Company II* chose a radical way to innovate its core business processes and provided a clear vision and direction for the project. On that basis, some preparation for the project already happened before this evaluation study. A manager was assigned who then assembled a core team, assessed the general project setting, and procured the required resources and room for maneuver to establish a hybrid project structure and organization that allows operative agility, while accepting superordinate milestones and phases.

Motivation & Objectives

The observed modus operandi at the beginning of the project was largely based on a top-down controlled planning approach. After the analysis phase, the project management first cascaded the milestone goal down into sub-phases for the entire period until the next milestone. This required a high initial planning effort with little added value for the project team, since the sub-milestones could only be defined very imprecisely on the basis of the little information available at this moment. As a result, the project team focused very much on the next higher-level milestone and considered the sub-milestones primarily as a general orientation. Thus, the gain in knowledge and the workload were concentrating on the time period before the project milestone, while earlier, several weeks passed without noticeable achievements.

The project manager has therefore looked for a way to balance the workload and achieve knowledge more consistently. Additionally, he[4] wanted to incorporate the gradually gained insight from the emerging specific requirements to define better sub-milestones ”on the way”. Another objective he formulated, was to find an effective way of coordinating the knowledge exchange between the sub-groups of the fast-growing team while sustaining and extending his *Servant Leadership* style (cf. findings in subsection 4.3.2).

Refining the established hybrid framework & project organization

At the time of this evaluation case study at *Company II*, the project already was amid the *Simulation I* phase (see adapted *Stage-Gate*, Element 2b). However, the established project management could be refined with compliance to the Hybrid

[4] In the following, the project manager is referred to with *he*, *him* or *his*, since it is a male person.

Reference Framework. To allow more agility on the operative project level in order to better incorporate the emerging knowledge into short-term planning, the project management decided to introduce the integrative planning routine (Element 2d) with three-month sub-milestones. As a consequence, all upcoming sub-milestones were no longer defined up-front (content), but only scheduled (date). This created better focus on the next sub-milestone and established the three-month planning cycle, e.g. observed and endorsed by ROTHER (2010), allowing constant adaption.

Refining the phases and milestones

The adapted *Stage-Gate* (Element 2b) helped the project manager and his team to restructure and refocus their efforts for achieving the next milestone, sub-milestone and target state. The proposed separation of the simulation phase in *Simulation I* and *Simulation II*, increased the performance of gaining knowledge during early target states by keeping these process prototypes simple. Additionally, it drew the project team's attention to a conceptional level allowing them to think more radically. This observation can be attributed to a reduced restricting influence of technical and organizational conditions assumed by the project team from the current (or past) status quo.

Vision alignment with the adapted target state cascade

To consider and integrate the previously formulated process vision into the daily project work, the background and principles of the *Toyota Kata Management Philosophy* - as a vision-oriented way of working[5] - were elaborated in a series of basic workshops together with the project team and made tangible through various simulation games[6]. The team profited from this input by structuring their bi-weekly jour fixes with compliance to the basic goals and attributes the process vision provided.

Continuous bi-directional communication & process prototype presentation

During the analysis phase, the exchange of information was rather coincidental, which initially worked fine with a small team size of seven people mostly collaborating in the same room. However, as the simulation phase progressed, the team expanded significantly and sub-project groups were formed. As a result, unstructured or incom-

[5] See subsection 5.3.1.

[6] In the beginning, paper planes, later, actual sub-components were used as a product for these process simulations.

plete information flows marked the communication between the project manager, the respective sub-project managers and the sub-groups leading to frequent date collisions, coordination issues and constant re-scheduling.
The integrated planning routine was not implemented instantly, but was built into the project step by step. By building on the personal relationships resulting from the established servant leadership style, the daily, twenty-minute coaching could be easily implemented (or rather refined). Since the bi-weekly meetings were better aligned with the process vision, the insights gained in the respective sub-teams could be transparently visualized on a workshop wall and demonstrated through the current process prototype. This tangible and experiential presentation of the results became to the dominant theme for the (sub-)milestone demonstrations, in which employees and managers from outside the project could be involved. The show of actual projects results (like presenting a prototype) enabled the team to obtain direct (customer) feedback and communicate the transformation of the company at an early stage, which led to fewer reservations and thus less resistance.
Preparing for these events at intervals of three months focused project work, facilitated a rolling-wave planning and structured the knowledge flows in the project team. As a consequence of the growing interest in the current state of the project, an internal marketing team started to communicate via a domestic social network on a weekly basis. All these aspects contributed step-by-step to establish standardized procedures for the information flow and short-term planning as suggested in the integrative planning routine (Element 2d).

Building, simulating and learning with the current process (prototype)
With the start of the simulation phases, the project team started to build process prototypes in a protected lab space. The structure, equipment and organization was build in compliance with the five change facilitators (see subsection 5.5.2).
The used environment gave the project team the opportunity to collaborate with internal and external project partners in further advancing the current state of the process prototype. During *Simulation I*, emphasis was put on the big picture, setting the general course and defining the fundamental process parameters. At this early stage, simple paper planes and basic equipment, such as tables and trolleys constituted an adequate environment for validated experimentation. Since the entire steps of order fulfillment - usually a process of months and years in this company - fitted in one hour of simulation and in one room, the perspective of the involved process

engineers changed and became more customer oriented and holistic. With the help of this simplified process representation, which was always supplemented by a current *Swimlane* chart, key obstacles, requirements and interfaces could be identified and addressed at a very early stage of the project.
The gathered knowledge from this phase was then used to find an implementation partner for a novel ERP system. *Simulation II* was then dedicated to the explorative and collective development of this integrated, corporate software in parallel to the new business process. In order to achieve this goal, software and process engineers collaborated in sub-groups with the future process owners in the lab to reach the next target states formulated every two weeks. In order to achieve sub-milestone goals, these sub-groups needed to coordinate and align their daily work with the bi-directional communication structures from the integrative planning routine (see previous segment). During this second phase, the lab was equipped with mobile and modular workstations. In this environment, the interdisciplinary team was able to build and simulate process prototypes within the novel ERP system[7] while concurrently emulating corresponding physical material flows. The process prototype steps are depicted in figure 6.1.

6.3 Analysis & Lessons Learned

By comparing and aggregating the results from the case studies in *Company I* and *Company II*, additional insights on the effects of the developed method as well as the related efforts and benefits are gained.

Focus
Despite the different backgrounds, project objectives, and implementation focus (see table 6.3), the proposed method for managing complex BPI projects has brought forth beneficial results in both companies. Since *Company I* already had gained experience with hybrid project management in various projects (see subsection 4.3.1), the main focus was set on the situational improvement of the current modus operandi to overcome actual project issues. The observed complex BPI project was related to the development of a business process for organizing the series production of

[7] The system was set up on an extra server with a copy of the company's original database, providing the team a safe space to experiment.

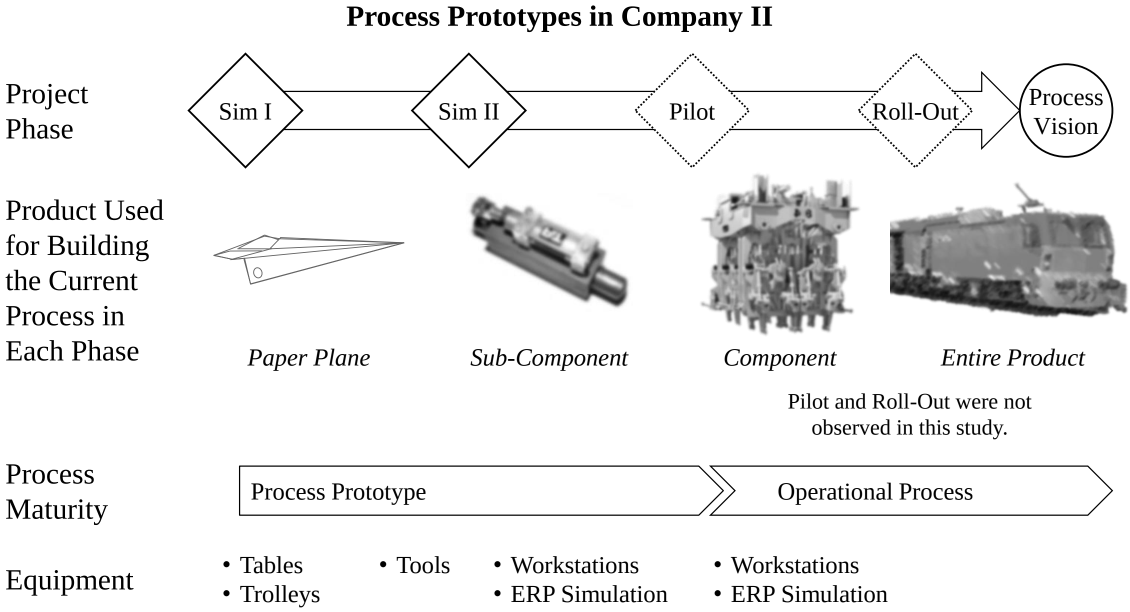

Figure 6.1: Evolution of the process prototype in the observed BPI project in Company II by reference to the used product.

electric drives and integrating it in their production network. Since this process involved innovative technologies, entailed several novel requirements, and was linked to numerous restrictions, the actual room for maneuver by the project manager was limited. Nevertheless, *Modules 1 & 3* from the developed modular method could be applied and provided benefits independently.

The BPI project in *Company II* represented a contrary situation in many aspects (see table 6.3) and marked a drastic transformation for the company. Thus, the project management had more responsibility but also more room for maneuver from the start. Since the basic idea for the approach in this project fitted to the premises of the developed method, *Company II* focused on *Module 2*, the procedural reference model, to establish a hybrid project management structure based on experimental learning.

General observations

Company I

Starting with an initial assessment of project challenges, the project team systematically identified current project issues and finally selected applicable practices to address them. Apart from deploying new techniques, discussing issues in a structured manner really helped the project team already. A team member stated: “it feels like taking training lessons of how we can become a better operating team.”

Table 6.3: Comparison of Company I and Company II

	Company I	*Company II*
Sector	Automotive	Railway Machinery
Property	Corporation	Family-Owned
Production Approach	Make-to-Order	Engineer-to-Order
Production Footprint	International Network	Local Production
Market	International	International
Project Objective	Process for Electric Drive Production and Integration in Network	Core Business Process for Customer Projects
Method Implementation Focus	Situational Improvement of Current Modus Operandi to Cope with Project Issues	Hybrid Reference Model & Team Evolution
Module Application	*Modules 1 & 3*	*Module 2*

From an external perspective could be observed that the provided tools from *Modules 1 & 3* supported the team in gaining a more objective view on the actual issues in the project. Following a methodical guideline increased the acceptance for changing the current modus operandi, since it outlined the setting and elucidated the mechanics rather than just imposing a new technique without a decision left to the team. The method helped to create better awareness in the beginning and entailed a sustaining, deeper understanding for complexity and a ”true” agile organization in the long-run.

Company II

In *Company II* the proposed procedural reference model provided guidance to reinforce the underlying hybrid project management structure by refining the involved components with a strong focus on the simulation phases. Scheduling sub-milestones on a three-month cadence and then incrementally defining and aligning them with the emerging knowledge from the operative daily work, as proposed by the hybrid framework, significantly improved the project’s progress. By applying the integrative planning routine, the project manager, together with his sub-project managers and team, pivoted along the path of instability by constantly transforming the emerging knowledge gathered by the team while attempting to reach the next target state into better next target states.

From the external perspective, the adoption of the method elements previously outlined (see subsection 6.2.2) led to a profound cultural change within the project team (and subsequently in the company as a whole). Before this BPI project, the management in this company heavily relied on a top-down MBO approach. From that starting point, the developed method helped to establish a management system based on validated, experimental learning.

Significant improvements

Company I

During the three-month observation, the team's understanding of the project's objectives significantly improved and harmonized. This trend correlated with the introduction of the *Definition of Ready* as proposed by the method (see subsection 6.2.1) at the beginning of the observation period. The formulation of acceptance criteria as part of the deployed practice during frequent and close coordination meetings created a closed information loop between the designated process owners and process developers.

The second practice proposed by the method and deployed by the team was *Pair Programming* (see subsection 6.2.1). According to the project manager, his coordination effort, the total number of scheduled meetings, and the required rework decreased during the three months of his observation. It was also found that the team adopted the acceptance criteria from the *Definition of Ready* permanently and systematically reflected on incoming new tasks and requirements.

A strong indication of the effectiveness of the method can be derived from the observation that the general doubts about the usefulness of agility as a project management approach, which were perceived at the beginning of the observational study, could be transformed into an intrinsic interest in them. For example, without an input by the project manager, the team members have investigated the practice *Timeboxing* (see table 5.6) in their own initiative and developed a framework for improving the synchronization of their work. This behavior is in line with the objective of the developed method to achieve an improvement in the project management primarily by empowering the people behind the project.

Company II

Compared to *Company I*, an actually quantifiable contribution by the developed method to the observable effects and improvements is even harder to achieve, since in this case, no individual practices have been deployed that allow a "before-and-after-comparison". However, cogent indications for a more effective and efficient management of current

obstacles related to step-wise introducing elements from *Module 2* were found. The previously observed high number of date collisions, coordination issues and constant re-scheduling of meetings between the project manager and his team decreased significantly, so that he could focus on tactical and strategic decisions. It was reported that the team learned to work autonomously and the standardized mechanisms for communicating and addressing issues created the necessary environment for it.
At the bottom line, the main measurable parameter observed during the study is the comparably small period of time required for developing and implementing an operational ERP system in a manufacturing company[8]. In just under a year after their first day of collaboration at the beginning of simulation phase II, the system was operational and launched for the start of the pilot phase. With this date, actual customer orders were handled through the novel processes and tools, including the organization of all sourcing, manufacturing, and delivery steps across the whole supply chain[9].

6.4 Economic Benefits & Trade-offs

In order to identify cost effects by applying vs. not applying the proposed method for managing complex BPI projects, a few aspects have to be considered in advance.

Cost of failure
According to the online survey (see section 4.2), innovation in manufacturing companies is most likely triggered by *customers & market trends*, *technology advancements*, and *competitors*. A management that, due to the involved complexity or other barriers, does not innovate its products, structures, and business processes to strengthen its market position sustainably, has to bear the opportunity costs[10] for its own total value. As a worst case scenario, the cost of a total business failure from poor management

[8] According to statements by the ERP provider, the shortest period of time so far in their history for a company that size.
[9] As depicted in figure 6.1, during the pilot phase, the product in scope of the novel business process was a component of the company's entire product. However, the considered part constitutes the "core" element including the essential technological and organizational aspects as well as a significant section of the total value creation.
[10] The New Oxford American Dictionary defines opportunity cost as "the loss of potential gain from other alternatives when one alternative is chosen" (Stevenson 2010).

decisions (in this case by not innovating) has to be considered. Since doing nothing is not an option, the question is whether doing it good or poor.

Costs of Good Quality (COGQ) vs. Costs of Poor Quality (COPQ)
Although, the amount of complex BPI projects in the industry increases (see survey in section 4.2), for one company, such a project still occurs quite rarely (maybe one in a decade). This means that the aggregated cost of managing BPI projects *inefficiently* is relatively insignificant compared to the risk-costs of managing them *ineffectively*. As a consequence, the following calculation of costs does compare alternative ways of managing BPI projects by estimating the additional efforts for identifying problems early in the project (COGQ) and the potential costs of amending them later in the project (COPQ)[11].

Interpretation
Table 6.4 lists the additional efforts of implementing the proposed method in the complex BPI projects observed in *Company I* & *Company II* on the left side. The right column is a record of potential events caused by identifying problems later in a project (e.g. during the implementation or affecting the planned SOP) and an allocated estimated risk-cost in descending order. The costs of finding and fixing significant problems in a BPI project increases drastically with each phase[12] including a probability of occurrence on the scale low/medium/high. The comparison of costs is based on the assumption that by implementing specific modules of the proposed method, the observed companies introducing agile techniques prevented problems during early phases of the complex BPI projects that otherwise would have been identified later.
In *Company I*, according the project manager, the assessment and application of two practices, adding up to €19,000 of additional effort in a period of six months, have prevented cost-intensive and very probable fire-fighting campaigns during the implementation phase, like in comparable situations before. The total amount was estimated to 100 manager person days adding up to €100,000. Without considering

[11] The COGQ/COPQ approach is inspired by a concept of comparing costs for good and poor quality during the manufacturing of products in the *Six Sigma Quality Management System* (see e.g. S. Koch 2015).
[12] The estimation of risk-costs for potential failure events is inspired by the "Rule of Ten" postulated by D. M. Anderson (2014). He claims that during the manufacturing of products it costs ten times more to find and fix defects with each process step in the supply chain.

Table 6.4: Estimated COGQ vs. COPQ during specific project phases observed in the BPI projects in Company I and Company II

COGQ		**COPQ**	
What is the additional effort for identifying problems early in the project?		*What is the potential cost of amending problems later in the project?*	
Company I			
Efforts for Module 1		Costs of potential events	
Assessment: 1 MPD	€1,000	1 year SOP delay	(l) €10 mil.
Efforts for Module 3		During Implementation:	
Definition of Ready: 1 MPD/month	€1,000	100 MPD for fire-fighting	(h) €100,000
Pair Programming: 2 MPD/month	€2,000		
6 months project phase:	€19,000		
Company II			
Efforts for Module 2		Costs of potential events	
Org. & planning: 1 MPD/month	€1,000	1 year SOP delay	(h) €2 mil.
Simulation effort: 10 MPD/month	€10,000	During Implementation:	
Simulation lab & equipment	€100,000	100 MPD for fire-fighting	(h) €100,000
18 months project phase:	€298,000		

COGQ: Cost of Good Quality
COPQ: Cost of Poor Quality
MPD: Manager Person Day (Labor Cost for Management per Day: €1,000)
Probability of Cost Occurrence: (low/medium/high)

the costs of an unlikely SOP delay, the method created economic benefit.

The drastic re-organization in *Company II* with an additional 18 months simulation phase occasioned an estimated extra costs of €298,000 for establishing a hybrid structure and providing the required environment and resources. However, in this project, the expected risk of delaying the SOP was considered to be particularly high by the project manager before this decision. The efforts should therefore be compared with the total cost of potential events adding up to €2,1 million.

The simple balance sheet in table 6.4 suggests that only a limited comparison of benefits and trade-offs is possible. For a precise breakdown, a project would have to be observed once with and in a second time without applying the method. Nevertheless, the estimation indicates why an investment in early prevention of problems in complex BPI projects by implementing a hybrid project management structure is likely to generate cost benefits. Depending on the level of risk costs and their probability of occurrence as well as the expected implementation efforts, modules of the developed method can be applied individually and situationally.

The examples of failed ERP implementation projects (see section 4.1) demonstrated the threat of BPI projects with immense costs and no significant outcome.

7 Conclusion

It was stated as the guiding problem of this thesis that manufacturing companies – and their project managers in particular – lack in methodical guidance for the management of Business Process Innovation (BPI). A BPI can also be referred to as complex technical planning project spanning over a considerable time from several months to a few years depending on the scope.
The analysis of literature and field study presented in this thesis exposed that such projects bring the conventional plan-driven Stage-Gate-based approaches prevalent in manufacturing companies to their limits. It was also stated that at the same time that Agile Project Management (APM) has a long and successful record in the development of complex software products and gained in interest over the recent years in the manufacturing domain as well. Adopting the underlying principles and the therewith related methods, frameworks, and tools to an conventional, plan-driven context is known as Hybrid Project Management (HPM). In the automotive sector, where software development became an increasingly important proportion of the product creation process, this trend emerged early. The HPM models were introduced to benefit from the advantages of APM in the proven process models and given organizational structures for developing and producing complex technical products. A general guideline on how to incorporate agile elements in manufacturing companies was not practice-approved to the date when this thesis project started.
The integrated method developed and outlined in this thesis builds on the same basic idea and can be classified as a HPM approach to incorporate agile APM principles into to the existing structures and procedures of managing complex BPI projects. Further, it is developed around some basic rudiments: first, to increase agility only where it is required due to a complexity that prevents the proven and practiced plan-driven project management from being effective. Second, to start small and bring quick improvement instead of trying to transform the entire project management approach from the beginning. Third, to establish a more profound and sustainable agile work culture by

applying adapted concepts that are proven and practiced in the manufacturing industry. The shop floor management routines manifested e.g. in the *Toyota Kata Management* are based on the same basic ideas of emergent practice than APM and can increase the operative agility of a project team.
Apart from helping practitioners in manufacturing companies to establish a sustainable agile working culture the developed method also contributes as a reference to the scientific domain engaged in that field. Within this final chapter, the project results are summarized and reflected on the three formulated research questions, limitations and assumptions are discussed, and future perspectives are suggested.

7.1 Summary & reflection on research questions

In the introduction of this thesis, a problem statement and objectives were formulated and subsequently incorporated in a superordinate research question (see chapter 1):
How can a method support practitioners in managing complex BPI projects in manufacturing companies more effectively?
Guided by the individual objectives of this thesis (see section 1.2) this issue was broken down into four research questions that provided a structure for this thesis. In the following, the major results are summarized and reflected on the formulated research questions.

Q1 How are BPI projects in manufacturing companies managed to date and what challenges do exist in the industry?
At the beginning of this thesis project, the insight into BPI projects in the manufacturing industry was quite limited and documented field studies rare. In chapter 4, reports from failed ERP implementation projects (section 4.1), a survey with innovation experts from the manufacturing industry (section 4.2), a case study with the two companies (I & II) (section 4.3), and eight interviews with experts from the field of BPI and APM (section 4.4) contributed to more profound insight. Based on these sources, it can be concluded that manufacturing companies are generally experienced in and focused on conventional plan-driven project management approaches. However, more companies and managers are getting interested in going new ways and are open-minded for testing agile approaches. The insight

into industry practice also revealed that switching entirely to an agile project management approach, like introducing a *Scrum* organization, can be challenging in a manufacturing company. The established structures and policy for measuring project progress are not reconcilable easily with the concepts of time-boxing and sprint reviews.

Q2 How can the complexity of BPI projects be addressed?

Managing a BPI project effectively requires the awareness of complexity and critical prerequisites by all people involved. The integrated method for managing complex BPI projects provides an assessment guidance (*Module 1*) with two distinct elements. The questionnaire with 24 guiding questions for assessing the complexity of a BPI project (element 1a) captures the insights from various complexity models and expert's experiences with such projects in the industry. With a checklist (element 1b), the practitioners can evaluate, whether the 14 critical prerequisites for a reasonable implementation of a the hybrid project approach that allows organizational agility on the operational level.

Both, the questionnaire and the checklist, are designed as guiding elements for a self-reflection. The tools do not take away the manger's decision for or against a certain approach.

Q3 Which procedural framework can support a more effective management of complex BPI projects in manufacturing companies?

The ideological pattern of a *Knowledge Creating Company* provides the basis for *Module 2*. It constitutes a procedural reference for the iterative planning of next target states and the formulation of process prototypes, allowing experimental, validated learning embedded in a *Hybrid Project Management* structure and therefore more agility in BPI projects.

The reference model defines an appropriate meta-structure that not only takes the involved corporate hierarchical levels into account, but also allows a precise breakdown of goals and activities within their specific time granularity.

According to the proposal, a BPI should be guided by a higher-level vision providing a direction and motivation for activities and actions in the daily work routine (element 2a).

To guarantee stability in a complex BPI project, the proposed procedural reference model is structured by an adapted *Stage-Gate* on the strategic level (element 2b). The phases are modified with regard to the experiences and observations of the

accompanied industrial projects (see section 4.3) and the references from Agile Process Planning (APP) (see 3.3.2).
In a conventional daily business routine in a non-complex environment, progress is achieved by accomplishing day-to-day goals and by following best practice (see 2.3). Since the BPI projects in focus are characterized as complex, the advancement requires emergent practice based on explorative, validated experimenting to incrementally discover cause-and-effect relations. Within element 2c, the PDCA cycle from the *Toyota Kata* (see 3.4), provides a basic scheme for problem-solving under these conditions.
To achieve the full potential of the adapted *Toyota Kata* as an operative progress routine in BPI projects, the iterative formulation of reasonable and tangible next target states is essential. The latter need to be aligned with the strategic direction provided by the process vision and milestones captured in the adapted *Stage-Gate*. The integrative planning routine for BPI projects (element 2d) fills this gap in-between the two poles of strategic stability and operative agility. It builds on a *Build-Simulate-Learn-Align* (BSLA) routine which combines elements from several problem-solving and prototyping pattern introduced in section 3.4 and ideas from the *Shop Floor Management* in production systems.

The integrated method for managing a complex BPI project results from the synergy of superimposing three individual modules and their nine elements. Module 1, the *Initial Assessment*, helps projects managers to understand the complexity and prerequisites of a specific BPI project. After analyzing the setting of a BPI project, their main interest is to foster *Explorative Learning*. Such a project should generally be structure according to the *Hybrid Reference Framework* elaborated as module 2. During *Phase 1 Analysis*, the management focus is upon *Preparation*. They formulate a process vision, assemble a core team, from a leading coalition, and set the general procedural and organizational parameters. In this section, the Hybrid Project Management enfolds its key advantage by merging strategic stability with operative agility. Then, in the last section, the attention shifts towards the actual *Implementation* by extending the practical experiences to the intended perimeter.

Q4 How can such an approach be incorporated and maintained in a manufacturing company?

Integrating organizational agility into conventional structures constitutes a paradigm shift for most project teams in the manufacturing industry and therefore requires activation effort and endurance by all involved persons. On this premise, *Module 3* is designed to assist project managers in continuously identifying areas of improvement (element 3a) and setting individual goals for operative agility based on them (element 3b). In combination, the module is intended to support project managers in establishing the right mindset for operational agility and to facilitate the implementation of the procedural reference model (*Module 2*). With the list of typical areas of improvement (element 3a), capturing insights from various project management literature domains and expert knowledge, can identify areas for improvement. They then set individual goals of agility by deploying practices based on expert recommendations captured in a heat-map.

7.2 Assumptions & Limitations

Manufacturing industry

The integrated method for managing complex BPI projects addresses companies in the manufacturing industry. In this field, the design of business processes demands technical know-how due to the involved production and product technologies and, therefore require the expertise of various disciplines (e.g., product designer, process engineers, production and supply chain experts, IT specialists, system integrators). The presented method has been designed on that premise. The emphasis on methods and tools from the *Lean Management Philosophy* puts companies in favor that already operate according to the underlying principles and values. However, an extension to other domains might be possible.

Complexity of BPI projects

The degree of complexity is an essential indicator whether a hybrid management model provides benefit compared to a conventional approach. Since the implementation of organizational agility in a BPI project consumes additional resources, only complex situations should be handled with it. *Module 1* of the method is designed to support this decision. It should be considered, that a good conventional plan-driven approach, established and integrated in a company's organization, will probably still perform better than a poorly executed hybrid approach. The analysis of economic benefits and trade-offs (see 6.4) provides exemplary indication, whether the additional expenses might prevent risk-costs later in a project.

Modularity of the method
The three modules build logically upon each other and in combination as a method unfold the desired added value to create more operational agility in BPI projects. However, the components can also be deployed individually to achieve benefits (see 6). Practical experience has shown that implementing the entire method during one BPI project might overexert the involved persons and stretch corporate policies. Since *Company I* already had made experiences with agile project management before, their individual access to the method was creating small nuclei and letting them grow and providing best practices for the following BPI projects. *Company II* chose a more radical approach from the start with the prospect of initiating a whole new management culture that transmits to several follow-up BPI projects. A step-wise adoption of the method might be reasonable.

Leading coalition & room for maneuver
The experiences during the case study have also confirmed the impression from the *Change Management* literature that transformation only works if a leading coalition of early adopters forms across the top management, project management and the project team. It does not require all persons to be convinced from the start, however, these early adopters need to persuade a critical mass and antagonize objectors. The method is built around the perspective and motivation of a project manager to cope with complexity. To be successful, the project manager needs room for maneuver with authorization by the top management board. This consent and space might be easier to achieve in SMEs.

Scientific approach & evaluation
In reference to the scientific approach and the chosen research methodology (see 1.3), the presented method and its modules were derived from an extensive literature review and various data from the industry. The data collection, analysis, and evaluation have been conducted carefully and reviewed in coordination with other researchers and industry experts. Nevertheless, the results aggregated and presented in this thesis reflect the author's opinions and judgments shaped by his research environment (see 1.3.4) - including the trans-disciplinary research project, the industrial context of a high-wage economy, and, in particular the author's personal heuristic framework and vision emphasizing the Japanese Management Culture.
The developed method was applied in two companies of different size (large and medium-sized) and within two unlike businesses (automotive and special machinery).

In combination, a significant portion of the manufacturing industry is covered and the method probably delivers similar results since it not technology-bound. Process industries like the chemical, pharmaceutical, or food and beverage sector tends to have more regulation and a higher degree of automation. The applicability of this method has not been studied in such environments.

Scientific contribution
The chapters *Fundamental Concepts*, *State of the Art Approaches in BPI*, and *Best Practice & Actual Needs in the Industry* make up a significant part of this work. In chapter *Fundamental Concepts*, the essential basics of the topics business processes, innovation, complexity and agility in manufacturing companies were put into context. Chapter *State of the Art Approaches in BPI* shows an overview of the latest concepts published in the scientific community, while chapter *Best Practice & Actual Needs in the Industry* provides an insight into two exemplary best practice leaders in handling project complexity with a more agile organization in the manufacturing industry. At this point, it must be emphasized that these two examples do not represent a general industry standard. Finding experts for the interview conducted in chapter 4.
The effort to compile, interpret, rearrange, and present the major topics and industry best practices reflected in this thesis in a comprehensible way should be understood as a substantial part – beside the presented integrated method – of its contribution to the scientific community.

7.3 Future Perspectives

Rounding up the achievements for BPI in science and industrial practice, new challenges and perspectives arise.

Longitudinal studies & meta-analysis
Although practical implications limit the scope for longitudinal studies in this field of BPI, a dedicated research project might address this topic directly. By focusing on a sufficiently dimensioned test group of SME (these might be easier to involve), several projects with the goal of transforming and digitizing business processes in the context of *Industrie 4.0* might provide valuable insights. A meta-analysis of these individual cases might bring forth consistent pattern. However, since data quality varies immensely, this might be a highly manual procedure.

Risk-cost-based decision support
A more profound risk-cost evaluation (see 6.4) might provide a decision support for project managers, whether additional resources and effort to identify and prevent potential problems at an early project stage is justified by a high pending risk. Quantifying risks is a major task in building insurance models.

Experimental lab environment
The available literature and data on the use of training factories or experimental labs for organizational change management and innovation is limited. A more in-depth analysis of how these environments need to be designed individually and what role didactic aspects play might be a promising perspective for a collaborative research between engineering and social sciences.

With respect to these future perspectives, the method for managing complex BPI projects in manufacturing companies as elaborated and outlined in this thesis might support the European industry in adapting their core procedures and structures more effectively to achieve the maturity of what currently is referred to as *Industrie 4.0*.

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Appendix

A.1 Additional Tables & Figures

Table A.1: Classical Stage-Gate model according to COOPER *1990.*

Basic Stage-Gate Model (Cooper 1990)
Stage 0: Idea Screen *Ideation through creativity techniques*
Gate 1: Pre-selection *Evaluation of ideas based on risk and feasibility criteria*
Stage 1: Scoping *Information gathering of technical and economical aspects*
Gate 2: Second Screen *Second evaluation of ideas based on new information and same criteria*
Gate 3: Go to Develop *Decision on the development plan*
Stage 3: Development *Prototype development; marketing, production, and test concepts; market analysis*
Gate 4: Go to Test *Test of the prototype*
Stage 4: Testing *Test and pilot production; more in-depth cost and budget planning*
Gate 5: Go to Launch *Final evaluation of budget, marketing, and production concept*
Stage 5: Launch *Marketing, sales; distribution and production*
Gate 6: Review *Review; lessons learned; portfolio integration*

*Table A.2: Assessment of areas of improvement in a BPI project (*Roider *2018).*

Problem Category	**Problem Characteristic**	**Consideration**	**Area of Improvement**
Target State	The target state is clear.	|X|O|O|	Clarify project objective and requirements
	There is uncertainty about the target state.	|X|X|X|	
Time Pressure	The superordinate project plan allows for a variety of considerations.	|X|O|O|	Expedite early results
	The overall project plan requires quick decisions.	|X|X|O|	
	The solution of the problem has a significant influence on relevant milestones.	|X|X|X|	
	The available time is sufficient.	|X|O|O|	Quick troubleshooting
	The available time is reasonable.	|X|X|O|	
	The available time puts the team under considerable pressure.	|X|X|X|	
Knowledge	The team has experience in applying the knowledge required to solve problems.	|X|O|O|	Facilitate continuous learning
	The technical knowledge required to solve the problem is available in the team.	|X|X|O|	
	The technical knowledge required to solve problems is not sufficiently available in the team.	|X|X|X|	
Technology	The team has experience in applying the involved technologies.	|X|O|O|	Expedite early results
	Some aspects in applying the involved technologies are unclear to the team.	|X|X|O|	
	Essential aspects in applying the involved technologies are unclear to the team.	|X|X|X|	
	The involved technologies are established.	|X|O|O|	Increase willingness to change
	The involved technologies are derivatives of known technologies.	|X|X|O|	
	The understanding of the involved technologies requires continuous learning.	|X|X|X|	

|X|O|O| = currently no need; |X|X|O| = consider; |X|X|X| = strongly consider

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Problem Category	**Problem Characteristic**	**Consideration**	**Area of Improvement**
Simultaneous Development	The problem can be solved independently of other departments.	|X|O|O|	Increase willingness to change
	Changes in associated departments have a significant impact.	|X|X|X|	
	The project goal is achievable independently from other projects or stakeholders outside the project.	|X|O|O|	Improve communication
	The project goal includes requirements from other projects or stakeholder outside the project.	|X|X|O|	
	Project goal is achievable only in close cooperation with other projects or stakeholder outside the project.	|X|X|X|	
Information Exchange	All persons involved in the problem solution have real-time knowledge of the project progress.	|X|O|O|	Improve communication
	In a regular jour fixe team members personally exchange current information on the project progress (e.g. with a common task board).	|X|X|O|	
	The exchange of information and progress status occurs irregularly or without the presence of all participants (e.g. due to absence, physical separation, exchange of information via documents).	|X|X|X|	
	All persons involved in the project have access to all available information. Every employee knows the essential and current tasks and activities in the entire team as well as relevant information from outside the team. Potential conflicts and synergies as well as relevant general parameters are taken into account by the team.	|X|O|O|	Increase transparency
	Each person knows is informed on the the team's relevant tasks and activities taking into account potential conflicts and synergies as well as relevant general parameters.	|X|X|O|	
	Persons only know their own tasks and activities.	|X|X|X|	

|X|O|O| = currently no need; |X|X|O| = consider; |X|X|X| = strongly consider

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Problem Category	**Problem Characteristic**	**Consideration**	**Area of Improvement**
	The current project challenge requires the expertise of a specific department (this department is represented by a representative in the project team).	|X|O|O|	Involve the customer/process owner
	The current project challenge requires the expertise of the entire project team.	|X|X|O|	
	The current project challenge requires the expertise of the entire project team with an intensive assistance of the process owner (customer).	|X|X|X|	
Coordination	The team members identify their tasks autonomously and work on them in coordination with the project management.	|X|O|O|	Enable self-regulation
	In meetings, the team members agree on what they have to work on and by when.	|X|X|O|	
	The team members receive tasks and a deadline.	|X|X|X|	
	The solution to the project challenge is clear and the team has experience with similar situations.	|X|O|O|	Learn from mistakes
	For the way to the solution of the challenge, an orientation towards best practice projects is possible or experts with appropriate experience can be involved.	|X|X|O|	
	The team cannot rely on any experience to solve the project challenge.	|X|X|X|	

|X|O|O| = currently no need; |X|X|O| = consider; |X|X|X| = strongly consider

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Problem Category	Problem Characteristic	Consideration	Area of Improvement
Trust	The team sees itself as such an entity and expresses this in its cooperation.	|X|O|O|	Strengthen team spirit and cooperation
	The team sees itself as an entity and takes measures to strengthen cooperation.	|X|X|O|	
	The team sees itself as an entity, but does not express this in the way it works (e.g. individual team members work predominantly on their own).	|X|X|X|	
	The team regularly and actively takes the time to continuously improve its cooperation in order to develop as a team and to perform its tasks effectively and efficiently.	|X|O|O|	Encourage self-reflection
	The team members are aligned with each other in their cooperation AND there is an open and honest way of interacting with each other, which enables a continuous improvement of the cooperation.	|X|X|O|	
	The team is in the finding phase but shows potential for an effective and efficient cooperation.	|X|X|X|	
Alignment	There is a common understanding of the target state among all participants.	|X|O|O|	Clarify project goal and requirements
	There is a lack common understanding of the target state.	|X|X|O|	
	The understanding of the target state is not the same for all participants.	|X|X|X|	
Motivation	Employees contribute their own ideas to the solution process and shape their own cooperation.	|X|O|O|	Foster motivation
	Employees are proactive and contribute their own ideas. However, the implementation of these ideas or the self-organization has potential.	|X|X|O|	
	The employees are merely concerned with completing assigned tasks. Little initiative is shown or suggestions for the working method are lacking. (This may be due to a lack of capacity or restrictions imposed by the environment).	|X|X|X|	

|X|O|O| = currently no need; |X|X|O| = consider; |X|X|X| = strongly consider

*Table A.3: 12 Principles from the Agile Manifesto Adapted to Business Process Innovation Projects (*KAGERER *2017a).*

	Principles from the Agile Manifesto Adapted to Business Process Innovation Projects
1	**Satisfy the customer** What is really important for the customer? Elaborate customer valued results. Evaluate your own activities and project success by the value of the results for the customer, not by the degree of implementation of the plan created at the beginning. Exemplary indicator: less objections by the team that certain customer wishes are not realizable.
2	**Welcome changes** The team implements changes quickly and efficiently, even if they are initially unknown and occur at short notice. Consequences are considered. Willingness to change outweighs the attempt to avoid changes. Dealing with changes due to a feedback are seen as an opportunity to improve the work result for competitive advantage. Exemplary indicator: "Feedback is important!" is a common consent. The result of accepted feedback often implies changes that usually do not attract broad approval.
3	**Deliver regularly** The operative results are achieved incremental and iterative in short periods of time. The focus is on an actual ”delivery”. (Intermediate) results are presented to internal or external customers. The delivered results are used for feedback and sharpen the requirements. The object is developed by experimental, validated learning.
4	**Foster interdisciplinary cooperation** Requester and developer work closely together and share their responsibility. Requirements do not have to be known in detail at the beginning, they can change or become more specific as the project progresses. In close coordination and cooperation, the implementation work can still start early. There is a shared responsibility. The cooperation is continuous throughout the entire project duration and includes frequent interaction (daily!).
5	**Motivate with support and trust** Employees are the factor that makes the difference between success and failure. The team can make decisions and plan independently in their area of responsibility. Decisions are made by those persons who are best suited to make them. The team is provided with an environment that is appropriate for its work. The team receives the help it needs and is freed from any handicap. Employees in turn bring motivation and passion to their work.
6	**Facilitate face-to-face conversation** ”The problem is not a lack of documentation, it is a lack of understanding!” Direct communication replaces documentation as an inefficient medium of communication. It fosters implicit knowledge that complements individual facts with the relationships between them. The people involved have the best knowledge and information available. Personal communication strengthens the team spirit, reduces language barriers and bridges physical separation.

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	Principles from the Agile Manifesto Adapted to Business Process Innovation Projects
7	**Work for customer-valued results** In the original version this principle demands working software code. In the context of hardware or process development there is a generalization towards customer-valuable results due to the longer development times. Customer valued results allow to identify problems at an early stage of development to make better decisions on the futher course. The the original objective of this principle, producing customer-valued results as an indicator to measure progress, is maintained.
8	**Maintain steady pace** There is a steady working pace that can be maintained over a longer period of time without causing overload or weariness. At the end of a project, calm is preserved and the work is finished ”in flow”. There is no need for constant overtime, avoiding a negative impact on morale, productivity and quality. Exemplary indicator: a strongly increasing workload before milestones ("milestone panic") is avoided, as well as a slackening off after reaching a milestone.
9	**Aspire technical excellence** ”Agile is NOT quick & dirty!” The quality of a concept/construction/process is essential. Finding solutions is a continuous activity. The right people with the right skills will create the right results. Establish an environment of continuous learning by encouraging the acquisition of new knowledge and the development of individual skills. Team members learn with and from each other.
10	**Value simplicity** Strive for simple solutions. These are easier to change. A limited set of rules stimulated creativity and avoids complexity in the solutions. For example: A simple process can be supplemented more easily than taking away something from a complicated one.
11	**Favor self-organization** Within the team, all necessary roles and skills are available, so that the team can decide who does what, when and how, independently of superordinate responsible persons. It can organize its work itself in terms of content. High interaction and few procedural rules support self-organization.
12	**Reflect and adapt regularly** The team reflects at regular intervals on how it can become more effective and adapts its behaviour accordingly. New methods are not accepted and applied blindly. They are questioned, refined and adapted to the specific situation. The team itself and its working methods develop continuously.

A.2 Experts Interviewed

Table A.4: List of experts interviewed for this theses with background descriptions contributed by ROIDER *(2018) and* KAGERER *(2017).*

Expert	Background
A	*Expert A* originates from the agile software development scene and advises international companies in modern and agile project management, mainly for larger IT-projects. His is an expert for introducing and maintaining the *Scrum* method in various sectors ranging from telecommunication IT-specialized service providers to machine part suppliers and car manufacturers. On this basis, *Expert A* gained profound insight into the challenges of introducing new project management methods and tools. He also posses a deep scientific understanding of the *Agile Manifesto*.
B	*Expert B* has gained great experience in the scientific elaboration of the mechatronic product development process. In particular, *Expert B* investigated in-depth, how arising complexity in his research field might be encountered through the embedding of *Scrum* in the development process. Therefore, a conducted detailed analysis of the agile product development research field under the special aspect of a mechatronic hardware engineering environment, had to be pioneered. In this sense expert C is proven in both research areas, engineering, as well as Agile project methods and moreover, has elaborated an integrative model which outlines an Agile mechatronic product development process.
C	*Expert C* advises companies on coping with the strategic, organizational, procedural and technological challenges resulting from the digital transformation and the underlying challenges in software development. He received his doctorate in mechanical engineering and held a management position at an automation technology manufacturer for several years.
D	*Expert D* has been working full-time as a *Scrum Master* in the software sector for about a year in *Company I*, a large manufacturer for premium automotive products. Before that he already gained one year of experience as a software developer applying agile principles. *Expert D* operates in a business unit, that has decided to adopt an agile working model based on the *Scrum* framework and has aligned its organizational structures accordingly. The department is positioned to generate maximum flexibility and customer orientation while maintaining high efficiency. Quick learning and collective knowledge-creation is in the focus, however, the department is primarily concerned with IT-related issues. Typical projects project provide a clear objectives, while detailed requirements emerge late leading to technical problems.

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Expert	Background
E	*Expert E* has an engineering background and is a certified *Scrum Master* as well as a trained agile coach according to the methods of Axel Schroeder (see SCHRÖDER 2017). This training program emphasizes on agile approaches for product development in the mechatronic environment in which the expert operates. The prevailing organization in his particular domain corresponds to the classic matrix organization, where conventional project management approaches are predominant. The complexity in his environment results from the combination of the organizational structure with a lack of experience with innovative technologies and the specific project tasks. As an agile coach, expert E supervises the adoption of agile approaches to individual sub-projects in *Company I* by integrating them into existing structures effectively.
F	*Expert F* is involved in developing processes and methods within the field of production planning in *Company I*. In this role, is in charge of agile pilot projects in process planning, implementing an Agile Process Planning (APP) approach by SCHNEIDER (2015) integrating *Scrum* to conventional process planning . These projects were funded by the top management and supported by a methodological team. *Expert F* received prior training in agile methods, however, without having gained practical experience or having undergone agile coaching training. Using his knowledge from the pilot projects, *Expert F* supports three departments and projects in introducing agile approaches.
G	*Expert G* is a project manager in the process planning department of *Company I*. Building on the Agile Process Planning (APP) approach (see SCHNEIDER 2015), he, together with *Expert F* and his team continuously refines this working method.
H	As the Chief Operation Officer (COO) and Managing Director for Operations & Industrial Engineering at *Company II*, a medium-sized enterprise manufacturing supply parts for rail network construction and maintenance, *Expert H* is currently managing a highly complex BPI project that involves the implementation of a novel ERP system together with a company-wide organizational, procedural, technical, and cultural reframing. *Expert H* has gained profound experience with such complex projects due to his leading role in his previous company, that successfully coped with a similar situation. *Expert H* also acquired theoretical knowledge by participating in professional training on the ideas of *Design Thinking* (see CUREDALE 2019), the *Lean Start-Up* method (see RIES 2019), and various modern project management approaches (see TIMINGER 2017).
I	Since the *Lean Management* expertise of *Expert I*, the author of this thesis, was directly involved in the evaluation of correlations between the principles of the *Agile Manifesto* and practices form the *Lean* domain, he is listed as an expert. *Expert I* has a long record on *Lean Management* due to his experiences as a consultant, trainer, and educator in this field.
J	*Expert J* gained his expertise as a *Lean* specialist in the industry before starting his academic career in this field. To this date, *Expert J* trains companies and educate students in merging the *Lean Philosophy* with data-driven approaches.

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Expert	Background
K	Like *Expert I* and *Expert J*, *Expert K* was significantly involved in the development and supervision of an Innovation Lab for Lean and Smart Processes and gained expertise during his consulting projects in the industry, as well as a trainer and educator.
L	*Expert L* is an in-house consultant at a globally active technology group with German roots. He has been working on the topic of Operational Excellence (OpEx) for several years and has many years of experience in *Lean Management* and especially in *Value Stream Mapping & Design*, *Shop Floor Management*, *Coaching*, *Lean in Administration*, *Hoshin Kanri* and *Toyota Kata*. He is also an expert for the evaluation of maturity levels and has international experience in this field.

A.3 Software Used

- Citavi™ 5: Reference management program
- Microsoft Excel® 2016: Spreadsheet application. Used for ....
- Microsoft PowerPoint® 2016: Slide show presentation program. Used for the graphical illustrations.
- TeXstudio 2.12.22: Integrated development environment for LaTeX typesetting.

A.4 Contributing Supervised Student Theses

As part of this PhD thesis, the following theses (Bachelor and Master) were supervised by the author at the Institute for Machine Tools and Industrial Management (*iwb*). During this collaboration, the students have been guided closely in terms of research clarification, objectives, scientific questions, approach, activities, and content. Wherever possible, the results were published in joint papers (see list of references A.5).
Additionally, the following table shows to which chapters the student theses have contributed. Illustrations segments that were developed together or that were adopted are referenced accordingly.
The author expresses his sincerest thanks to all students for their great creativity and commitment in supporting this research.

Table A.5: List of supervised student theses.

Name	Title of thesis / semester paper	Type	Year	Input for
KAGERER 2017a	An Agile Management Framework for the Systemic Manufacturing Change Management	BT	2017	3.3, 4.3, 4.4
KAGERER 2017b	Application Potential of Agile Project Management Methods for the Systemic Change Management	BT	2017	3.3, 4.3, 4.4
L. MALIK 2017	Entwicklung eines literaturbasierten Komplexitätsmodells fuer Produktionsänderungen	MT	2017	2.3, 5.2
LOHNER 2018	Vorgehensmodelle und Routinen in komplexen Innovationsprojekten	MT	2018	2.2, 2.4, 3.4
BEUL 2018	Unterstützung der Umsetzung innovativer Projekte in produzierenden Unternehmen mit Hilfe von Lernfabriken	MT	2018	4.4, 5.3
ROIDER 2018	Entwicklung einer Methodik zum agilen Umgang mit technischen Problemen in der Prozessplanung - am Beispiel der Elektromobilität	MT	2018	2.1, 2.3, 3.3, 4.3, 4.4, 5.1, 5.2, 5.4, 6.1
KUBITSCHEK 2019	Complex Changes: A Framework for Integrating Organizational Culture in Change Projects	MT	2019	2.3, 3.4
NEUBERT 2019	Auswahl und Einsatz von Problemlösungsmethoden in komplexen Innovationsprojekten der Produktion	MT	2019	2.2, 3.3, 5.2, 5.4
RIDOLFI 2020	Toyota-Kata-Projektmanagementmodell für Geschaeftsprozessinnovationen in produzierenden Unternehmen	MT	2020	2.4, 3.3, 3.4, 4.1, 4.3, 5.3, 6.1

MT: Master's thesis, BT: Bachelor thesis

A.5 Publication List

Preliminary results of this thesis have been used for own, conference or journal publications and are listed in the following.

BRANDL et al. 2018

BRANDL, F. J.; KAGERER, M.; REINHART, G.: A Hybrid Innovation Management Framework for Manufacturing – Enablers for more Agility in Plants. Procedia CIRP 72 (2018), pp. 1154–1159.

BRANDL et al. 2019

BRANDL, F. J.; KAGERER, M.; BRAUN, C.; MILLER, M.; REINHART, G.: Survey on Innovation in Manufacturing Companies. Ed. by I. für WERKZEUGMASCHINEN UND BETRIEBSWISSENSCHAFTEN (*iwb*). URL: https://www.iwb.mw.tum.de/fileadmin/w00bwm/www/Forschung_und_Industrie/SFB_768/Studie_zum_Agilen_Projektmanagement_im_Innovationsmanagement_der_Produktion_16_9_short.pdf.

BRANDL et al. 2020

BRANDL, F. J.; RIDOLFI, K. S.; REINHART, G.: Can we Adopt the Toyota Kata for the (Re-)Design of Business Processes in the Complex Environment of a Manufacturing Company? Procedia CIRP 93 (2020), pp. 838–843. URL: http://dx.doi.org/10.1016/j.procir.2020.03.086.

BRANDL et al. 2021

BRANDL, F. J.; ROIDER, N.; HEHL, M.; REINHART, G.: Selecting practices in complex technical planning projects: A pathway for tailoring agile project management into the manufacturing industry. CIRP Journal of Manufacturing Science and Technology 33 (2021), pp. 293–305.

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List of Abbreviations

AHP	Analytical Hierarchy Process
APM	Agile Project Management
APP	Agile Process Planning
BML	Build-Measure-Learn
BSLA	Build-Simulate-Learn-Align
BTFR	Build-Test-Feedback-Revise
BPMN	Business Process Model and Notation
BPR	Business Process Re-engineering
BPD	Business Process Design
BPI	Business Process Innovation
BPRD	Business Process Re-Design
CBR	Case-Based Reasoning
CIP	Continuous Improvement Process
CIRP	College International pour la Recherche en Productique
COGQ	Costs of Good Quality
COPQ	Costs of Poor Quality
CRC	Collaborative Research Center
DRM	Design Research Methodology
EC	Engineering Change
ECM	Engineering Change Management
EVL	Explorative Validated Learning
eEPC	extended Event-driven Process Chain
ERP	Enterprise Resource Planning
GDP	Gross Domestic Product
GTM	Grounded Theory Method
HPM	Hybrid Project Management
HTL	Hypothesis-Test-Learn

IDEF	ICAM Definition for Function Modeling, where ICAM is an acronym for Integrated Computer Aided Manufacturing
IVPM2	Iterative and Visual Project Management 2
iwb	Institute for Machine Tools and Industrial Management
KPI	Key Performance Indicator
LMU	Ludwig-Maximilians Universität München
LOP	List of Open Points
MBO	Management by Objectives
MC	Manufacturing Change
MCM	Manufacturing Change Management
MTO	Manufacture to Order
MVP	Minimum Viable Product
MVPS	Minimum Viable Production System
NPD	New Product Development
OCM	Organizational Change Management
PEP	Produkentstehungsprozess
PDCA	Plan-Do-Check-Act
SCOR	Supply Chain Operations Reference
SOP	Start of Production
SIPOC	Supplier-Input-Process-Output-Customer
SME	Small and Medium-sized Enterprise
SSM	Soft Systems Methodology
TPS	Toyota Production System
TUM	Technische Universität München
TRIZ	Theroy of Inventive Problem Solving
VSM	Value Stream Map
WGP	Wissenschaftliche Gesellschaft für Produktionstechnik (The German Academic Association for Production Technology)

Eidesstattliche Erklärung

Ich erkläre hiermit eidesstattlich, dass ich die vorliegende Arbeit selbstständig angefertigt habe. Die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sind als solche gekennzeichnet.

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(Felix J. Brandl)