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The interplay of digitalisation, strategy and dynamic capabilities.

Insights from an exploratory study in German Mittelstand firms.

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Abstract

Digitalisation requires a reassessment of firms' existing resources and capabilities. Decreased value of resources and capabilities might lower strategic fit between the firm and the market. Firms can respond to changes in the environment through a change in strategy, manifested in a redirection of capability investments. However, the link between strategy and digitalisation has received little attention in academic literature so far. We explore and explicate the influence of digitalisation on firm strategy and shed light on the role of dynamic capabilities in strategy transformation. We conduct an exploratory, qualitative case study based on semi-structured interviews with top management from the German Mittelstand mechanical engineering industry and industry experts. We find firms start to shift their strategy from pure differentiation to a hybrid strategy. Firms complement differentiation advantages by generating cost advantages simultaneously. Findings suggest digitalisation both enhances existing competitive advantage and increases operational efficiency. Strategy transformation is supported by primarily four dynamic capabilities: human resource management capability, learning capability, collaboration capability and business development capability. Further research with other firms and industries is needed to support the findings.

Keywords: Digitalisation, Strategy, Dynamic Capabilities, Competitive Advantage, German Mittelstand

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Glossary

Digitalisation: the use of digital technologies to create value beyond pure efficiency increases.

Digitisation: a two-step action or process of converting analogue data into digital format.

Digital technologies: all types of electronic equipment, machines and applications that break down information into numeric code (usually binary code).

Dynamic capabilities: higher-order organisational capabilities that help the firm alter its stock of resources into a new resource bundle, thus to demonstrate responsiveness to market change to improve chances for competitive advantage and long-term survival.

Strategy transformation: a redirection of capability investments.

Competitive advantage: the firm's ability to create more economic value than the marginal (breakeven) competitor in its product market.

German Mittelstand: German firms that are typically small to medium in size, benefit from market leadership in a market niche with high quality products, and have a family-like corporate culture that emphasises long-term focus and continuity.

Mechanical engineering firm: produces machines which make semi-finished goods or ready-to-sell products. These machines are sold to business customers which are positioned at intermediate links of a value-adding chain.

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1 Introduction

Digitalisation, a technology- and social-induced phenomenon (Tilson et al., 2010) that may challenge how incumbent firms compete, entails a significant contemporary technological change. Empirical evidence has already shown that incumbent firms often struggle to adapt to technological change (Christensen, 2013; Tushman and Anderson, 1986). However, digitalisation not only builds on new technologies, but also on the increased interlinkage of economic actors shaping market environments (Tilson et al., 2010). This differentiates digitalisation from pure technology-based changes.

Digitalisation has affected the value of established firms' resources and capabilities (Helfat et al., 2007). Digitalisation may thus open up capability gaps, i.e. increase the distance between the firm's existing capability configuration and the optimal capability configuration (Lavie, 2006), and thus lower strategic fit with the market environment. This influences firms' product-market position (Henderson and Clark, 1990) and may in turn diminish incumbent firms' performance as many once successful firms demonstrate (e.g. Kodak, Blackberry, Nokia). Consequently, effectively reconfiguring firms' resource and capability pool is critical to avoid declining firm performance (Leonard-Barton, 1992; Nelson and Winter, 1982). This makes digitalisation a highly relevant subject for strategy.

However, the link between digitalisation and strategy has received surprisingly little attention in strategy research so far. Prior research has primarily focused on digitisation, i.e. the technical conversion of analogue data into digital format (e.g. Benner, 2010; Tripsas and Gavetti, 2000) and research can mostly be found in consultancy reports (e.g. Bughin et al., 2017). Organisations can respond to digitalisation through strategy transformation. In this thesis, strategy transformation is analysed by observing changes in firms' resource base. Changes in the environment may lead to a redirection of capability investments (Helfat et al., 2007) which in turn change the organisation's resource and capability pool. Such adjustments indicate a strategic change in priorities. Thus, strategy transformations may help organisations enhance existing or even create new sources of competitive advantage (Rosenbloom, 2000). However, given little existing knowledge on the link between digitalisation and strategy, the implications on firms' responses to digitalisation and the consequences on competitive advantage have yet remained relatively unexplored.

Recent strategy research has increasingly emphasised intangible assets to support firms in creating various forms of competitive advantage (Teece, 1998; Hall, 1992). The resource-based view (RBV) (Barney, 1991; Wernerfelt, 1984) attributes differences in firm performance that cannot be explained by industry conditions to the value of its ordinary resources and capabilities. In essence, if a firm has access to a resource that is valuable, rare, costly to imitate and non-substitutable (VRIN), it can achieve a sustained competitive

advantage. However, increasing complexity, speed and hypercompetition in the business sphere (McNamara et al., 2003; d'Aveni and Gunther, 1994) have led to criticism of the RBV's proposition in dynamic environments. As an extension of the resource-based view, the dynamic capabilities view particularly addresses this criticism. *Dynamic* capabilities describe higher-order capabilities that represent the firm's ability to integrate, reconfigure and renew its existing *ordinary* resources and capabilities (Eisenhardt and Martin, 2000; Teece et al., 1997). Therefore, dynamic capabilities support the firm's behavioural orientation in responding to environmental changes and facilitate greater strategic fit with the market (Helfat and Peteraf, 2003). They help modifying the firm's ordinary resources and capabilities to new sets of VRIN resources. Dynamic capabilities may thus support organisations in their attempt to increase performance by adjusting their capability pool to new market demands resulting from digitalisation.

1.1 Problematisation

Digitalisation may significantly change the strategic conditions for incumbent firms. For German Mittelstand firms from the mechanical engineering industry this is particularly true (Mohr et al., 2017). Mechanical engineering firms produce machines which make semi-finished goods or ready-to-sell products. These machines are sold to business customers which are positioned at intermediate links of a value-adding chain. These firms do not necessarily compete with each other due to their embeddedness in other firms' value chains within a broad range of industries. In the mechanical engineering industry, digitalisation is a relatively new pervasive phenomenon. In previous eras, manufacturing has been described by progressive centralisation of operations, which originates from the time of the first Industrial Revolution and the transformation from artisan-based craft production to the factory system (Skinner, 1969; Taylor, 1911). Nowadays, industrial firms are under the influence of digitalisation. Within such firms' factories, the influence of digital technologies is typically referred to as "Industry 4.0" or "Industrial Internet of Things" (IIoT). This comprises smart engineering and manufacturing techniques in the production process. Industry 4.0 was first promoted to the top of the political agenda in Germany in 2011 through a technology initiative of the German government (Bundesministerium für Bildung und Forschung, 2011). However, even though the terms digitalisation and Industry 4.0 seem omnipresent, their effects on mechanical engineering firms are still relatively unknown from a strategy perspective.

The mechanical engineering industry is of primary importance for the German economy. It is the largest employer among Germany's industrial production sectors with more than 1,000,000 employees in more than 6,400 companies (VDMA, 2017). In the mechanical engineering sector in Germany, the vast majority of firms is considered part of the Mittelstand, i.e. firms that are typically small to medium in size, benefit from market leadership

in a market niche with high quality products, and have a family-like corporate culture that emphasises long-term focus and continuity (De Massis et al., 2018). Given that the Mittelstand is often considered the "backbone of the German economy", solving the challenges brought by digitalisation is critical for further national economic development.

1.2 Purpose and research questions

Digitalisation requires a reassessment of firms' existing resources and capabilities. Decreased value of resources and capabilities might lower strategic fit between the firm and the market (Barney, 1991). Firms can respond to changes in the environment through a change in strategy, manifested in a redirection of capability investments (Helfat et al., 2007). However, the link between strategy and digitalisation has received little attention in the academic literature yet.

Strategy research has indicated that dynamic capabilities may facilitate a firm's strategy transformation and thus contribute to competitive advantage (Teece et al., 1997). Despite a growing body of research in the field of dynamic capabilities, those have often remained "abstract and intractable" (Danneels, 2008, p.536). For this reason, more empirical investigations are needed.

Therefore, the purpose of this thesis is to explore and explicate the influence of digitalisation on firm strategy and in this context, uncover and shed light on the role of dynamic capabilities in strategy transformation involving digitalisation. By investigating this subject, we further aim to find indications whether and how digitalisation affects firms' competitive advantage.

We seek to find out *how* and *why* the expected changes occur and thereby broaden existing knowledge on digitalisation, strategy and dynamic capabilities. Thus, finding answers to the following three research questions contributes to narrowing the research gap:

1. How does digitalisation affect firm strategy?
2. How do dynamic capabilities help firms respond to digitalisation in strategy transformation?
3. How does strategy transformation in response to digitalisation contribute to competitive advantage?

1.3 Contribution and delimitation

This paper contributes to existing knowledge in two ways: First, we provide insights on how digitalisation affects firm strategy and competitive advantage. Second, we also shed

light on how dynamic capabilities operate in the context of digitalisation and thereby empirically contribute to their tangibility.

We answer scholars' call for qualitative, smaller sample studies with a cross-sectional study based on 21 semi-structured interviews with members from the top management team of German Mittelstand mechanical engineering firms and industry experts. This qualitative study is intended to complement the "seeming dominance of quantitative studies" (Ambrosini and Bowman, 2009, p.46) in the dynamic capabilities literature by reducing their "high level of abstraction" (Danneels, 2002, p.1112). The interviews generate fine-grained and context-specific data (Rouse and Daellenbach, 1999; Godfrey and Hill, 1995) from key strategy decision makers.

We exemplary investigate *B2B mechanical engineering firms from the German Mittelstand* and *the context of digitalisation* to answer the research questions. This is a relatively coherent group in terms of size, industry, corporate culture and national origin. Thus, we can also provide insights for this specific type of firm beyond general implications for strategy research.

Findings indicate firms start to shift their strategy from pure differentiation to a hybrid strategy. Firms complement differentiation advantages by generating cost advantages simultaneously. It seems digitalisation both enhances existing competitive advantage and increases operational efficiency. This strategy transformation is supported by four dynamic capabilities: human resource management capability, learning capability, collaboration capability and business development capability.

1.4 Research outline

This thesis employs the term digitalisation as an exogenous development affecting organisations' resources and capabilities. This leads firms to rethink their strategies and thus digitalisation also influences competitive advantages. Dynamic capabilities support the reconfiguration of the organisation's resources and capabilities. Consequently, Digitalisation, strategy, dynamic capabilities and competitive advantage are closely interlinked. Their intuitive connections are summarised in the respective sensitising concept presented in Figure 1. In line with Blumer (1954), the purpose of this concept is to provide an overarching frame for the remainder of this thesis and in particular, for the empirical investigation. Therefore, we want to "merely suggest directions along which to look" instead of providing "prescriptions of what to see" as sensitising concepts "rest on a general sense of what is relevant" (Blumer, 1954, p.7). Sensitising concepts thus guide the empirical investigation and enable the researcher to constantly test, improve and refine interrelationships.

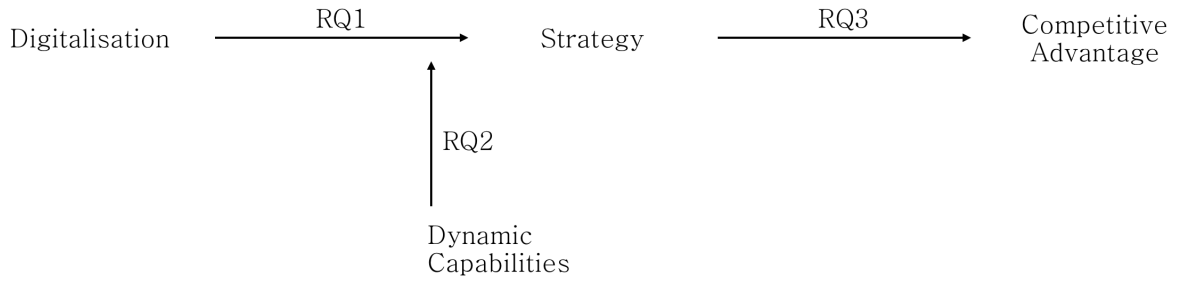

Figure 1: Sensitising concept

The remainder of this thesis is structured as follows: First, an in-depth literature review on both digitalisation and dynamic capabilities is presented (section 2). Following this, we present our methodological choices (section 3). The final sections integrate the results (section 4), discussion (section 5) as well as conclusions, implications and further research (section 6).

2 Theoretical background

This section synthesises the knowledge from the strategic management literature on dynamic capabilities and from the strategic management and information systems literature on digitisation, digitalisation, and digital transformation to provide the necessary context for the remainder of the thesis.

2.1 Digitalisation

Researchers and practitioners likewise ambiguously and interchangeably use *digitisation*, *digitalisation* and *digital transformation*. All these terms describe organisational change influenced by new technologies despite their meaning is not the same (Ross et al., 2017). This leads to confusion and misleading interpretations. Therefore, this section aims to discern and consolidate existing knowledge about the terminologies and attempts to contribute to a greater comprehensibility in their use without proclaiming universally valid concepts.

Digitalisation describes "the sociotechnical process of applying digitising techniques [*understood as digital technologies*] to broader social and institutional contexts" (Tilson et al., 2010, p.749). Digitalisation is thus characterised by two components: *technological development* and *increased embeddedness of market actors* (Graumann et al., 2016; Kane et al., 2015; Brennen and Kreiss, 2014). These two factors are explained below.

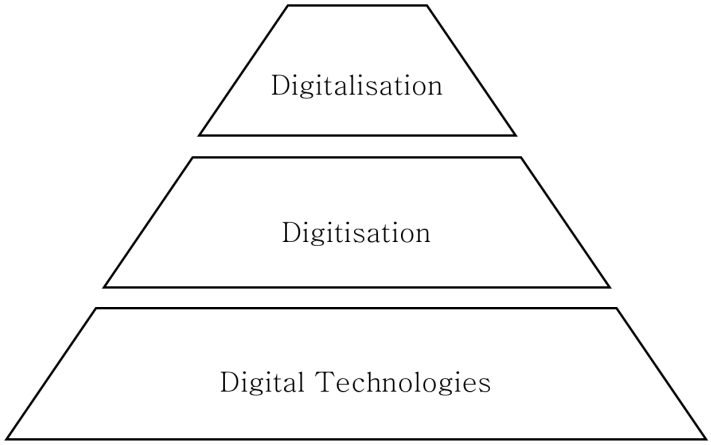

Figure 2: The basis of digitalisation

2.1.1 Factor 1: Technological development

At the core of digitalisation are digital technologies (Figure 2). Digital technologies are understood as all types of electronic equipment, machines and applications that break down information into numeric code (usually binary code) (cp. Tilson et al., 2010). The coded information can be used for data processing, communication and interlinkage with equipment that utilises digital technology. Typical examples include interconnected machines equipped with smart sensors in an industrial environment or the data upload into cloud-based storage for decentralised data processing. An overview of some of the most relevant technology trends related to digitalisation (e.g. Internet of Things and Artificial Intelligence) is given in appendix A.

Digitalisation is often confused with *digitisation*. However, *digitisation* and *digitalisation* are not to be considered the same. We regard *digitisation* as a two-step action or process:

1. the conversion of analogue data into a digital format (e.g. measuring machine's operating temperature with a digital instead of an analogue thermometer) (Brennen and Kreiss, 2014), which allows

2. the automation (i.e. reduce the amount of human involvement to complete a task) of non-digital processes facilitated by technical support systems (e.g. packaging of production components through robots and controlled by human beings). This often includes the interlinkage of digital technologies.

As such, the purpose of *digitisation* is purely data procedural and thus does not provide value beyond potential efficiency increases (e.g. greater throughput rate in production processes). By building on digital technologies, *digitisation* is considered the technical backbone for value creation in the *digitalisation* context (Berger, 2015). *Digitisation* thus

functions as the enabler for *digitalisation* (Ross et al., 2017).

Its infrastructural property (Tilson et al., 2010) makes digital technologies easily available to a relatively broad set of market actors. Digital technologies thus lower barriers for new market entry and contribute to crowding the market (Coltman et al., 2015; Bharadwaj et al., 2013; Tilson et al., 2010). For example, in the mechanical engineering industry, due to the relatively low upfront investments needed, 3D printing facilitates the entry of new market players that are not necessarily rooted in mechanical engineering. Simultaneously, buyers benefit from the greater availability of alternative options. The combination of both effects increases competitive intensity which translates into greater value creation in the market (Berger, 2015).

2.1.2 Factor 2: Increased embeddedness of market actors

The wide-spread availability of digital technologies allows new forms of interlinkage. Digital technologies therefore promote relationship building between market actors. This may improve firms' embeddedness in inter-firm networks. Thus, firms' actions are increasingly embedded in "ongoing structures of social relations" (Granovetter, 1985, p.481). Existing literature emphasises that a firm's embeddedness positively influences its performance (Owen-Smith and Powell, 2004; Ahuja, 2000; Hagedoorn, 1993).

One contemporary example is the increased importance of platform-based business models where the platform's attractiveness results from increased participation and interlinkage of market actors. This exemplifies the increased relevance of ecosystems and the interactions among its constituents in co-creating value (Gawer and Cusumano, 2014). For example, this new source of doing business has brought the mechanical engineering companies Dürr AG, DMG MORI, Carl Zeiss, ASM Assembly Systems together with the technology company Software AG to establish the Adamos platform recently. The goal of this project is to facilitate collaboration between mechanical engineering firms whenever suitable and possible (Adamos, 2018). This example shows how economic coordination efforts may change industry organisation (Richardson, 1972). Firms that have too few embedded relations may struggle to realise certain economic benefits (Uzzi, 1997).

Digitalisation allows market actors to strengthen existing and establish new relationships. Geographical barriers that previously limited exchange are reduced. Increased embeddedness positively influences firms' innovation capacity (Teece, 1986). In this context, market actors from various locations are involved as cultural agents and thus contribute to the technological discourse (Pace, 2013). Consequently, social relations and digitalisation are intertwined in a continuous reciprocal and reinforcing relationship. Thus, the application of digital technologies in a social context amplifies digitalisation. Digitalisation is there-

fore regarded as an ongoing phenomenon that is interlinked with and shaped by the social context, can be observed in practice and is socially constructed (Berger and Luckmann, 1991).

2.1.3 The link between digitalisation and strategy

Porter and Millar (1985) indicated more than thirty years ago that the emergence of digitalisation severely affects the competitive landscape (Figure 3). They imply that firms need to strategically address threats and opportunities from digital technologies. They argue that digital technologies change competition in three ways:

1. by altering industry structures (e.g. barriers to entry, substitutes, etc.), the rules of competition change (e.g. "In the new world, it is not the big fish which eats the small fish, it's the fast fish which eats the slow fish." (Schwab, 2015));

2. by enabling companies to create new forms of competitive advantage and thus providing firms with new ways to surpass their competitors (e.g. through lower cost, enhanced differentiation or a changed competitive scope); and

3. by opening up new business opportunities which are often adjacent to a firm's existing business.

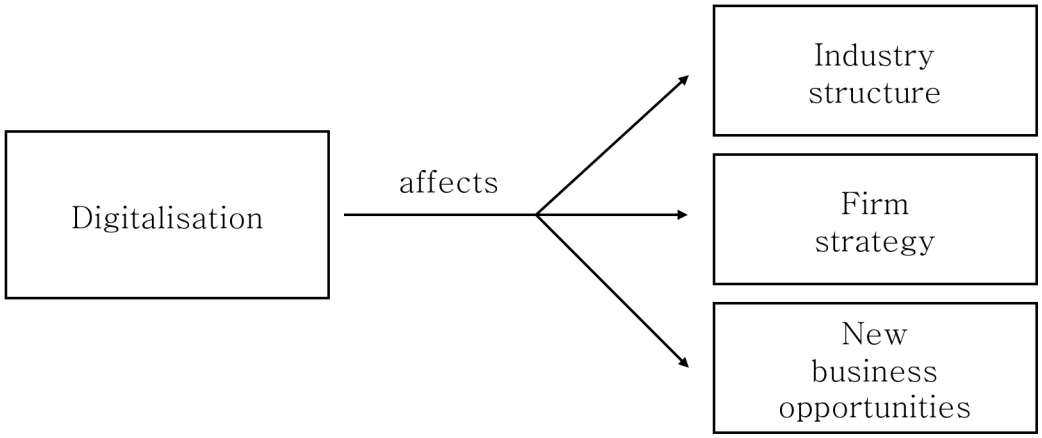

Figure 3: Effects of digitalisation on competition

Subsequently, firms are considerably affected as digitalisation changes the strategic positioning of a firm, the set of available alternatives to choose from as well as the value of each alternative, and finally, the strategic actions to sustain or enhance competitive advantage. Thus, digitalisation impacts all levels of firm strategy. Digitalisation may request a strategy transformation, a redirection of capability investments to adjust to changes in the environment (Helfat et al., 2007). Adjustments can have several expressions that

need to substantially relate to a firm's future prospects, for example, to products, policies concerning scope and diversity, organisational structure, administrative systems, coordination, critical resources and capabilities, routines and other processes (Agarwal and Helfat, 2009).

The impact of digitalisation makes firms typically undergo a form of digital transformation (Chen et al., 2012; Yoo et al., 2010). The term *digital transformation* is understood as a transformation process affecting the core elements of each business to reap the benefits of digital technologies such as increases in productivity and innovation. For example, for mechanical engineering firms the traditional business model "goods in exchange for money" might be complemented by data-driven services (Coreynen et al., 2017; Baines et al., 2009). Digital transformation is comparable to any other business transformation and likely to require a change in firms' resources and capabilities (Kotter, 1996; Romanelli and Tushman, 1994; Haveman, 1992). Following this, we consider digital transformation as a strategy transformation in response to digitalisation. Given the lack of academic consensus on such terms, we use the term strategy transformation for the remainder of this thesis.

To synthesise section 2.1, digitalisation is understood as a technology- and social-induced phenomenon. We regard digitalisation as the use of digital technologies to create value beyond pure efficiency increases.

Digitalisation challenges firms' market position as it likely affects the value of their existing resources and capabilities. Thus, digitalisation may request a strategy transformation, a redirection of capability investments to account for potential capability gaps. A capability gap is described as the distance between the firm's existing capability configuration and the optimal capability configuration following the technological change (Lavie, 2006). To avoid declining firm performance, firms have to close capability gaps (Tushman and Anderson, 1986). Dynamic capabilities are one facilitator in doing this. These support firms' attempt to reconfigure their existing resources and capabilities into new VRIN resource and capability bundles (Eisenhardt and Martin, 2000; Teece et al., 1997). This may increase strategic fit with market needs.

2.2 Dynamic capabilities

The resource-based view proposes firms are bundles of resources and capabilities and these bundles are heterogeneously distributed across firms. In case these differences persist over time, firms can implement value-creating strategies that competing firms cannot execute simultaneously. This, in turn, can lead to a sustainable competitive advantage (Barney, 1991; Prahalad and Hamel, 1990; Wernerfelt, 1984). Therefore, the key to firm survival

and success is in a firm's competence to create distinctive skills and capabilities which provide the means for resource differentiation from its competitors (Dierickx and Cool, 1989). Thus, both resources and capabilities are interlinked: The bigger the set of resources and the more favourable the capabilities to use these resources, the more likely a firm develops an advantageous competitive position (Amit and Schoemaker, 1993). However, some firms endowed with a large stock of initially valuable assets have not managed to sustain superior performance over time. This is attributed to market dynamics. Market dynamics can be induced, for example, by changes in technology.

Increased market dynamics over the last two decades have forced firms to constantly adapt, renew and reconfigure their resource and capability pool. Thus, the resource-based view has been expanded, with some researchers even suggesting a dynamic resource-based view (Helfat and Peteraf, 2003). The dynamic capabilities view extends earlier work on distinctive competence (Learned et al., 1969), organisational routines (Nelson and Winter, 1982), core competence (Prahalad and Hamel, 1990), architectural competence (Henderson and Cockburn, 1994) as well as various capability types (e.g. generic, organisational, ordinary, dynamic, heterogeneous, and homogeneous (Winter, 2003; Zander and Kogut, 1995; Collis, 1994; Amit and Schoemaker, 1993). These concepts point towards the same direction as they deal with the firm's ability to balance continuity and change in its basic functional resources and capabilities as effective as possible. The purpose is to increase strategic fit with market needs (Miles and Snow, 1994). This notion is captured by the dynamic capabilities view.

2.2.1 The foundation of dynamic capabilities

Following its inception marked by Teece et al. (1997), an exponentially growing number of literature on dynamic capabilities has been published, aiming for increased conceptual clarity and practical applicability. Nevertheless, the dynamic capabilities view is still vaguely conceptualised and even its most basic premises are open for debate (Winter, 2003; Kraatz and Zajac, 2001; Williamson, 1999). The lack of consensus becomes evident as dynamic capabilities have been characterised by multiple competing definitions (Table 1 for an overview of the most common definitions).

Table 1: Overview on dynamic capability definitions

Author	**Definition of dynamic capabilities**
Teece et al. (1997), p.516	"the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments"
Eisenhardt and Martin (2000), p.1107	"the firm's processes that use resources – specifically the processes to integrate, reconfigure, gain and release resources – to match or even to create market change"
Zollo and Winter (2002), p.340	"learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness"
Zahra et al. (2006), p.918	"the abilities to reconfigure a firm's resources and routines in the manner envisioned and deemed appropriate by its principal decision-maker"
Helfat et al. (2007), p.4	"the capacity of an organization to purposefully create, extend or modify its resource base"

The fact that no commonly accepted definition of dynamic capabilities has yet been found might partly be attributed to two factors: First, the initial outset provided by Teece et al. (1997) leaves room for interpretation and refinement for scholars from various fields. Second, academic literature commonly distinguishes between two levels of organisational capabilities, ordinary capabilities and dynamic capabilities. However, some scholars still apply the ordinary capability understanding to the concept of dynamic capabilities (Salvato, 2003).

2.2.2 Hierarchy and examples of organisational capabilities

There are some essential differences between an *ordinary capability* and a *dynamic capability*. We follow Eisenhardt and Martin (2000, p.1116) who describe dynamic capabilities as "combinations of simpler capabilities and related routines, some of which may be foundational to others and so must be learned first", thus indicating a hierarchy of organisational capabilities with more narrow, ordinary capabilities at the bottom. A conceptual overview is provided in Figure 4 and a comparison of both capability types is given in Table 2.

Ordinary capabilities "reflect an ability to perform the basic functional activities of the firm" (Collis, 1994, p.145). He mentions examples such as logistics and marketing campaigns and is supported by Amit and Schoemaker (1993, p.35) who claim that ordinary capabilities are "developed in functional areas, e.g., brand management". Ordinary resources and capabilities are linked with efficiency in operations such as tangible assets,

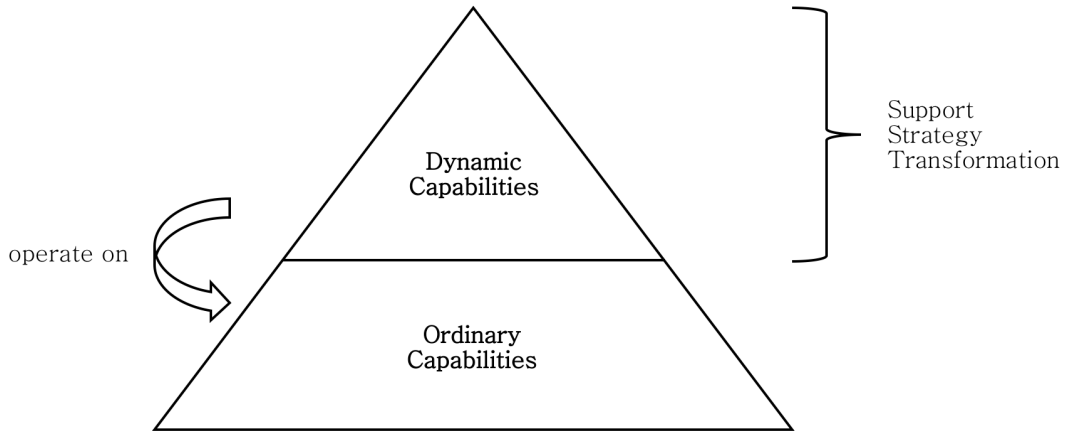

Figure 4: Hierarchy of organisational capabilities

inventory or financial controls that are most likely insufficient for both long-time survival and competitive advantage (Teece, 2007; Teece et al., 1997). This results from the risk that resources and capabilities can be imitated by competitors and become best practice or even obsolete once the environment exhibits a significant change. For example, the mass diffusion of personal computers led to changes in job requirements as these have become standard in the business world. The value of human resources, that have not managed to extend their skills, has significantly been reduced for their respective firms. Therefore, this class of capabilities only enables the firm "to earn a living now" (Winter, 2003, p.992), thus improving the firm's "technical fitness" (Helfat et al., 2007, p.7). Even though other researchers label this capability type as substantive capabilities (Zahra et al., 2006) or as zero-level capabilities (Winter, 2003), their basic understanding is the same: Ordinary capabilities help the firm efficiently perform its current activities. However, resources and capabilities can only be effective in the long-term if they change and are adapted to the life-cycle of the firm and the industry environment to generate sufficient rents.

Dynamic capabilities emphasise the dynamic improvement of firm activities. They are thus directed towards such change in the underlying resources and capability pool of the firm. They apply to the intentional modification of the firm's stock of resources to maximise strategic fit with the environment. Dynamic capabilities are one step removed from the ordinary capabilities (Ambrosini et al., 2009), not as sensitive to the firm context as ordinary capabilities and may therefore be effective across firm-specific contexts. These "more metaphysical strategic insights (...) enable firms to recognize the intrinsic value of other resources or to develop novel strategies before competitors" (Collis, 1994, p.145). Dynamic capabilities enable "a firm to switch gears" (Hayes and Pisano, 1994, p.78),

Table 2: Comparison between ordinary and dynamic capabilities

Characteristic	Ordinary capabilities	Dynamic capabilities
Purpose	Create technical fitness, competitive return for short-term	Create evolutionary fitness, competitive return for long-term
Origin	Can be bought on strategic factor market	Must be built by firm itself
Perspective	Static	Dynamic, forward-looking
Activities	Analysis and optimisation	Sensing, seizing, reconfiguring
Executed by	Administrators	Entrepreneurs and managers
Examples	Logistics, marketing campaigns	Collaboration, innovation

indicating a strategy transformation, and guide "the ability of an organization to learn, adapt, change and renew itself over time" (Dierkes et al., 2003, p.110). As such, they are associated with "evolutionary fitness" (Helfat et al., 2007, p.7) and help the firm to make a living in the long-term. Common dynamic capabilities in the literature are the collaboration with other economic parties (Eisenhardt and Martin, 2000) or innovation capability (Wang and Ahmed, 2007). In this context, new product development is a complex activity that relies on knowledge and learning processes within often interdisciplinary teams. Over the course of this process, teams typically generate tacit knowledge that is difficult to express in order to solve an organisational challenge (Goffin and Koners, 2011). One such example is deep industry expertise and experience that can hardly be made explicit. Zollo and Winter (2002) follow this idea and conclude that organisational learning routines or "learning-to-learn" capabilities serve as mechanism underlying dynamic capabilities. This is strongly associated with Nonaka and Takeuchi's (1995) knowledge spiral or Argyris's (1976) concept of double-loop-learning that questions existing organisational routines. Other examples of dynamic capabilities also include more formal organisational restructurings and reconfigurations (Girod and Whittington, 2017) that facilitate learning and development of new skills.

Research also suggests that dynamic capabilities are rather built by the firm and not bought on a strategic factor market (Helfat et al., 2007; Dierickx and Cool, 1989), follow a path dependency (Zollo and Winter, 2002) and comprise both explicit processes or tangible corporate structures and tacit elements (e.g. corporate culture, networks, leadership styles) embedded in the processes and thus are deeply rooted in the firm (Eisenhardt and Martin, 2000; Collis, 1994).

Researchers use different terminologies of dynamic capabilities but the core understanding is the same. Therefore, we apply the following understanding of dynamic capabilities in this thesis:

Dynamic capabilities are higher-order organisational capabilities that help the firm alter its stock of resources into a new resource bundle, thus to demonstrate responsiveness to market change to improve chances for competitive advantage and long-term survival. Dynamic capabilities may thus give valuable guidance for strategy transformation efforts in response to digitalisation.

2.2.3 The link between dynamic capabilities and strategy

A firm needs to make choices between deepening its existing set of capabilities and broadening the capability stock (Pisano, 2017) as well as on the size of the investment on each of these dimensions (Dierickx and Cool, 1989). These choices aim for aligning a firm's strengths and weaknesses with exogenous threats and opportunities. In other words, these investments determine a firm's commitment to certain domains of competence and are central to executing its strategy. Dynamic capabilities play an integral part in the strategy transformation process as they help a firm alter its stock of resources into a new VRIN resource bundle. Their influence on firm strategy from a theoretical perspective is described in this section.

Dynamic capabilities can be discerned into the firm's "capacity to (1) sense and shape opportunities and threats, (2) seize opportunities, and (3) maintain competitiveness through enhancing, combining, protecting, and, when necessary, reconfiguring the business enterprise's intangible and tangible assets" (Teece, 2007, p.1319). Following this, dynamic capabilities comprise activities of three different types, i.e. those who absorb knowledge (sensing), those who connect knowledge with products and markets (seizing), and those who change the firm's resource base to align with its needs (reconfiguring). An overview on the relationship with firm performance is given in Figure 5.

First, "sensing" is concerned with activities such as scanning the market environment, searching for and exploring new opportunities. This includes following technological in-

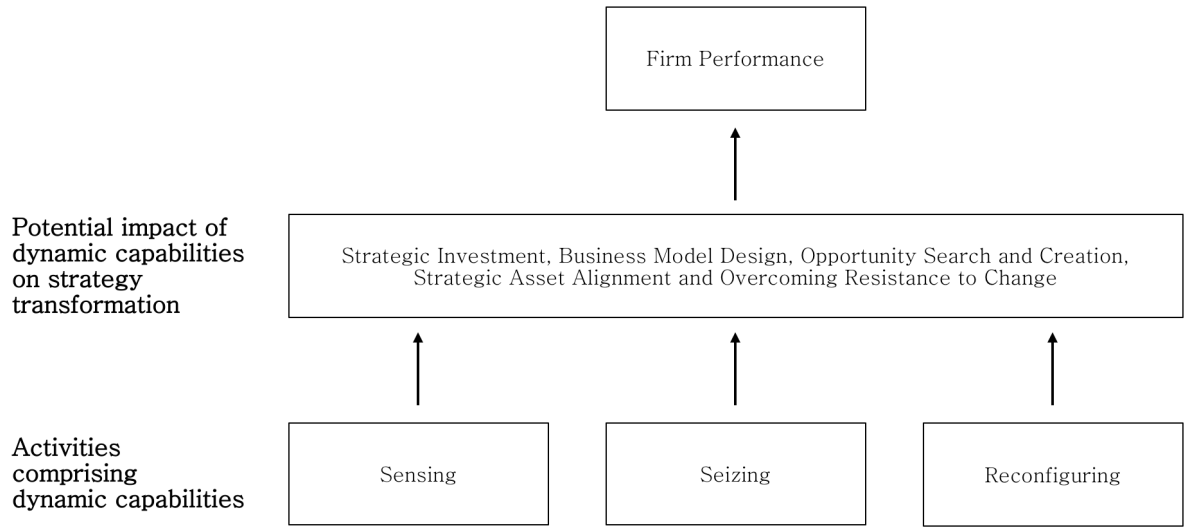

Figure 5: Dynamic capabilities in firm context, adapted from Helfat and Peteraf (2015)

novations, actively seeking customer feedback and collaborations, and a corporate environment embracing discussion and openness (O'Reilly and Tushman, 2008) to learn, sense, filter and shape opportunities (Teece, 2007). One practical example to sense new market opportunities is the lead user approach (Von Hippel, 1986). This apporach allows firms to learn about customers facing special needs before the marketplace encounters them.

Second, a firm must be able to respond to market opportunities and threats in a timely manner. "Seizing" describes preparing the organisation for decision-making, with respect to its structure, decision processes or incentives (Teece, 2007). This subsequently involves acting upon strategic insight (Harreld et al., 2007) and requires the capability to develop and assess different investment opportunities to eventually make strategic investments. One such seizing activity might be the comparison of several business model designs (e.g. compare different ways to gain revenue), as it is build on an underlying logic whose predicted outcomes can be compared (Zott and Amit, 2007).

Third, reconfiguring is understood as the continuous renewal of the organisation by aligning and realigning the organisation's existing set of assets. This is implemented by activities promoting knowledge management, corporate governance or strategic fit (Teece, 2007). Typical examples include continuous incentive alignment, e.g. by producing contracts that motivate people to work for common goals and thus produce the desired results (Gottschalg and Zollo, 2007), or the establishment of learning and knowledge sharing mechanisms (Nonaka and Takeuchi, 1995), for example, by setting up regular project team meetings to ensure information is shared.

One example how sensing, seizing, and reconfiguring can operate in practice is Amazon's launch of the Kindle e-book. This exemplifies how their innovation capability is employed. The Kindle marked the entry in a new product category and a new way of book content delivery, thus indicating a strategy transformation as new resources were necessary to accomplish this. Sensing the threat to its core-business of selling books, Amazon quickly developed a first market offering before gradually orchestrating its resources towards making the Kindle an integral part of its customer offering. This example suggests a close link between dynamic capabilities and strategy transformation: Strategy deals with "the long-term goals and objectives of an enterprise", and with "the adoption of courses of action and the allocation of resources necessary for carrying out these goals" (Chandler, 1962, p.13). Strategy thus involves the identification of environmental opportunities and threats, the interpretation of relevant information as well as the evaluation of organisational capabilities and constraints to consequently establish a change in the "pattern in a stream of decisions" (Mintzberg, 1978, p.935). In other words, dynamic capabilities are an "instrument of strategic analysis" and therefore "key factors in optimizing the strategic course of the company's future" as they support managerial decision-making on where and how to invest scarce resources (Vivas López, 2005, p.668).

2.2.4 The link between strategy and competitive advantage

Strategy transformation is the firm's attempt to increase its market orientation. This is supported by dynamic capabilities. However, academic literature has not yet found consensus whether dynamic capabilities induce competitive advantage. Competitive advantage is understood as the firm's ability "to create more economic value than the marginal (breakeven) competitor in its product market" (Peteraf and Barney, 2003, p.314), i.e. a relative indicator about the firm's economic rent in comparison with other market players (Brandenburger and Stuart, 1996; Ghemawat, 1991).

Two major schools of thought have evolved around Teece et al. (1997) and Eisenhardt and Martin (2000) that disagree on whether dynamic capabilities lead to competitive advantage (Peteraf et al., 2013). As a result of disagreement among academic researchers, in this thesis we follow Helfat et al. (2007) who argue that the effect of dynamic capabilities depends on how dynamic capabilities change the firm's resource base. Dynamic capabilities aim to change the firm's set of resources to achieve optimal fit with the environment. However, this change need not necessarily result in a modified set of resources that meets the VRIN criterion (Barney, 1991). The renewal may even have a negative effect on the firm's competitive position as it could also result in competitive parity or even competitive disadvantages, depending on the assessment of the modified set of resources.

This is in line with other scholars who argue that dynamic capabilities are indirectly linked

with organisational performance. For example, Zott (2003) and Bowman and Ambrosini (2003) claim dynamic capabilities induce changes in the set of organisational resources which in turn influences performance. As a consequence, "their development does not ensure organizational success" (Zahra et al., 2006, p.927). It is obvious that a firm that possesses VRIN resources now will not be able to sustain a competitive advantage once the environment exhibits any significant change. The resources might no longer fulfil the VRIN criterion. At worst, resources that are not updated following a significant environmental shift might even present the firm with core rigidities that hinder its development (Leonard-Barton, 1992). In the context of mechanical engineering firms and digitalisation, these inappropriate sets of knowledge may be knowledge on material properties that might become irrelevant or knowledge on project management methods that are no longer appropriate. Therefore, we conclude that dynamic capabilities can lead to competitive advantage if they support the strategy transformation towards investments in capabilities that finally become a new set of VRIN resources.

2.3 Research gap

The implications of technological change are well-understood in research as empirical evidence shows that incumbent firms often struggle to adapt (Christensen, 2013; Tushman and Anderson, 1986). However, digitalisation is not only a technological change but also a social-induced phenomenon, presenting firms with an even bigger challenge. Nevertheless, very few researchers distinguish between the essentially different concepts of *digitisation*, *digitalisation* and *digital transformation* which indicates that academics have not fully been able to disentangle the complex nature of this phenomenon.

Like any other change, digitalisation requires a reassessment of the fit between a firm's capabilities and resources and the market. In light of digitalisation, firms may be demanded to reconfigure their resource base by acquiring or developing entirely new sets of capabilities and resources. This reconfiguration process indicates a redirection of capability investments and thus a strategy transformation. This aims to maintain existing and build-up new competitive advantages. Practitioners are encouraged to respond to the need of strategy transformation, for example, by building dynamic capabilities (Eisenhardt and Martin, 2000; Teece et al., 1997). Dynamic capabilities support the modification of an organisation's resource base.

Following the argumentation above, it is well-known that the concepts of strategy, competitive advantage and dynamic capabilities are closely interlinked. However, academic studies have, so far, not investigated their interrelations in the context of digitalisation. In particular, not enough research has accumulated on the effects of digitalisation on firm strategy. Furthermore, while existing academic work has contributed to a fruitful debate

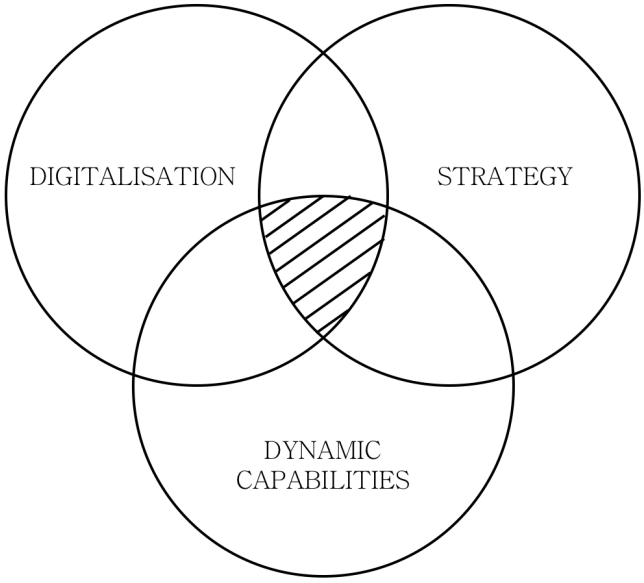

Figure 6: Research gap

about the concept of dynamic capabilities, empirical studies tend to be relatively vague and intangible (Danneels, 2008), and as such, provide limited insights for managerial practice.

To reduce the outlined research gap visualised in Figure 6, it is required to develop a coherent understanding of digitalisation first and subsequently, analyse how firms change their strategy in response. This is addressed by research question one (How does digitalisation affect firm strategy?). Building on this, research question three analyses the effects of strategy transformation on firms' competitive advantage in response to digitalisation (How does strategy transformation in response to digitalisation contribute to competitive advantage?). As a secondary purpose, we follow Ambrosini and Bowman (2009, p.46) who call for "fine-grained case studies" to understand "the subtlety of resource creation and regeneration processes" and aim to shed light on the role of dynamic capabilities in firms' strategy transformation processes in response to digitalisation. This is addressed by research question two (How do dynamic capabilities help firms respond to digitalisation in strategy transformation?) and might increase the dynamic capabilities' level of tangibility as suggested by Kraatz and Zajac (2001).

3 Methodology

In this section, the methodological choices for approaching the research questions are motivated. Furthermore, the characteristics of mechanical engineering firms from the German Mittelstand are presented as a particular unit of analysis. The section finishes with a discussion on how the study design affects the quality of the results.

3.1 Methodological fit

High quality research in the field of management is characterised by internally consistent choices of the elements comprising the research project (Edmondson and McManus, 2007). Following this, it is critical that the research design fits the research question to make a relevant contribution to existing work (Saunders et al., 2009; Edmondson and McManus, 2007). Consequently, it is relevant to consider that existing research on the link between digitalisation, strategy and dynamic capabilities is immature. In particular, as the dynamic capabilities view has yet mostly delivered insights on a conceptual level, a more detailed understanding of the relatively unexplored patterns below the surface is vital.

This thesis intends *to explore and explicate the influence of digitalisation on firm strategy and in this context, uncover and shed some light on the role of dynamic capabilities in strategy transformation involving digitalisation.* This thesis therefore has an exploratory purpose. Consequently, we do not intend to test existing theoretical constructs but instead develop them further. This is in line with Weber's *"verstehen"* rather than *"erklären"*. Other than that, the dynamic capabilities view per definition requires researchers to study organisations from the inside to understand their paths, routines and processes. As discussed in the theoretical background, the phenomenon of digitalisation causes various changes in the competitive landscape and forces organisations to respond appropriately. This involves various economic actors and their interrelations both within and between organisations which makes qualitative research particularly relevant (Flick, 2014). In light of dynamic capabilities research, this asks for deeper knowledge on "what processes are involved, the role of management, the reconfiguration of the dynamic capabilities, and the interaction with the environment" (Easterby-Smith et al., 2009, p.6). We opted for a qualitative study for two reasons: First, it provides a more holistic understanding of the phenomena when initially open-ended data collection is interpreted (Bryman and Bell, 2015; Gummesson, 2000) and when a contemporary phenomenon is investigated (Yin, 2009). Thus, we gain a more nuanced understanding of the *why* and *how* as opposed to the *what*. Second, a qualitative study helps to uncover potential unknown-unknowns (Mullins, 2007) that we may not be aware of. In the following, the reasoning underlying our choices in this research project is described on the basis of Saunders et al. (2009).

Research philosophy

The research philosophy determines the trajectory for the research project as it affects acceptable ways of data collection, analysis and usage to make a relevant contribution (Saunders et al., 2009). In other words, it provides the frame for this research project. Each of the following research stages is based on assumptions about the sources and the nature of knowledge. This thesis is rooted in an epistemological aspect of realism and an ontological aspect of interpretivism, which is why observations and conclusions depend on the researcher. This is because we aim to understand organisational activities, which are necessarily embedded in a social context. Thus, we regard an interpretative and phenomenological viewpoint the most suitable to make sense of the complex business environment. The decision is further based on two reasons: First, little practical insight on the relation between digitalisation, strategy and dynamic capabilities is available, which makes understanding their interrelation critical. The interpretivism and realism philosophies enable us to analyse the totality of the situation (Rush, 2014) to get a more nuanced and comprehensive picture of the digitalisation phenomenon in practice and the dynamic capabilities driving strategy transformation. Second, as this choice guides the further design of the research project, the interpretivist stance encourages to investigate a number of cases in detail instead of claiming to generalise results that can be applied in different settings (Flick, 2014; Eisenhardt, 1989).

Research approach

This thesis' research approach is motivated by continuous juxtaposition. In other words, we go "back and forth" between the results from the *how* and *why* type inquiry and the sensitising concept. This approach deepened our understanding of both the findings and the theory in a productive manner (Dubois and Gadde, 2002). Following this, an abductive research approach was chosen due to the interpretivist and realist philosophies of this research project and the lack of a sufficient theoretical framework. Consequently, little existing theoretical knowledge on dynamic capabilities and digitalisation was collected from literature but further explored and developed through empirical findings. Therefore, we do neither aim to test existing nor provide new theory to the research field (Ketokivi and Choi, 2014) but instead enrich existing theoretical views.

Research strategy

This thesis follows a multiple case study analysis. As a form of empirical inquiry, a case study "investigates a contemporary phenomenon within its real-life context" (Yin, 2009, p.23). Therefore, it is particularly preferred over other research methods when the boundaries between an underlying mechanism and the context cannot be clearly determined as it is the case for the digitalisation phenomenon due to the lack of conceptual clarity, as discussed earlier. Moreover, this method allows us to capture what Hodkinson

and Hodkinson (2001, p.3) call "lived reality". Therefore, compared to other research methods, case studies are likely to obtain more detailed results. We thus follow Ambrosini and Bowman (2009, p.46) who claim "what we need are fine-grained case studies" to understand "the subtlety of resource creation and regeneration processes". What is more, we aim to overcome some of the problems such that "the notion of dynamic capabilities is abstract and intractable" (Danneels, 2008, p.536). In this thesis, multiple case studies are conducted to allow for data comparison and juxtaposition. In particular, we aim for analysing the commonalities across firms. This provides a more comprehensive and valid picture of the research phenomenon at hand (Yin, 2009; Corbin and Strauss, 2008). Thus, as it is more the overarching common features across firms that account for the main body of analysis, the research design can be considered a cross-sectional design (Bryman and Bell, 2015), drawing on multiple case investigations at a single point in time.

Research choice

The approach in this thesis is further a multi-method research design (Yin, 2009). Therefore, multiple data collection techniques and sources are employed to create a more accurate representation of the phenomenon at hand (Gerring, 2004) and to mitigate the lack of objectivity following this thesis' ontological philosophy of interpretivism. In particular, the method is divided into three phases: (1) pre-study with exploratory literature review and validation through industry expert interviews, (2) collection of "real-world" empirical data in a main study, (3) triangulation of data through additional information sources and interpretative guidance through expert interviews in a post study. This three-step research approach qualifies this thesis as a multi-method study (Tashakkori and Creswell, 2007).

Various forms of triangulation are reflected in the research choices to reduce our own biases and validate the findings. Triangulation broadly describes "the combination of methodologies in the study of the same phenomenon" (Denzin, 1970, p.291) and is employed to increase the accuracy of the research results. Four types of triangulation - investigator, data, theory and methodological - are applied in our research (Flick, 2011; Denzin, 1970). Firstly, as the study was conducted by two researchers (e.g. interviews were always conducted in pairs), investigator triangulation allowed to balance individual subjective bias. Secondly, with respect to time, space and people different data sources were used, thus enabling data triangulation (Flick, 2014). The mix of various sources of primary and secondary data mitigated the risk of informant bias (Flick, 2011). As a result, construct validity is increased (Gibbert et al., 2008; Jick, 1979). Thirdly, the phenomenon under investigation was approached discussing and synthesising different theoretical views within the dynamic capability view. This is known as theory triangulation. Finally, methodological triangulation was employed by continuously reassessing the interview guide and

sensitising concept through the juxtaposition of theory and empirical findings to increase the validity of the field research (Flick, 2011).

An overview of the research process is given in Figure 7.

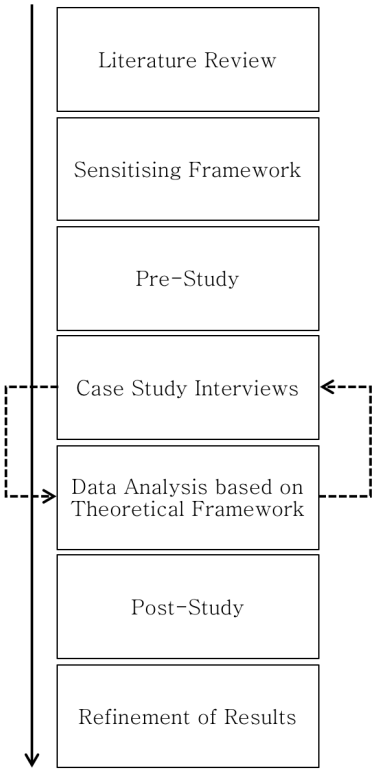

Figure 7: Overview of the research process

3.2 Data Collection

The data collection in this thesis was divided into three studies (Figure 8).

Study 1's overarching purpose is to lay the foundation for the subsequent main study. It primarily consists of a thorough literature review to establish an understanding of the concepts discussed (i.e. digitalisation, strategy, dynamic capabilities, German Mittelstand) based on secondary, qualitative data. To get an understanding about most influential publications, libraries and data bases were used and articles were evaluated on the basis of citations (Creswell and Zhang, 2009) and their relevance in literature reviews (e.g. Dosi et al., 2008). The literature review resulted in the deduction of the research gap. Both the understanding of the outlined concepts and the existence of the research gap in practice were validated with three industry expert interviews following the literature review. Afterwards, a research outline was developed based on the information gathered. In a subsequent step, three other industry experts were employed to first, guide us in the

identification of a set of potential case study firms for study 2 and second, to verify the interview guide for the main-study in a follow-up discussion. This first study thus laid the foundation for the subsequent field work.

Study 2 consists mainly of the actual field work and pursues the purpose to gather "real-world" empirical data. We performed semi-structured interviews with executive level employees of the case study companies. Due to time, financial and geographical constraints, the majority of the interviews was conducted via telephone. Telephone interviews are regarded advantageous with respect to logistics and greater scheduling flexibility (Cachia and Millward, 2011; Musselwhite et al., 2007; Sturges and Hanrahan, 2004) as most of the executives face tough time constraints. Even though there is little research on the effects of telephone interviews in qualitative studies, some findings indicate they are a versatile data collection tool (Carr and Worth (2001), p. 521) that delivers rich, detailed, and high quality data (Sturges and Hanrahan, 2004; Chapple, 1999). Nevertheless, we are aware of the challenges arising around telephone interviews such as the increased difficulties to recognise visual cues which may deter disclosure of sensitive information and may make responding to interviewee's body language more complicated (Groves, 1990). Furthermore, trust building between the parties demands greater effort, interviewers run the risk of losing contextual data, and responses might be misinterpreted (Novick, 2008). Moreover, during telephone interviews participants might get distracted by activities in their environment (McCoyd and Kerson, 2006). However, distractions were also proclaimed during face-to-face interviews (Sturges and Hanrahan, 2004).

We tried to mitigate these risks by sending guiding questions in advance to enable interviewees' to prepare, by presenting ourselves and by engaging in small talk before the start of the interview. We also followed Burke and Miller's (2001) suggestion and used a script for introducing the study prior to the interview. Additionally, we guaranteed anonymisation of responses to increase trust. Furthermore, to mitigate misinterpretation of results, we were both present at all interviews and also analysed the responses together. Since some scholars indicate there is no clearly preferred way of conducting interviews when comparing telephone versus face-to-face interviews (Novick, 2008), we opted for a mix of interview types and thus also conducted some of the interviews face-to-face. Based on the collected experiences of conducting interviews, after each, the interview guide was refined to tailor the investigation to the interviewee respectively. What is more, to ensure that respondents felt comfortable throughout the interviews, they were conducted in respondents' mother tongue, German.

Study 3 pursues a twofold purpose: (1) to reduce the risk of bias through triangulation of the qualitative, primary data gathered in study 2 and (2) to seek interpretative guidance

to allow for a richer evaluation of the results. To complement the data of the main study, interviewees answered follow-up questions via e-mail or in short phone calls. Other than that, publicly available company reports and websites were analysed. In a subsequent step, the cross-checked results were discussed in four industry expert interviews allowing for better sense-making in the interpretation of the data.

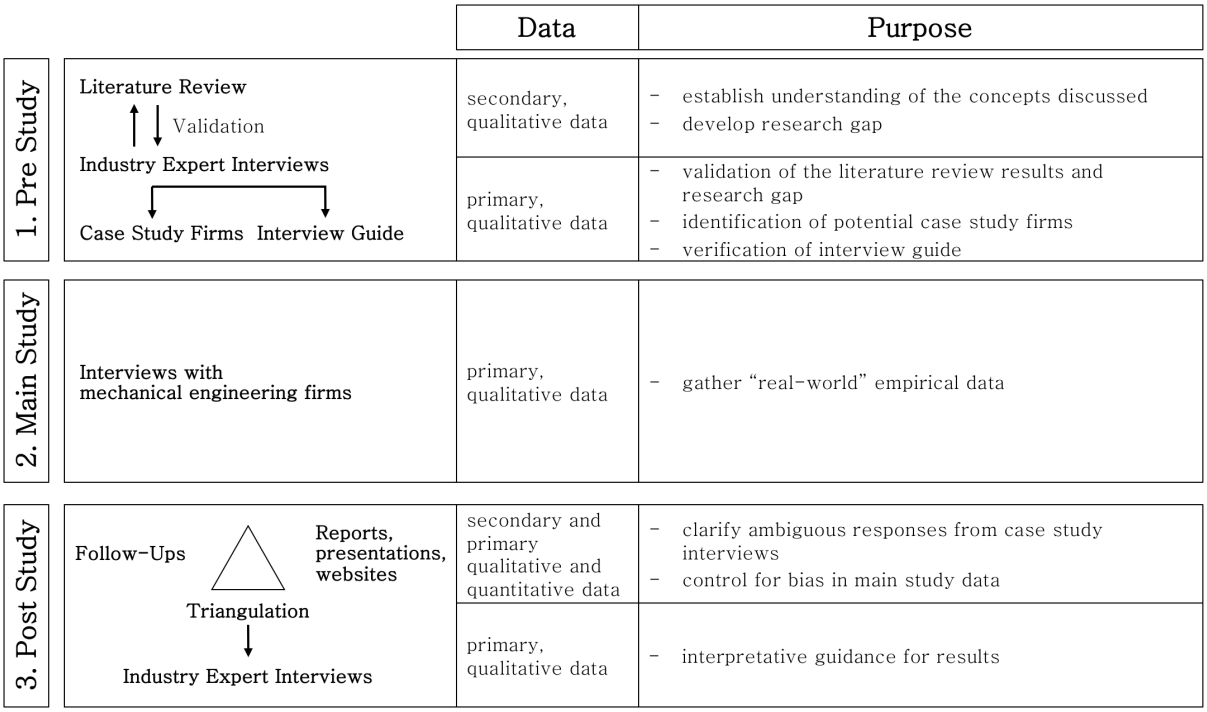

Figure 8: Overview on the studies conducted

3.3 Unit of analysis

To explore the research questions presented in section 1.2, we delimit this thesis to a narrowly defined unit of analysis. The careful examination of a group of peers allows for better comparison between different case companies as those operate under alike conditions (e.g. comparability in business models, external influences, competitive situation, nature of the products, etc.) and thus are likely to be comparably affected by digitalisation. Even though this exploratory, qualitative study does not aim to establish causality, investigation of alike firms allows to obtain better identification of patterns and thus more in-depth results for the phenomena under investigation. Thus, we exemplary investigate B2B mechanical engineering firms from the German Mittelstand as those are a relatively coherent group in terms of size, industry, corporate culture and national origin. The following paragraphs present our understanding of the German Mittelstand (in particular, mechanical engineering firms) and its exposure to technological change. We thus provide rich information for the reader to be able to transfer findings to his own context.

3.3.1 Characteristics of the German Mittelstand

The term *German Mittelstand* describes a subset of German mid-sized firms that are internationally renowned for their close customer relationships, a high product quality and their innovation orientation (De Massis et al., 2018). Nevertheless, its misleading application in both public press and research has led to some confusion about its meaning (Damken, 2007; Khadjavi, 2005; Hamer, 1990).

Therefore, this thesis regards a Mittelstand firm as a company,

1. where one person or family simultaneously owns and manages the firm; and
2. that makes an annual revenue between 100 million and 3.5 billion EUR.

This view uses both quantitative and qualitative criteria and thus follows propositions by the Mittelstand Institute at the University of Bamberg (Becker et al., 2008) and prior research (Berghoff, 2006). The point is that the nature of Mittelstand firms cannot be captured by solely quantitative criteria (e.g. number of employees or annual revenue) as Mittelstand also refers to a way of firm orientation and spirit that requires a qualitative dimension.

De Massis et al. (2018) identify six traits that account for German Mittelstand firms' strengths to outcompete other (often larger) firms in the market and that should serve as the basis for further analysis. These characteristics are (1) niche focus and customer collaboration; (2) globalisation strategy; (3) preference for self-financing; (4) long-run mindset; (5) superior employee relations; (6) community embeddedness. Other characteristics that make Mittelstand organizations distinct from other types of organizations are such firms' distinct guiding values, continuity, conservative forecasting, and mutual respect. The Mittelstand spirit has its foundation in the combination of ownership and control of the firm over the course of several generations (Decker and Günther, 2017), idiosyncratic resources that originate from a culture of "familiness" (Habbershon and Williams, 1999) as well as close ties between the family owners and their firm (Berrone et al., 2012), and strong management devotion with quality orientation. Subsequently, value in Mittelstand firms is created collaboratively with a managerial mindset on mutual interests for all parties, including suppliers and customers to sustain long-term relationships built on trust and reliability (Lehrer and Schmid, 2015). The above-mentioned characteristics allow to place the collected data in a context when interpreting the results.

3.3.2 Mechanical engineering firms in times of technological change

Mechanical engineering firms produce machines which make semi-finished goods or ready-to-sell products. These machines are sold to business customers which are positioned at

intermediate links of a value-adding chain. Due to frequent technological innovation and high quality standards, most firms from the export-oriented German mechanical engineering industry benefit from an advantageous competitive position internationally (VDMA, 2017). Traditionally, the vast majority of German mechanical engineering firms is considered part of the Mittelstand. These firms were always subject to changes as technological advancements altered the way products were manufactured. For example, over the course of three industrial revolutions, mechanical engineering has undergone significant advancements. Each, the introduction of water- and steam-powered mechanical production systems, the mass production enabled by electrical energy as well as the invention of programmable logic control systems, changed the way factories were operating (Wee et al., 2015; Botthof and Hartmann, 2015; Kagermann et al., 2013). Given the technological and societal advancements through digitalisation, the industry is currently at another important crossroad that could once again change the way manufacturers operate.

The critical question that remains to be answered is first, *how* firms from the German Mittelstand adjust their strategy to encounter and seize the technological upheaval and second, which role dynamic capabilities play to renew, integrate and reconfigure their stock of resource in this process. The distinct characteristics of Mittelstand firms may influence how such firms deal with times of increasing change.

3.4 Interview sample

Purposive sampling methods was employed for data collection which allows to focus on a particular phenomenon for the population of interest. This sampling technique was chosen for practicality reasons as it it allowed to reach the targeted sample relatively quickly. This was necessary due to the short time frame of this thesis. However, due to a lack of randomness, it may be exposed to selection bias. This was tried to mitigate in study 3 by data triangulation from both secondary sources and independent industry experts. In line with Bryman and Bell (2015), data collection and sampling primarily consists of a two-stage process. This relates to the research setting (in this case, the choice of the company) and to the choice of respondents (here, the respective interviewee's position in the organisational hierarchy). Firstly, by studying companies from one specific industry a relatively homogeneous sample is drawn to control for industry context, resulting in higher comparability across cases. Secondly, the phenomena and concepts under investigation are related to a firm's strategy for which top management is responsible. Those have the best overview in breadth about strategy and firm activities. Since these are considered primary knowledge carriers, retrospective sense-making is avoided (Mezger, 2014). Therefore, the chosen interview partners are members of this employee group.

In a first step, we consulted six leading industry experts who work at the intersection

of digitalisation and mechanical engineering and conducted unstructured interviews to select relevant case studies. By contacting industry experts, we got external insights on the industry and its respective players. This helped to determine a subset of potential case study partners (Rouse and Daellenbach, 1999). According to the industry experts, the firms on the list exhibited a certain degree of organisational response to digitalisation. No previous relationships existed to the potential case study objects. 64 firms were approached via the central contact e-mail addresses in February 2018, but no positive responses were granted in the first attempt. Subsequently, we directly reached out to each mechanical engineering firm's CEO office. Following this, we were able to schedule 15 interviews of which 11 were part of the main study. In a final step, we conducted four semi-structured interviewees, two with industry experts that worked in the industry for more than ten years and two with CEOs of mechanical engineering firms to validate our findings. A full list of the case companies is provided in Table 3. The respective interviewees are presented in appendix B. In total, 13 interviews were conducted via telephone, seven were conducted in person, and one was conducted via Skype.

3.5 Interview design

Semi-structured interviews were conducted for data collection. This approach is based on an open-ended question format which facilitates a conversation between the interviewer and the interviewee. It is thus known as responsive interviewing (Rubin and Rubin, 2011). Semi-structured interviews are suitable to retrieve richer information compared to a fully structured questioning setting (e.g. a questionnaire) as they aim to lead to a collaborative conversation enabled by trust-building between the interview's parties (Ryan and Dundon, 2008). In line with Scheele and Groeben (1988) this research method allows to explore an interviewee's body of knowledge - his *subjective theory* - about a particular topic. Thereby, the flexibility of the interview format allows the respondent to elaborate on his experiences and assumptions which influence the information shared. Through the interaction between the researcher and the respondent, new knowledge can be created (Ponterotto, 2005). This suits the explorative nature of this thesis.

An interview guide was used to direct the discussion while simultaneously leaving room to spontaneously react to interviewee's responses which were of particular interest (Rubin and Rubin, 2011). This allowed to obtain a more complete image of the interviewee's perspective. The flexible application of the interview guide enabled us to tap into certain areas of interest and thus to deepen our understanding of the interviewee's knowledge.

The interview guide was developed to find answers to the three research questions and in line with the sensitising concept. The first part of the interview guide concerns whether and how digitalisation affects firm strategy (RQ1) and subsequently, whether and how

Table 3: Overview on case study firms

Firm	Industry	Revenue (mEUR)	Number of employees	Exemplary digitalisation project
Alpha KG	Textile	740	8,800	Web shop predictive analytics
Beta GmbH	Plant manufacturing	450	2,200	Automated spare parts service
Gamma GmbH & Co. KG	Packaging	950	5,200	Data-driven services
Delta AG	Industrial image processing	143	650	Plug & Automate
Epsilon GmbH	Automotive	1,975	11,500	Interconnected sensors & VR service
Zeta AG	Pumps & valves	2,100	16,000	End-to-end e-sales process
Eta GmbH & Co. KG	Intralogistics	775	4,200	Launch of two digital labs
Theta KG	Glas & construction material	220	1,500	Manufacturer independent platform server
Iota SE	Plant manufacturing	2,200	11,500	Platform for centralised machine control
Kappa AG	Cleaning technologies	2,330	12,300	Cloud architecture
Lambda GmbH	Steelworks	3,050	13,900	Platform for standardised machine performance data
Mu GmbH	Surface mount technology	460	850	IIoT platform
Ny GmbH & Co. KG	Plant manufacturing	732	2,640	Software-based machine surveillance

strategy transformation in response to digitalisation contributes to competitive advantage (RQ3). What is more, a profound literature review of empirical dynamic capability studies was carried out as a basis to understand the impact of dynamic capabilities on strategy transformation in the digitalisation context. This information was analysed with respect to its relevance in the context of this thesis. The mechanical engineering industry is considered among the five most innovative industries in Germany (VDMA, 2017). Consequently, innovation is a particularly critical corporate activity to ensure future growth and firm survival. We follow the view that dynamic capabilities cannot simply be measured and can hardly be observed. This is in line with other researchers (e.g. Drnevich and Kriauciunas, 2011; Lavie, 2006). For this reason, dynamic capabilities need to be analysed by understanding a firm's processes and routines which manifest in its underlying skills and activities (Eisenhardt and Martin, 2000). Following this, the third part of the interview guide was designed to explore new product development and opportunity search processes in the context of digitalisation as examples of dynamic capabilities (RQ2).

For each interview the guide was individually adapted to better fit the respondent's background, function and the respective case company aiming to improve the quality of information obtained. The interview guide is presented in appendix C.

3.6 Quality of Study

In contrast to quantitative research with its well-established assessment methods (validity, reliability, replicability etc.), there has yet no consensus been found how to most suitably evaluate qualitative research (Flick, 2014). Some researchers argue that the assessment methods from quantitative research can be equally applied to quantitative research (Yin, 2017); others do not consider those at all (Stake, 1995). For our thesis we apply the assessment criterion *trustworthiness* (Lincoln and Guba, 1985) to evaluate the quality of our study. According to the researchers, trustworthiness can be divided into the following components: credibility, transferability, dependability, and confirmability. Each of the components is discussed below.

3.6.1 Credibility

Credibility concerns questions like "how believable are the findings?" and "how congruent are the findings with reality?". It parallels internal validity which is often applied in quantitative research. Credibility is considered the most important factor in conducting "trustworthy" case study research (Guba and Lincoln, 1989; Eisenhardt, 1989). Due to the lack of a universal criterion in assessing whether a theory is "good or not", a high level of credibility is needed to ensure that a theory is build on findings that are relevant and valid. Although this thesis does not aim to develop a new theory, the findings aim to deepen

and complement existing knowledge, making credibility an important quality measure. In particular, "triangulation" and "member-checking" have been used as methods to ensure credibility of our study. In addition, the interviews' respondents were asked to check the transcripts of the dialogues in which they participated for whether their words match what they actually intended to say. This is considered one of the most important provisions researchers can make to increase credibility (Guba and Lincoln, 1989).

3.6.2 Transferability

Transferability concerns the external validity of the conducted study and thus relates to the question whether it is possible to generalise the findings of a particular case to other contexts beyond its immediate setting (Merriam, 1998). By its very nature the findings in case study research are often very specific in its details and consequently researchers should not attempt to draw universally valid conclusions. Instead, academics should utilise the advantage of the in-depth analysis of the objects under investigation to learn more about their uniqueness. This is what Lee et al. (2007) understand by particularisation rather than generalisation. As such the cross-sectional comparison between the specific actions of each case company allows us to get a better qualitative understanding of the concepts and their relationship to each other. For practitioners in similar situations, we leave it to the reader's judgment whether the findings presented may be applicable to their own positions (Bassey, 1981). As researchers we aim to provide enough contextual information for allowing the reader to make such a transfer (Firestone, 1993; Guba and Lincoln, 1989).

3.6.3 Dependability

Dependability concerns the replicability of a study. That is whether similar results can be obtained given the study would be conducted again in the same context, with the same methods and participants (Shenton, 2004). The fast development of digitalisation leading to a continuously changing context for the objects under investigation hampers by its very nature the replicability of the study (Marshall and Rossman, 2014; Fidel, 1993). As such, our findings are tied to the situational context in which the study is performed and conclusions are "static and frozen in the 'ethnographic present'" (Florio-Ruane, 1986, p.9). Nevertheless, to ensure reliability at least in this very moment the process of the study is well documented in terms of (1) the research design and its documentation, (2) the operational detail of gathering data and (3) the reflective appraisal of the study allowing the reader to critically assess the execution of the research practices employed (Shenton, 2004). According to Flick (2014) and Kirk and Miller (1986) one key aspect determining reliability is the quality of recording and documenting data. All interviews were transcribed which allows to trace back the data origins thus enabling a clear distinction between the interviewee's statements and our interpretation even at a later stage.

3.6.4 Confirmability

Confirmability is understood as objectivity in the field of quantitative research. Confirmability concerns the question to what extent the investigator has allowed his values and beliefs to affect the research process and interpretation of the results. Despite objectivity is regarded an important quality measure, total objectivity can hardly be achieved as research is carried out by humans and is thus subject to human error. Thus, the intrusion of the researcher's biases is inevitable (Patton, 1990). Nevertheless, we installed several measures to ensure that the findings are based on the informant's experience and ideas and not subject to our own preferences. Firstly, triangulation as outlined before allowed us to getting exposed to different types of information and thus to reduce our biases. Secondly, we transparently present and justify our choices in the research design (section 3.1). Third, an audit trail (Shenton, 2004) allows to trace the course of our research step-by-step (Figure 7).

3.7 Data processing and analysis

After interview conduction, all interview recordings were transcribed within 24 hours. The qualitative data obtained was then coded to identify patterns such as recurring themes in the interviewees' answers. Following Glaser's (1978) concept of *theoretical coding*, in a first step - the so called *open coding* - first level concepts were attached to the transcribed data (Gioia et al., 2013).

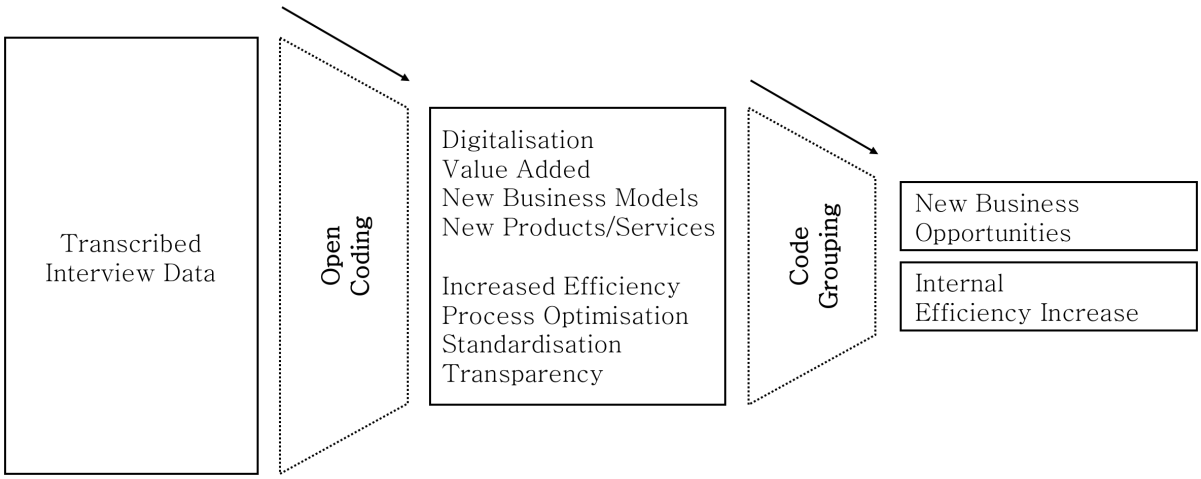

Figure 9: Exemplary coding process for "Digitalisation" with multiple filters

In a second step - the so called *pattern matching* (Trochim, 1989) - grouped data was then compared to and matched with the predefined concepts of digitalisation, strategy, dynamic capabilities and competitive advantage. Following Hood (2007), the sample size is defined by theoretical saturation among the four concepts in this thesis instead of seeking representativeness. Not all empirically based patterns overlapped with the

predicted concepts so that new *core categories* emerged (Strauss, 1987). The analysis also served as basis to identify gaps in the data which were addressed in follow-up interviews to get a more holistic picture of the interviewee's perspective. The combination of all data allowed to understand the characteristics of the four concepts in this specific research and industry context. An exemplary overview on the coding process is given in Figure 9.

4 Empirical findings and analysis

This section describes the synthesis of the empirical data. Figure 10 describes the analysis logic. This section is organised along the research questions presented in section 1.2. Section 4.2 relates to research questions 1 and 3. Section 4.3 relates to research question 2. Due to the firm- and respondent-specific proprietary data, quotations are presented in an anonymised format.

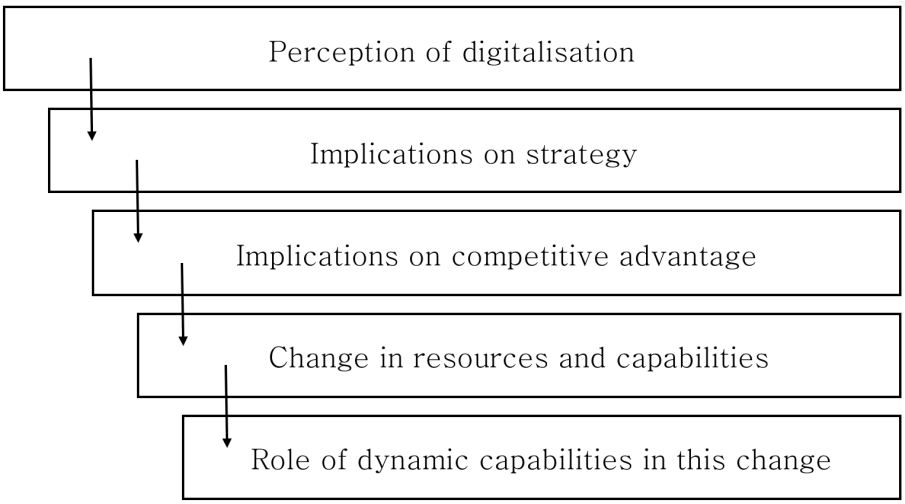

Figure 10: Structure of the underlying analysis logic

4.1 How does digitalisation affect the market environment?

4.1.1 Firms' previous market position

Formerly, German Mittelstand mechanical engineering firms have striven for quality leadership in niche markets. They have focused on a differentiation strategy build on close customer relationships and superior product quality. The study revealed firms' differentiation strategy has been supported by the following competencies:

1. *Deep customer and industry knowledge*: Through years of experience, companies are very familiar with their industry, their customers and technical feasibility.

2. *Quick strategy diffusion*: The medium size of companies allows for rapid diffusion of new strategies so that those can be implemented in a timely manner.

3. *Learning-on-the-job*: Learning-on-the-job has always had a high relevance to stay up-to-date with respect to technical competencies.

4. *Adaptive capacity*: Traditionally, the industry is subject to constant change resulting from technical advancements. Accordingly, due to industry turmoils from the past, many companies are experienced in transformation processes.

The summarised competencies have been derived from the interviewees statements and seem to be plausible when compared with publicly available secondary data. They serve as starting point for further presentation and interpretation of findings and allow comparison with future scenarios. To explore the effects of digitalisation on firm strategy and competitive advantage, we next present our findings on how the study participants perceive the phenomenon of digitalisation.

4.1.2 What is digitalisation?

The following presents a synthesised understanding of how digitalisation is perceived in practice. However, the notion of digitalisation differs across firms. Some follow just one of the two point of views presented below. We also find that practitioners, similar to academic researchers, do often not distinguish between the essentially different concepts of digitisation, digitalisation and digital transformation.

From an empirical stance, digitalisation is regarded as the use of information technology to solve complex challenges and thus to create added value. This is done in two ways:

1. Increase in operational efficiency along the entire value chain (e.g. higher speed of production, enhanced sustainability and increased output quality) through standardisation of processes and products, automation by reducing human interaction and thus optimising the entire production process. The increase in efficiency concerns both the internal machine production of the mechanical engineering firm and the use of its machines at the client's site;

2. Facilitation of new products, services and business models.

One typical example is the Head of Strategy at Zeta AG as he explains he has

"a two-fold understanding of digitalisation: On the one hand, digitalisation helps us improve and optimise processes, increase standardisation, doing things differently from the past. On the other hand, digitalisation is thinking in new dimensions, particularly towards new business models".

The basis of both manifestations is the creation of increased transparency through digital technologies (Figure 11). On the one hand, digital technologies facilitate increased data

collection. The IT-supported analysis and synthesis of data subsequently leads to knowledge gains. On the other hand, digital technologies enable the increased interlinkage of actors which leads to a better exchange of information. Both advantages can then be translated into the creation of the above presented added values. This is in line with our synthesised understanding of digitalisation in section 2.1.

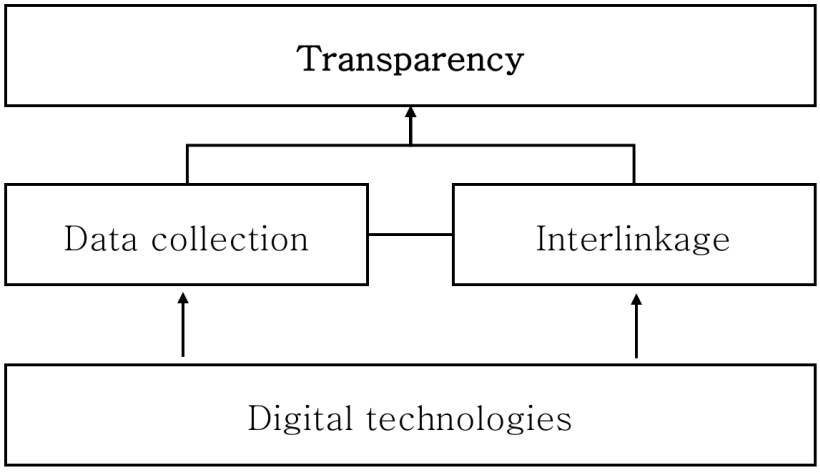

Figure 11: Transparency through digital technologies

Market changes independent of digitalisation
Digitalisation is only one phenomenon affecting the competitive landscape along with other factors (e.g. globalisation). As such, it is difficult to disentangle their effects individually and almost impossible to attribute changes to one particular phenomenon. Even though digitalisation offers chances for both increased value creation and operational efficiency, German Mittelstand mechanical engineering firms also face increased competition from Asian market players that benefit from much lower (labour) cost. The quality gap between these low cost market actors which typically offer standardised goods, and high quality German Mittelstand manufacturing firms has also narrowed in recent years. One reason for this is that German Mittelstand firms increasingly face technical boundaries. This fact adds to the complexity of the problem at hand.

To conclude, digitalisation is regarded the use of digital technologies that provide value beyond pure efficiency increases. The next three sections outline how digitalisation affects the competitive landscape with respect to industry structures, firm strategy and new business opportunities as outlined in section 2.

4.1.3 How does digitalisation affect industry structures?

Even though digitalisation seems associated with new opportunities, digitalisation also raises concerns regarding arising threats. Representative for the majority of firms, the

Head of Strategy of Zeta AG affirms

"if digitalisation creates too much transparency in the market, we are afraid of losing our competitive advantage. This is especially relevant for some of the more standardised goods offered through online market places."

The platform economy is a new opportunity brought by digitalisation that connects market actors and reduces transaction costs of business transactions. Thus, platform-based business models indicate that ownership in physical assets is no longer a strict necessity to be an industry player. Therefore, new platform-based business models are considered a critical threat for incumbents.

As stated in the interviews, two types of platform business models have evolved: On the one hand, digital market places where industrialised goods and services are exchanged; and on the other hand, Industrial Internet of Things (IIoT) platforms which capture and bring together smart sensor data from various machine systems to complement manufacturing execution systems by transforming these into smart, usable data. The latter enables optimised manufacturing management. In addition to being positioned at an intermediary position in the value chain, mechanical engineers are mainly concerned to be cut off from the direct contact with customers.

These developments are expected to increase competitive intensity as platforms can be set up by both new market entrants and direct competitors. The Director Digital Transformation at Eta GmbH & Co. KG explains:

Of course, digitalisation means that there are competitors out there today that we have not even thought about previously. Such companies have no idea about intra-logistics. They start with a clever platform idea and crowd the market. Of course, we have to be careful not to be overrun by these.

Despite digitalisation has made some physical products obsolete in other industries (e.g. CDs), "digital" substitutes seem unlikely in the near future. As the Head of Strategy at Zeta AG exemplifies:

"We are not likely to observe disruptive products as something always has to be transported physically. Pumps distribute pressure and that cannot be digitalised unless we invent to beam".

4.1.4 The effect of digitalisation on new business opportunities

In addition to a change in the industry structure, digitalisation also brings about new opportunities for value creation. Most of them represent new innovative product features

and service offerings that build on digital technologies. These new opportunities can be both adjacent to and distant from existing business. For example, one interviewee explained that his firm has now managed to sell existing products through a new online distribution channel.

The main opportunities from digitalisation seem to lie in new product features (e.g. smart sensors) and services (e.g. complementary offerings such as predictive maintenance). In this context, maintenance services can make a considerable and recurring contribution to firms' sales. As explained by the CEO of Lambda GmbH,

"offering services is an attractive additional business beyond the sale of a machine".

Moreover, business models and operational efficiency are not so much in the centre of attention due to the following reasons:

1. **Business models**:
   First, digitalisation does not only affect mechanical engineering firms but also their clients. A significant share of their customers seems not yet prepared for new data-driven business models due to privacy concerns.

   "Customers are concerned to lose control on confidential information, for example, regarding their production output quantity."
   (Vice President Technology at Delta AG)

   Second, new business models appear to only complement and not substitute the existing business model "goods in exchange for money". The Senior Inhouse Consultant at Iota SE raises the point

   "the current business model has high set-up cost in the range of two- to three-digit million investments for our clients. At the moment, only the big players can afford that".

   Third, implementation challenges such as which billing unit to use in pay-per-use models, which level of insurance to provide in the event of a production outage or how to cover high upfront investments in case of highly customised machines play a role.

2. **Increases in operational efficiency:**
   Internal efficiency gains are difficult to realise with highly customised products. German Mittelstand manufacturing engineering firms typically produce highly customised machines. Due to the low share of standardised goods, it is difficult to achieve economies of scale.

In response to this challenge, some firms adapt by introducing a sequential production process. This comprises of the production of standardised components in a first, and the composition into individualised solutions in a second step. The product can be further customised by booking desired features through software support. For Eta GmbH & Co. KG, the Director Digital Transformation explains the following principle:

"You buy a product "A" that guarantees to process a number of X packages in a given time; if you buy the product A with software B you can handle an increased processing volume of 20 percent. It's like Tesla: You buy a car and the equipment is unlocked via the subscription you have booked".

To conclude section 4.1, digitalisation brings about both threats and opportunities. On the one hand, digitalisation has the potential to change industry structures. One example are platform-based business models which likely decrease barriers for new market entrants as well as poses threats for intensified direct competition. The described changes in industry structures might shift the relevance of industry players leading to a possible redistribution of rents. On the other hand, digitalisation enables new business models, products, and services that increase value creation. In addition, digitalisation facilitates increased operational efficiency that lowers cost of production.

4.2 How do firms respond to digitalisation?

4.2.1 Implications on strategy

To counter the threats and seize the opportunities from digitalisation, firms respond with strategy transformation. However, most case study firms do not fundamentally change their strategic direction. They use the opportunities of digitalisation twofold: First, to strengthen their focus on differentiation. Second, as opposed to the past, to pay more attention to cost reduction. The Head of Corporate Strategy at Theta KG illustrates this matter that concerns the majority of mechanical engineering firms:

"We are still technology leader in all markets we operate in. However, we should also not forget about costs of production to remain competitive. But: We never intend to enter a price war".

Complementing differentiation with the aim to generate cost advantages at the same time indicates a shift towards a hybrid strategy. This change might be for two reasons:

1. Firms from the mechanical engineering industry are increasingly aware that they can no longer compete by the means of quality differentiation through longer product life and higher reliability only. Therefore, the Head of Strategy at Zeta AG mentions

"the quality term today must be extended, must be defined in new, more and different dimensions".

This is achieved by complementing the technical sophistication of their solutions (in the sense of hardware performance) with innovative product features and services based on digital technologies.

2. Digitalisation enables firms to increase operational efficiency through automated production and interlinkage of machines. These facilitate higher efficiency in the entire value chain. Therefore, firms can keep the cost gap to Asian manufacturers as narrow as possible. This ensures that products can be offered with a positive profit margin as customers are only willing to pay a limited price premium.

To summarise, it seems that digitalisation does not make mechanical engineering firms significantly change their strategic direction. Instead they smoothly transition towards a hybrid strategy, aiming to generate differentiation and cost improvements at the same time.

4.2.2 Implications on competitive advantage

The current competitive advantage is based on close customer relationships, superior product quality, and complementary services (see Figure 12). For example, the Vice President Technology Delta AG explains

"with our key accounts, we operate in close ties with the customer like nobody else in the market".

Strategy transformation towards a hybrid strategy can or cannot lead to competitive advantage. It depends on whether the change in the firm's existing resources and capabilities towards the new resource pool leaves the firm with VRIN resources and capabilities. In the context of digitalisation, we observe a two-fold effect:

First, digitalisation strengthens existing competitive advantages (i.e. differentiation through 1) closer customer relationships, 2) superior products, and 3) complementary services). Digital technologies complement firms' resources. The complementing enables firms to offer innovative product features which they were not able to offer before and which their competitors cannot build on. As such, the resources to develop these offerings can be considered VRIN. For example, this comprises special software development capabilities.

Second, digitalisation allows increases in internal efficiency. For example, automation increases production efficency and new project management methods decrease time-to-market. The reduced costs do not lead to competitive advantage but narrow the cost

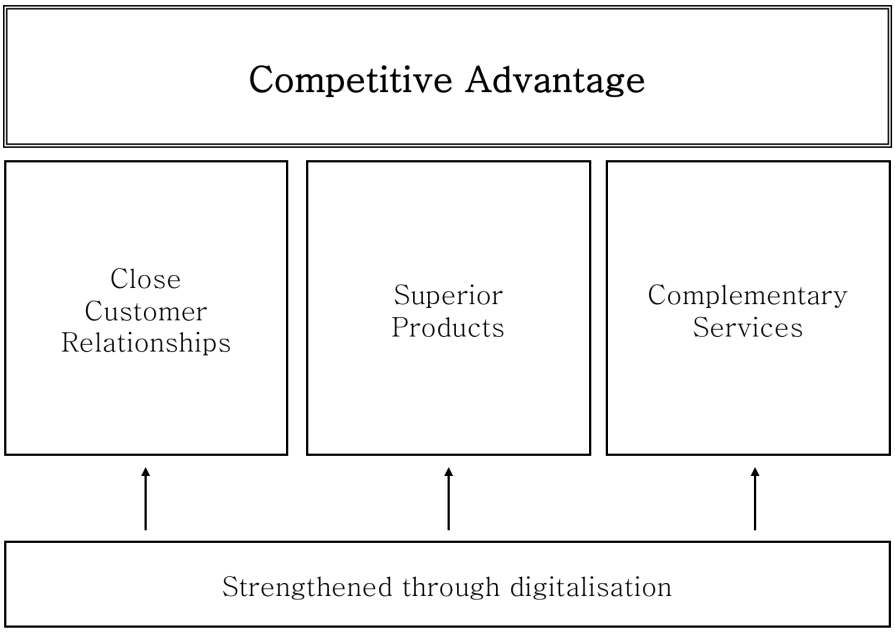

Figure 12: Differentiation strategy of case study firms

distance to low cost competitors from Asia that produce more standardised goods. As such, resources used to achieve greater efficiency are valuable and non-substitutable, but neither rare nor inimitable and as such point towards being best practice.

Digitalisation allows greater differentiation through two mechanisms:

1. *Higher degree of customisation:* The means of customisation do no longer solely lie in the adaptation of physical machinery. Industry players aim to break down production systems into standardised machinery modules which allow more modular solutions.

   "We now deliver an increasing share of standardised products. This allows us to both leverage synergies in production but also assemble the parts tailored to customers' specific needs",

   reports the Head of Corporate Strategy at Theta KG. What is more, a higher degree of customisation beyond the physical machinery park can be achieved on a software level. Consequently, machines are no longer shipped and installed to serve a single predefined purpose but are rather flexible for adaption to future requirements, e.g. through software updates, modular extensions, updated inter-linkages or re-designs.

2. *New features and services*: Digitalisation enables mechanical engineering firms to develop innovative products build on digital technologies as well as offer innovative services (e.g. predictive maintenance based on big data analysis being fed with

machine sensor data). These are new to the market and enable the firms to serve customers in a unique manner. Representative for the majority of firms, the Head of Digitalisation at Gamma GmbH & Co. KG explained:

"Nowadays, new technologies enable us to realise solutions we only dreamt of in times before digitalisation".

Customisation increases bonding as the client is increasingly dependent on the mechanical engineering firm. This is strengthened by offering bundles of goods and services tailored to the individual customer needs. This works through two mechanisms: First, by combining offerings through collaborations with other firms. Second, by complementing hardware with software offerings (e.g. a solution monitoring the entire machine park integrates machinery from different manufacturers). Thus, digitalisation allows mechanical engineering firms to tie customers more closely to their firm and shift from being a problem solver to becoming a solution provider. Integrated solutions lead to high switching costs and may create a vendor-lock-in effect. This vendor-lock-in effect results from financial investments in integrated solutions or from time investments (e.g. in the form of personal connections between the client and the mechanical engineering firms built up over time).

The monetary impact of differentiated offerings depends on the cost of good or service delivered. If this only comprises the digitisation of previously analogue functions, customers are not willing to spend more. Instead, clients expect these services. With respect to new functions that are enabled by digitalisation and add significant value, customers are willing to pay more.

To conclude, strategy transformation in response to digitalisation seems to induce enhanced competitive advantage. Achieving greater operational efficiency is one aim of the hybrid differentiation strategy but does not lead to competitive advantage compared to cost leaders in this case. However, it might prove beneficial compared to companies that have not implemented such best practice.

4.2.3 How do firms' capability configurations change?

Digitalisation requires a reassessment of the value of the firms' resources and capabilities as their value could change. In order to implement changes in their strategic direction firms indicate a redirection of capability investments. This refers to both existing as well as new resources and capabilities. On the one hand, case study firms expect to be able to build on the strengths they have build up through their long standing experience. They benefit from their deep customer and industry knowledge as well as their distinctive adaptive capacity to technological change which they have proven in the past. On the

other hand, they also belief that a new culture of increased customer centricity is inevitable to sustain their competitive advantage. For successfully transforming their organisations to this new self conception, firms balance the exploitation and development of existing with the exploration and building of new resources and capabilities. For example, the case study firms suggest the skills mentioned below will increase in importance. Thus, the existing resource base is likely to be rather upgraded and complemented instead of being completely replaced.

- *Methodological competences*: This comprises the development of new project management methods (e.g. SCRUM) and creativity techniques (e.g. design thinking).
- *"No blame" culture*: Involve the customer earlier and more intensively in new product development and creation of a culture characterised by constructive criticism.
- *Market sensitivity*: Closer observation and better anticipation of market changes - especially of disruptive threats.
- *Agility*: Increase speed to respond faster to market changes.
- *Employee motivation*: Encourage curiosity and drive of employees that support the creation and implementation of new ideas.
- *Entrepreneurial thinking*: Entrepreneurial mindset comprises combinatorial skills and cross-functional thinking beyond business functions (e.g. thinking "outside the box").
- *IT skills*: Greater necessity for employees with technological understanding and abilities for software development.
- *Collaboration*: The ability to build and pursue partnerships due to the increasing complexity of problems which makes it more and more difficult to develop solutions all alone.
- *Interdisciplinary working*: The frequently encountered matrix organisation supports working in interdisciplinary teams and across multiple locations.

Companies do not yet feel prepared to fully seize the opportunities and respond to the threats of digitalisation given their current set of resources and capabilities. This indicates a gap between the current capability configuration and the optimal capability configuration following digitalisation. The capability gap seems to relate to one particular area of capabilities and resources: human resources. Not only hard factor deficits like expert knowledge but also soft factor shortcomings like a lack of suitable corporate culture are concerned. This exemplifies the importance of realising cultural change. This was identified as biggest challenge in implementing digitalisation projects. Exemplary for most firms, the CMO at Alpha KG identified that

"digitalisation potential can only be seized if a firm has employees that reflect on opportunities from digitalisation. However, when generating new ideas based on digital technologies with "analogue" thinking employees you quickly face boundaries".

This suggests human resources are a major constraint to realise the potential of digitalisation. This not only relates to current operations but also when making decisions for new projects:

"In the current business environment, money is no limiting factor. We try to pursue all promising ideas. The only barrier we are facing are resource constraints in terms of human resources",

the Senior Inhouse Consultant at Iota SE reveals.

4.2.4 Attempts to close capability gaps

Mechanical engineering firms appear to have difficulties attracting the required human resources on strategic factor markets. Therefore, firms specifically employ three strategies to close gaps:

1. Firms buy knowledge from external partners. In the absence of previous knowledge, companies start to tap into new business areas and technologies by seeking support from external service providers like consultancies. This is pursued in the form of "qualifying collaborations". Over the long-term, companies prefer to build up their own competencies.

   "When approaching unfamiliar topics, in the short-term, we rely on external advisors. However, in the long-term we prefer to build up our own competences - especially if we draw on these competences more frequently",

   as explained by the Senior Inhouse Consultant at Iota SE.

2. Firms pursue partnerships with institutions or other market actors. Co-operations with universities and industrial education are intended to provide access to state-of-the-art research and to tie talents to the company at an early stage. In larger companies, the acquisition of new skills sometimes takes place through the acquisition of other companies. On the other hand, smaller companies try to compensate competence deficits through co-operations with partners. Furthermore, some companies have used open innovation to solve complex problems they could not solve alone and thus benefit from skills available in the crowd.

3. Firms develop their own human resources. Companies grant employees budget and time for advanced training, but it is mainly based on each employee's initiative as few institutionalised employee training programmes exist. Respondents report that the pursuit of new digitalisation initiatives takes place either externally in spin-off "Digital Labs" or internally in "Digital Business Units" where certain competencies specific to digitalisation are concentrated.

To conclude sections 4.2.3 and 4.2.4, mechanical engineering firms seem to face a capability gap through digitalisation. This primarily relates to human resources. Therefore, the firms' capability and resource pools need to be upgraded and complemented to cope with new demands. For example, this relates to existing capabilities such as project management or new capabilities such as software development. The latter can be used for both increased operational efficiency and development of new products as software is becoming increasingly part of both internal operations and the produced machines. Firms employ buy-, collaborate- and build-strategies to close these capability gaps. The updated and complemented resource pool is needed to effectively implement the strategy transformation towards a hybrid strategy.

4.3 How do dynamic capabilities help a firm respond to digitalisation by contributing to strategy transformation?

Dynamic capabilities build on activities firms perform and skills firms possess. They are thus inherent in a firm's routines and processes. When grouping the skills, activities and competencies that the study shows increase in importance to sustain competitive advantage in times of digitalisation, the following dynamic capabilities can be derived: *human resource management capability*, *learning capability*, *collaboration capability* and *business development capability*. This approach is necessary as dynamic capabilities cannot simply be measured and can hardly be observed.

Each dynamic capability compromises a number of activities of three different types, i.e. those who absorb knowledge, those who connect knowledge with products and markets, and those who change the firm's resource base to align with its needs (compare to Figure 5). Thus, they are closely linked with strategy transformation and in turn, with firm performance. Firms might possess more dynamic capabilities in general, but the results show these four dynamic capabilities are particularly relevant in the context of digitalisation (Table 4).

4.3.1 Human resource management capability

So far the findings indicate that the human resource pool of German Mittelstand mechanical engineering firms may have to change. Employees' hesitation to change and adherence

Table 4: Dynamic capabilities relevant in the context of digitalisation

New skills, competencies and resources	Dynamic capability
New methods, "no blame" culture, employee motivation, entrepreneurial thinking, IT skills	Human resource management capability
New methods, "no blame" culture, employee motivation	Learning capability
Collaboration	Collaboration capability
Market sensitivity	Business development capability

to established routines and processes can sometimes provide a hurdle and as such can develop into a core rigidity if this change is not carried out. Thus, twofold changes are considered necessary: First, on a skills level (i.e. new tools and IT skills). Second, on a mind-set level (i.e. ”no-blame” culture, entrepreneurial thinking, drive, curiosity). Therefore, this concerns existing and potential new human resources.

The experience and know-how of longstanding employees is valued but they might be stuck in routines and ways of thinking, further training of those will likely be required. The training of existing employees asks for a process of need identification (”sensing”), a selection process which employees to develop further (”seizing”) and the actual training of the selected (”reconfiguring”), probably through the introduction of institutionalised training programmes.

A new culture of increased customer centricity will probably demand new human resources as initiators coming from outside the organisations. Solely upgrading existing human resources will likely not be sufficient to meet the challenges of digitalisation. Therefore, firms need to attract new human resources to complement the existing human resource pool. To achieve this, the organisation has to be able to establish routines that identify what kind of new employees they require given the changed requirements for human resources (”sensing”), attract the targeted group of employees (”seizing”) and integrate new employees into the organisation as well as alter organisational structures (”reconfiguring”) to benefit from the combination of both the experience of longstanding employees and the drive and curiosity of new ones. These examples can be summarised as a firm’s *human resource management capability*, defined as the ability to upgrade and reconfigure its human resource pool.

4.3.2 Learning capability

Given the increasing speed and complexity in the market place, continuous learning has gained in relevance. Overall, mechanical engineering firms are asked to question their longstanding routines to be able to adapt to the new market needs brought by digitalisation.

The source of organisational learning can lie either outside or within organisations. In the center of learning is the human resource. Internally, firms draw on learning among colleagues through sharing experiences. Externally, firms learn from customers, competitors or other external players through observation and interaction. For example, the Head of Digitalisation at Gamma GmbH & Co. KG affirms:

"That's why we also exchange ideas with other companies that already started building a digital business a few years ago. In the end, it is the exchange of know-how and the exchange of experience. What technologies do others use? What drives others? What else can we learn from others? The topic of exchange, gaining experience and learning from others, is what this whole event is about."

One other example for external learning is involving customers at an early stage and learning from their needs. This ensures that product offerings are developed in line with market needs. This requires to recognise whether product offerings still meet customer needs ("sensing"), derive consequences that ensure this (e.g. new specification outline for products) ("seizing"), and put things into practice (e.g. through making adjusted products) ("reconfiguring").

One example for internal learning is joint problem solving. This involves a consistent pattern from defining a problem and locating its root cause ("sensing"), developing action alternatives ("seizing") and implementing the chosen solution ("reconfiguring"). In light of digitalisation, greater complexity makes the identification of experts that hold specific and rare knowledge even more relevant. Making their tacit knowledge explicit and using that knowledge for improvements in a system (e.g. production methods) supports the organisation in moving forward.

Organisational learning must be complemented by a culture of constructive criticism which emphasises learning from mistakes. This complements employees' openness to new opportunities, willingness to learn and to develop themselves. The examples can be summarised as a firm's *learning capability*, defined as the ability to upgrade and reconfigure its knowledge generation mechanisms.

4.3.3 Collaboration capability

Digitalisation has led to changed demand for mechanical engineering firms. On the one hand, they have to solve problems that become increasingly complex and that can seldomly be developed all alone. On the other hand, customers expect to purchase integrated solutions instead of independent goods. Both require mechanical engineers to operate beyond their core competencies. However, to maintain their deep expertise in some areas, they are likely to collaborate with partners to serve their customer to a high degree of satisfaction. Partners can be various players both within the traditional value chain and beyond. One example is the collaboration between five mechanical engineering firms and the software company Software AG to jointly develop the IIoT platform Adamos. The ability to identify potential partners ("sensing"), establish co-operations ("seize") and derive benefits in terms of a broadened capability set ("reconfiguring") constitutes an organisations collaboration capability.

4.3.4 Business development capability

Firms aim to identify prospects for sustainable business and translate market changes into opportunities for development.

"We aim to early detect technological advancements using trend radars, where we check for every interesting technology and what influence it can have on our company. We also spread the knowledge and discuss it with experts from different areas. When a technology becomes extremely relevant, we decide how to take advantage of it."
(Senior Inhouse Consultant at Iota SE)

Digitalisation as a particularly quickly advancing phenomenon is likely to require a greater need for increasing sensitivity to market changes, a greater need to quickly react to changes and to depict external changes as opportunities for new business development through entrepreneurial thinking. The emergence of new technologies requires to continuously assess their impact on the market. Subsequently, their market potential must be evaluated and actionable solutions how to use new technology be developed. Finally, concrete action plans for the most promising technologies must be implemented. The prompt sensing of market changes through opportunity search ("sensing"), the deduction of concrete business opportunities ("seizing"), the direction of investment decisions to seize spotted opportunities and consequently the adaptation of the firms' resources and capabilities ("reconfiguring") is what we summarise as a firm's *business development capability*.

To conclude section 4.3, mechanical engineering firms from the German Mittelstand seem to be supported by four dynamic capabilities in their transformation towards a hybrid strategy. In order to do so, the human resource management capability allows firms that

their skills continue to meet market needs. The learning capability ensures organisations effectively use the accumulated knowledge of their human resources and to avoid making mistakes twice. The collaboration capability facilitates partnerships to jointly develop solutions together with various actors. The business development capability enables the translation of opportunities into sustainable business.

5 Discussion

This section discusses the results presented in section 4 and includes an updated version of the previously outlined sensitising concept (see Figure 1). Subsequently, we discuss a few of the many issues touched upon in this study.

5.1 Findings in light of the theoretical background

Empirical evidence has shown that incumbent firms often struggle to adapt to technological change (Christensen, 2013; Tushman and Anderson, 1986). Simultaneously, previous research uses digitalisation, digitisation and digital transformation often interchangeably. Independent of their differences, their underlying technological change challenges firms' market position (Porter and Millar, 1985) by affecting the value of their existing resources and capabilities (Teece et al., 1997). Firms can respond to changes in the environment through a change in strategic priorities, manifested in a redirection of capability investments (Helfat et al., 2007) and thus close potential capability gaps. Dynamic capabilities are considered higher-order organisational capabilities that help the firm change its existing resource and capability pool and thereby improve chances for long-term survival.

Following the argumentation above, it is well-known that the concepts of strategy (transformation), competitive advantage and dynamic capabilities are interlinked. However, strategy research has, so far, not investigated their interrelations in the context of digitalisation. In particular, not enough research has accumulated on the effects of digitalisation on firm strategy.

We find that digitalisation is the use of information technology to solve complex challenges and thus to create added value. It goes beyond increasing operational efficiency described as digitisation. In response, firms indicate a change towards a hybrid strategy complementing their current differentiation focus with increasing cost awareness. Findings suggest that this goes along with firms seizing the opportunities of digitalisation to strengthen their competitive advantage while achieving greater operational efficiency through best practice. The strategy transformation can be observed through changes in ordinary resources and capabilities. Findings indicate that this change is performed

through upgrading and complementing the existing resource and capability pool, in particular with respect to human resources. We find that four dynamic capabilities are particularly relevant in the context of digitalisation: human resource management capability, learning capability, collaboration capability and business development capability.

5.2 Revised sensitising concept

Following the findings discussed above, we update our sensitising concept by adding more details for each of the concept's components to increase its level of tangibility. What is more, *"operational efficiency"* is added as secondary component to the concept as it contributes to the success of mechanical engineering firms' hybrid strategy. The revised concept is presented in Figure 13.

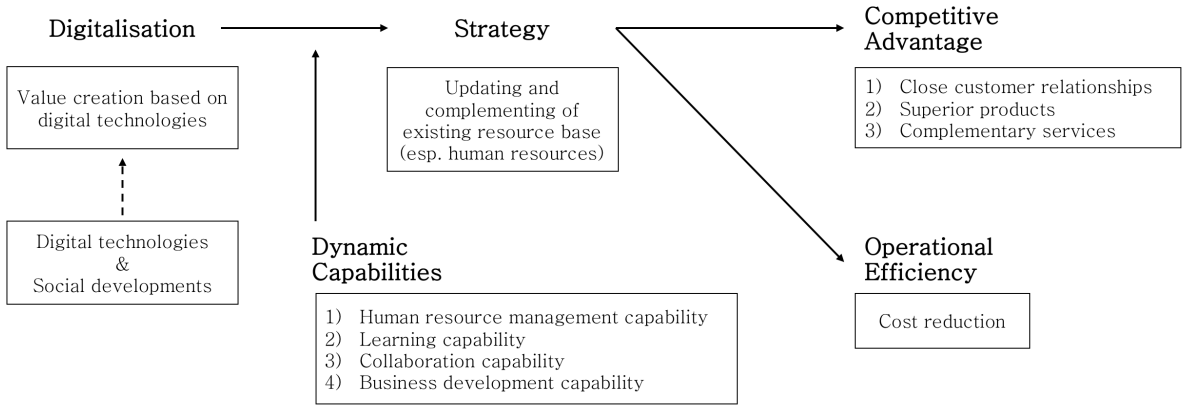

Figure 13: Revised sensitising concept

5.3 Findings in light of strategy research

5.3.1 Implication of different understandings of digitalisation

Firms exhibit a different understanding of what constitutes digitalisation. Following this, firms sense different opportunities from digitalisation which is reflected in corporate actions. Even though many share a comparable view that major opportunities of digitalisation lie in the value creation from new products and services, some seem to focus more on increasing operational efficiency based on technological advancements. The reasons for this could be manifold but we suppose three possible explanations:

1. Top management executives are typically more senior in age. Executives are often senior and coined by their longstanding experience. This path-dependency can prove to be a hurdle when assessing the opportunities of new developments as experience might be one mediator for environmental perception. Thus, digitalisation may make it easier for younger employees ("digital natives") to become part of top management

as they are often more open-minded. This became apparent through our study as interviewed executives responsible for digitalisation exhibited great differences in age which might have translated into different points of view.

2. The position and job description respectively might influence what executives consider relevant. When assessing opportunities of digitalisation, managers may filter perceived opportunities as they look through a lens that evaluates opportunities in light of their position specific responsibilities. We recognised this as the responsibility for digitalisation among the case study firms was located at different functional roles (e.g. CEO, CIO, CDO). As interviewees with different job descriptions exhibited differences in response patterns, this might have influenced how digitalisation is understood.

3. The educational background may lead to different perceptions. For example, managers with a more technical background may differ in their focus compared to managers with a business background. The study revealed that those responsible for digitalisation exhibited a broad range of academic backgrounds (e.g. mechanical engineering, law, business, information systems). We recognised comparable views among interviewees with comparable academic background but differences between backgrounds.

The foregoing claims share the assumption that heterogeneity in managerial cognition is associated with heterogeneity how opportunities are sensed and seized. This could possibly prove to be one factor explaining why some firms exhibit a greater emphasis on achieving lower cost compared to others. Previous strategy research shows that differences between managers affect their respective firms' actions (Gavetti, 2012; Kaplan et al., 2003). This becomes apparent in different stages: For example, Eggers and Kaplan (2013) suggest that firms whose managers are more attentive to emerging technologies more quickly and correctly sense new opportunities and threats. Furthermore, differences between managers might also explain how information is interpreted, i.e. which action alternatives are derived. For example, empirical studies show that insufficient understanding of which resources and capabilities provide value to the company led to the decline of Polaroid (Tripsas and Gavetti, 2000) or Smith Corona (Danneels, 2011). As a result, differences in managerial skills between executives may explain a significant share of variation in firm performance (Thomas, 1988; Weiner, 1978; Lieberson and O'Connor, 1972). This is termed "CEO effect" (Helfat and Peteraf, 2015).

5.3.2 Motivation to shift towards a hybrid strategy

We find that firms have started shifting their strategy from a differentiation to a hybrid strategy. We assume this is a viable reaction for profit maximising economic actors. In

particular, prior competitive advantage has been reduced due to an increase in competitive intensity resulting from low cost competitors that catch up in traditional quality categories (i.e. product life and reliability). Their offering therefore exhibits a significantly improved price-performance-ratio and may thus threaten differentiators' market shares and profitability in the future. Anticipating this, firms are required to strategically respond. This leaves firms with three options: Either enhance their current differentiation strategy, shift towards a cost leadership strategy, or shift towards a hybrid strategy. Each option is discussed below:

1. *Enhanced differentiation:* Findings suggest that firms increasingly face technical boundaries, making further machine improvements in traditional dimensions very difficult and costly, if not impossible. This, in turn, would lead to a significantly increased cost base. To still remain profitable, firms would need to charge even higher prices. However, customers are not willing to pay a significant price premium such that charging significantly more than low cost market players has become increasingly difficult. Therefore, a strategy of further differentiation would likely undermine German Mittelstand mechanical engineering firms' profitability.

2. *Shift towards cost leadership:* Moving towards a cost leadership strategy would aim for achieving the lowest cost structure in the market. Findings suggest that this move is very difficult to achieve for three reasons:

   (a) Organisational structures are designed for producing superior products. Moving towards a cost leader strategy would require significant organisational change.

   (b) A big share of products is manufactured in Germany. Consequently, labour costs are significantly higher than in Asia. Even though automation provides opportunities to lower production costs, it will likely not be possible to achieve the same low level as Asian market players.

   (c) The nature of the product offering is highly customised. This hinders achieving significant economies of scale.

3. *Shift towards hybrid strategy:* To counterfeit decreasing firm performance, firms combine the advantages of simultaneously focusing on differentiation and cost reduction, previously two exclusive strategies. Exploiting the potential of new technologies supports a hybrid strategy. German Mittelstand mechanical engineering firms benefit on the one hand from new technological opportunities that increase product quality in new dimensions (i.e. differentiation), and on the other hand, use digitalisation for greater automation in their own production (i.e. operational efficiency). Compared to low cost market players from Asia, where production is more labour intensive, Mittelstand firms might be successful in adopting such a hybrid

approach. Therefore, new digital technologies might solve the trade-off between product quality and productivity (Piller and Schoder, 1999).

Digitalisation and globalisation blur boundaries between countries and thus reduce barriers to enter new markets. This contributes to market crowding and thus likely reduces the average price. Therefore, nowadays German firms compete internationally across continents and compete with firms that produce under different conditions. These relatively new conditions may make a hybrid strategy more important (see Figure 14).

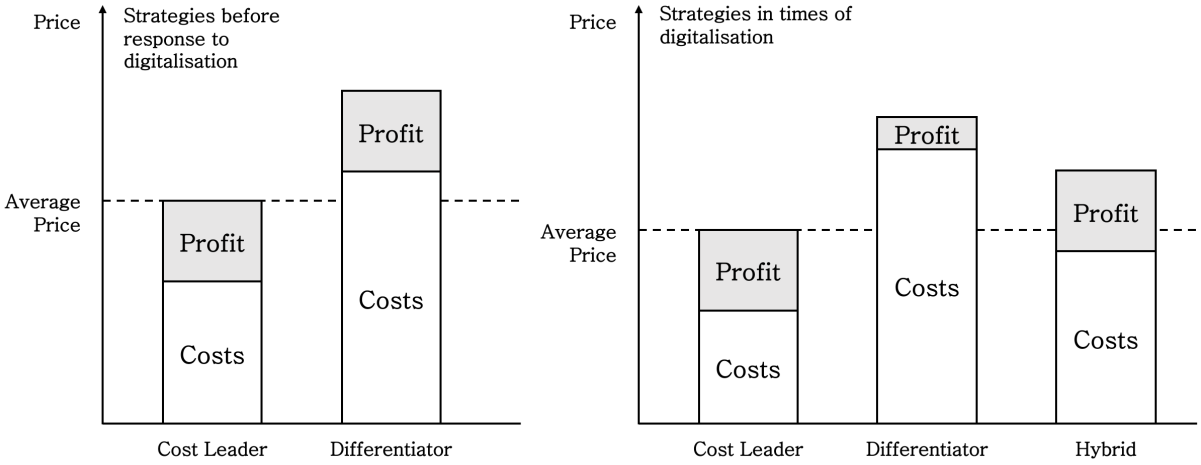

Figure 14: Illustration of competitive strategies before and in times of digitalisation

Initially, Porter's (1979) outline of generic strategies clearly argued against simultaneously pursuing two theoretically incompatible strategies. He emphasised that such firms would neither be able to become a specialist in one area nor generate sufficient economies of scale to achieve satisfactory profitability. However, empirical evidence comparing the effects of pursuing either pure or hybrid strategies is inconclusive (Spanos et al., 2004). On the one hand, some researchers indicate that firms which combined differentiation with low cost performed significantly better than firms with pure strategies (e.g. Wright et al., 1991; White, 1986). On the other hand, further researchers did not find any evidence that hybrid strategies deliver greater returns (Dess and Davis, 1984; Hambrick, 1983). However, much of the confusion seems to be attributed to the fact that previous research has not yet been able to clearly identify when firms deliberately pursue a hybrid strategy as opposed to unintentionally being stuck-in-the-middle (Dess and Rasheed, 1992). Nevertheless, practical examples from firms in other industries beyond mechanical engineering (e.g. Toyota, Canon, Honda) indicate that the shift towards a hybrid strategy might be attributed to the pursuit of both differentiation and cost leadership strategies at the same time (Ishikura and Porter, 1983). For example, Toyota is known for its quality offering (even though under pressure) and its competitive price level.

5.3.3 Which role do dynamic capabilities play in strategy transformation?

We find that four dynamic capabilities are particularly relevant in the context of digitalisation: human resource management capability, learning capability, collaboration capability, and business development capability. These support firms in altering their resource base to be able to perform activities that require new skills in a digitalisation context (compare section 4.2.3). These four dynamic capabilities have also been identified by other researchers in other contexts. This indicates that these are neither new nor only relevant in the digitalisation context. However, they seem to gain in relevance. Already Teece et al. (1997, p. 515f.) suggests the relevance of human resource management capability and learning capability:

"Indeed, if control over scarce resources is the source of economic profits, then it follows that such issues as skill acquisition, the management of knowledge and know-how, and learning, become fundamental strategic issues. It is in this second dimension, encompassing skill acquisition, learning, and accumulation of organisational and intangible or invisible assets, that we believe lies the greatest potential for contribution to strategy."

Other researchers also consider learning and knowledge creation routines an important dynamic capability (Rosenkopf and Nerkar, 2001; Helfat, 1997; Henderson and Cockburn, 1994). These are particularly relevant in industries "where cutting-edge knowledge is essential for effective strategy and performance" (Eisenhardt and Martin, 2000, p.1108). This is the case for the mechanical engineering industry. Some indicate that learning is even "involved in the creation and evolution of dynamic capabilities" (Zollo and Winter, 2002, p.340) and thus resides at an even higher level.

Researchers often refer to terms like "coordinate," "combine," and "integrate" when investigating capability development (e.g. Barreto, 2010; Ettlie and Pavlou, 2006; Eisenhardt and Martin, 2000). This hints at the relevance of collaboration beyond the boundaries of the firm in inter-firm collaborations. These routines refer to alliance and acquisition activities that aim for getting access to external resources that reside outside organisational boundaries (Lane and Lubatkin, 1998; Powell et al., 1996). This is particularly relevant in environments characterised by discontinuous technological change. In the case of mechanical engineering firms in this study, collaborations enable the firms becoming full service providers without building up own expertise in every field and thus contribute to a shift from goods-dominant logic towards service-dominant logic (Vargo and Lusch, 2004). Digital technologies ease combining the strengths of multiple partners. In particular, Anand et al. (2010) find collaborations help secure access to new technologies and even support technological laggards in catching up. However, they suggest success is more

likely if the firm has access to complementary resources.

One such complementary capability could be the business development capability. It seems to be comparable with what other researchers consider the new product development capability (Winter, 2003) or innovation capability (Wang and Ahmed, 2007), just extended by the element business model innovation. Thereby, the development of new products and services is complemented by *how* (e.g. revenue model) and *where* (e.g. distribution channel) firms generate revenues. One such example from the German mechanical engineering Mittelstand is the exploration of a pay-per-use business model.

Dynamic capabilities may consist of either tangible (e.g. organisational structure) or tacit elements (e.g. "no-blame" culture). Each of the four dynamic capabilities outlined in this study exhibits both tangible and tacit elements. For example, the learning capability can be tangible in the form of an institutionalised knowledge management system, regular feedback sessions and professional development programmes. Tacit elements may comprise a culture of questioning routines driven by motivated and curious employees. This indicates that both tacit and tangible elements complement each other. However, it remains to be investigated which of both elements is more relevant in light of dynamic capabilities.

Dynamic capabilities are inherent in a firm's routines and processes and non-tradable. Thus, they cannot be acquired on strategic factor markets (except for the case of business unit acquisition) and must be built by the firm itself. German Mittelstand mechanical engineering firms show a long-term focus on continuity. These values can be associated with a preference for building up new capabilities themselves. This could be a basis for developing further dynamic capabilities in the long-term. However, the value of dynamic capabilities might change over time. For example, German Mittelstand mechanical engineering firms nowadays feel a greater need for collaboration compared to the past. This makes the collaboration capability more important than a few decades ago.

Replicating this study at a later point in time would probably reveal more or other dynamic capabilities. It could also be the case that some dynamic capabilities cannot be observed or that they do not operate at all times. This does not necessarily indicate that the firms do not possess those anymore (Easterby-Smith et al., 2009).

5.4 Transfer of findings

For practitioners in comparable situations, we leave it to the reader's judgement whether the findings presented may be applicable to their own positions. Nevertheless, in a first attempt, this section gives an indication whether and how the findings from this study may be transferred to other contexts beyond its immediate setting. In particular, we discuss how the findings may be transferred to other German mechanical engineering firms, to other Mittelstand firms, to firms from other countries and what general transfer we suggest.

5.4.1 Transfer to other German mechanical engineering firms

Mechanical engineering firms produce machines which make semi-finished goods or ready-to-sell products. These machines are sold to business customers. Within this industry, the major differentiation criterion between firms' market offering is their machines' degree of customisation. We assume that large mechanical engineering firms produce more standardised goods as they often do not operate in a single niche and also produce standardised components for smaller mechanical engineering firms. Given their large production output, they can likely reap greater economies of scale which might indicate that they already follow a hybrid strategy consisting of both differentiation and cost focus. Thus, we assume that large firms probably do not change their strategy in response to digitalisation in the sense of Porter's (1979) generic strategies.

Close customer relationships are less relevant for large mechanical engineering firms. These are not as much part of such firms' competitive advantage due to the production of more standardised goods. Instead, large firms likely rely more on their brand reputation to differentiate themselves from competitors. Digitalisation might open up new forms of differentiation for such firms (e.g. mass customisation). Unlike Mittelstand firms, the workplaces of large mechanical engineering firms are often located at more attractive sites. Consequently, they might not be as restricted in carrying out new digitalisation initiatives as opposed to Mittelstand firms. As such, acquiring the right human resources might be easier.

5.4.2 Transfer to other Mittelstand firms

The high share of customised machines is relatively specific to the mechanical engineering industry. However, other Mittelstand firms also often follow differentiation strategies based on other means. They are not necessarily required to perform strategy transformation towards a hybrid strategy. This could depend on the geographical scope of their operations and the nature of competition in their markets and industries.

The effects of digitalisation on competitive advantage can hardly be transferred to other Mittelstand firms. This depends on the market, the customer and the nature of competition. For example, customisation is less developed in the consumer goods industry and products are more standardised. This might ask for other means of differentiation (e.g. brand reputation).

5.4.3 Transfer to other countries

When transferring findings to other countries, we distinguish between countries with comparable competitive conditions and countries with different competitive conditions compared to Germany.

In the first case, findings can likely be transferred as the cost structure in Western economies will likely be on a similar level. However, they might also compete with market players from low cost countries. In case firms do not possess the means for further differentiation, while simultaneously not being able to lower the cost sufficiently, they are at risk to be stuck-in-the-middle. One example from a different industry is the automotive company Opel that has not yet managed to drive down costs to compete on price with Asian market players. At the same time, they cannot deliver superior product quality to realistically compete with premium brands like BMW or Audi.

In the second case, findings might be more difficult to transfer for firms from countries with a lower cost structure. Given their often lower technological development, they do not have the competencies to differentiate their products significantly. However, digitalisation opens up opportunities for further lowering production costs through automation. Implementation of a greater level of automation in production might take some more time as such firms' production process is typically more labour intense and thus requires larger internal changes.

5.4.4 General transfer

Both opportunities of digitalisation (new products, services, and business models and increases in operational efficiency) are visible in other contexts. However, the relevance of each opportunity varies. In general, cultural shifts towards greater customer centricity is becoming increasingly important. This also requires solutions for getting access to critical resources as problems are increasingly complex.

Dynamic capabilities seem not to be firm-specific. However, they may differ in their idiosyncratic details as firms are influenced by path-depencies and employ different routines and processes. The relevance of each dynamic capability might also differ across firms,

industries or countries. Nevertheless, competitive advantage always depends on the ability to create new VRIN resource bundles.

To conclude the discussion, it seems that executives' understanding of digitalisation affects firm strategy. One factor contributing to this could be managerial cognition. Further, the effects of digitalisation can hardly be discerned from other influencing factors. Therefore, the consequences for strategy should be analysed in light of the market environment and industry context. Digitalisation facilitates hybrid strategies as new digital technologies solve the trade-off between product variety and productivity. Moreover, it seems some dynamic capabilities increase in relevance in the context of digitalisation.

6 Conclusion

This section outlines the conclusions of the study, followed by theoretical and managerial implications. Finally, limitations and recommendations for future research are presented.

6.1 General conclusion

Digitalisation requires a reassessment of firms' existing resources and capabilities. Lower value of resources and capabilities might lower strategic fit between the firm and the market. Firms can respond to changes in the environment through a change in strategy, manifested in a redirection of capability investments (Helfat et al., 2007). Effectively reconfiguring firms resource and capability pool is critical to avoid declining firm performance. Dynamic capabilities help the firm change its existing resource and capability pool and thereby improve chances for long-term survival.

The link between strategy and digitalisation has received little attention in strategy research so far. Thus, the purpose of this thesis was to explore and explicate the effects of digitalisation on firm strategy (RQ1) and in this context, shed some light on the role of dynamic capabilities in a strategy transformation process (RQ2). By investigating this subject, we further aimed to find indications whether and how strategy transformation in response to digitalisation contributes to competitive advantage (RQ3). To find answers to our three research questions, we delimited this study to German Mittelstand mechanical engineering firms. Finding answers to digitalisation is critical as their future prospects are significantly affected.

By conducting an exploratory, qualitative study based on semi-structured interviews with industry experts and managers, we found indications how digitalisation, strategy, dynamic capabilities and competitive advantage are linked.

First, we find that firms shift their strategic direction from pure differentiation to a hybrid strategy as prior competitive advantage has been reduced due to an increase in competitive intensity. This does not constitute a fundamental shift in strategy. Firms rather complement their pursuit for differentiation advantages by generating cost advantages simultaneously. Digitalisation facilitates hybrid strategies as new digital technologies solve the trade-off between product quality and productivity. Using the means of digitalisation to follow a hybrid strategy requires firms to update and complement their existing resources and capabilities. Thus, firms may face capability gaps through digitalisation. This primarily relates to human resources. Digitalisation makes new skills relevant that firms do not necessarily possess today. They employ buy-, collaborate- and build-approaches to close these capability gaps. Firms exhibit a preference for building up capabilities and resources themselves in the long-term.

Second, four dynamic capabilities were identified that are of particular importance in strategy transformation in response to digitalisation: *human resource management capability*, *learning capability*, *collaboration capability* and *business development capability*. Each of them compromises activities of three different types, i.e. those who absorb knowledge, those who connect knowledge with products and markets, and those who change the firm's resource base to align with its needs. The identified dynamic capabilities provide critical support for reconfiguration of the resource and capability pool. Dynamic capabi-lities thus ensure that firms' resources and capabilities fit with market needs.

Third, we observe a two-fold effect on competitive advantage: On the one hand, digitalisation strengthens existing competitive advantages. Thus, a greater level of differentiation through closer customer relationships, superior product and service quality, and complementary offerings is possible. Bonding with the customer is increased through new means of customisation and mechanical engineering firms' shift to becoming solution providers. Higher switching costs may lead to vendor-lock-in. On the other hand, digitalisation allows increases in operational efficiency. This comprises increased production efficiency or shorter time-to-market in product development. However, such cost reduction does not lead to competitive advantage on its own because it leverages best practice.

6.2 Theoretical implications

The results outlined above help narrow the research gap on the link between digitalisation, strategy, competitive advantage and dynamic capabilities. Our findings thus contribute to existing theoretical knowledge in two ways:

1. We provide insights on how digitalisation affects firm strategy and competitive advantage. Our investigation indicates digitalisation leads to a shift in strategy from

pure differentiation to a hybrid strategy. Furthermore, digitalisation appears to strengthen existing competitive advantages and allows increased operational efficiency.

2. We shed light on how dynamic capabilities operate in the context of digitalisation and thereby empirically contribute to its tangibility. Our investigation suggests that human resource management capability, learning capability, collaboration capability and business development capability support firms in pursuit of strategy transformation.

Furthermore, we contribute to the clarification of the essentially different concepts of digitisation, digitalisation and digital transformation. We regard digitalisation as the use of digital technologies to create value beyond pure efficiency increases. Other than that, we complement existing, mainly quantitative studies with a qualitative case study to better understand "the subtlety of resource creation and regeneration processes" (Ambrosini et al., 2009, p.46). Lastly, our method of primarily conducting telephone interviews proved to generate rich and fine-grained data. This study could provide further support for telephone interviews in the future. We thus add to the existing methodological discussion on qualitative studies (Novick, 2008).

6.3 Managerial implications

This thesis contributes to a greater understanding of viable strategic directions in response to digitalisation. Managers can use the means of digitalisation to successfully implement hybrid strategies. On the one hand, this calls for increased differentiation through enhanced customer relationships, offering innovative products and complementary services. Particular importance gains complementing products with data-driven services and the shift from solely offering products to integrated solutions. To achieve this, managers are encouraged to build collaborations with other market actors. On the other hand, managers can improve operational efficiency through modularisation based on standardised components. These do not contradict customisation as they can be assembled to customised offerings.

Dynamic capabilities provide critical support for strategy transformation. The identified dynamic capabilities (human resource management capability, learning capability, collaboration capability, business development capability) provide dimensions along which managers can systematically analyse how they can strengthen their capability and resource base in response to digitalisation.

Finally, managers are encouraged to lead both the public and internal debate on digitalisation to contribute to both its clarity and its effects. From an internal perspective,

this will not only reduce perceived danger of work place redundancy but also produce more engaged and motivated employees, in particular those who possess critical skills for future business development (e.g. software developers). It is therefore important to tie these talents to the company at an early stage. The chance for a rapid career development, high job security and world market leadership are just a few benefits many German Mittelstand firms can offer. However, often their greatest limitation compared to international corporations is the low attractiveness of their location. Therefore, new forms of addressing potential applicants, e.g. via hackathons, could be one appropriate instrument to experiment with.

From an external perspective, engaging in public debate signals knowledge on a contemporary phenomenon and increases credibility for new software-based offerings. This will support a firm's transition from a pure mechanical engineering firm offering products towards a provider of integrated solutions. In this context, it might also prove helpful to engage in and coordinate discussions with other firms and trade associations to establish more common technological standards. The results will also help overcome both customers' data security concerns and customers' hesitancy in adopting new solutions. Thus, it is also recommended to constantly communicate the value added of such innovative offerings as some of them tend to be in need of explanation.

6.4 Limitations

First, this study is of qualitative nature with a specific unit of analysis. The conclusions of this study may provide suggestive evidence and as such cannot be confirmed by this study alone. For practitioners in comparable situations, we leave it to the reader's judgement whether the findings presented may be applicable to their own positions. To support transferability, we provided rich contextual information for allowing the reader to make such a transfer.

Second, we initially outlined that many more firms would have been suitable for conducting this study. Thus, gaining access to respondents was a challenge to overcome. In particular, top management is typically short in time and certainly has other priorities. Relationships with gatekeepers to management boards of such firms would have been beneficial in gaining more respondents. We addressed this by directly contacting each mechanical engineering firm's CEO through his personal email address.

Third, access to top management does both benefit and limit results. On the one hand, executives are very knowledgeable about their firm. On the other hand, they do not know the details of each and every project. Thus, further enriching the data by more interviews with employees from other levels of each firm would have widened the picture

and added depth at each firm. We mitigated this bias by triangulation of interview data with se-condary data and interviewing industry experts. Both sources provide information beyond organisational boundaries.

Fourth, the majority of interviews were conducted via phone. This makes conveying and recognising visual cues difficult. However, how phone interviews affect results as opposed to face-to-face-interviews has not yet been found consensus on (Novick, 2008). To reduce bias, we also conducted face-to-face interviews whenever possible. Moreover, in line with Burke and Miller (2001), we used a script for introducing the study prior to the interview and engaged in small talk before the study. Furthermore, interview transcripts were reviewed by the interviewees.

Fifth, given the dynamics of digitalisation one might argue that a longitudinal study would have been more appropriate. Nevertheless, given the short time frame of this thesis, data collection for a longer time period was simply not possible. We addressed this by interviewing managers with long-standing experience and deep industry expertise. These are able to reflect on current and past developments and envision future paths of their organisations. As managers are considered primary knowledge carriers, retrospective sense-making is avoided.

6.5 Directions for further research

Our study opens up a variety of future research streams. We have studied how a set of market actors from one specific industry has changed its strategy in response to digitalisation. Therefore, conducting comparable studies in other industries or with firms exhibiting characteristics other than Mittelstand peculiarities would strengthen our knowledge with respect to strategy and competitive advantage in the context of digitalisation. Other than that, further insights on how Mittelstand characteristics affect strategy transformation in response to digitalisation would be valuable.

What is more, a greater number of both qualitative and quantitative longitudinal studies can provide more comprehensive insights how the value of dynamic capabilities changes over time. This could also draw on more detailed insights from different organisational levels. With respect to dynamic capabilities, findings from both empirical (Brady and Davies, 2004; Figueiredo, 2003) and theoretical research (Zott, 2003; Eisenhardt and Martin, 2000) indicate that capability development acts as mediator on the relationship between dynamic capabilities and performance. It would be of interest to investigate how the development of dynamic capabilities is carried out to further increase practical relevance. For future studies, it would also be interesting to analyse how firms with other strategic foci apart from differentiation respond to digitalisation.

Our findings suggest that executives' understanding of digitalisation and thus managerial cognition affects firm strategy. Further research is encouraged to investigate how managers' skills and traits affect the perception and translation of opportunities into corporate action in the context of digitalisation.

References

Adamos (2018), 'World market leaders combine strengths in adamos', Website. last checked: 13/03/2018.
URL: *https://en.adamos.com/about-adamos*

Agarwal, R. and Helfat, C. E. (2009), 'Strategic renewal of organizations', *Organization Science* **20**(2), 281–293.

Ahuja, G. (2000), 'Collaboration networks, structural holes, and innovation: A longitudinal study', *Administrative Science Quarterly* **45**(3), 425–455.

Ambrosini, V. and Bowman, C. (2009), 'What are dynamic capabilities and are they a useful construct in strategic management?', *International Journal of Management Reviews* **11**(1), 29–49.

Ambrosini, V., Bowman, C. and Collier, N. (2009), 'Dynamic capabilities: An exploration of how firms renew their resource base', *British Journal of Management* **20**(1), 9–24.

Amit, R. and Schoemaker, P. J. (1993), 'Strategic assets and organizational rent', *Strategic Management Journal* **14**(1), 33–46.

Anand, J., Oriani, R. and Vassolo, R. S. (2010), 'Alliance activity as a dynamic capability in the face of a discontinuous technological change', *Organization Science* **21**(6), 1213–1232.

Argyris, C. (1976), 'Single-loop and double-loop models in research on decision making', *Administrative Science Quarterly* **21**(3), 363–375.

Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R. H., Konwinski, A., Lee, G., Patterson, D. A., Rabkin, A., Stoica, I. et al. (2009), Above the clouds: A berkeley view of cloud computing, Technical report, Technical Report UCB/EECS-2009-28, EECS Department, University of California, Berkeley.

ASTM (2010), 'F2792–10', *Standard Terminology for Additive Manufacturing Technologies* .

Atzori, L., Iera, A. and Morabito, G. (2010), 'The internet of things: A survey', *Computer networks* **54**(15), 2787–2805.

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S. and MacIntyre, B. (2001), 'Recent advances in augmented reality', *IEEE computer graphics and applications* **21**(6), 34–47.

Baines, T. S., Lightfoot, H. W., Benedettini, O. and Kay, J. M. (2009), 'The servitization of manufacturing: A review of literature and reflection on future challenges', *Journal of Manufacturing Technology Management* **20**(5), 547–567.

Barney, J. (1991), 'Firm resources and sustained competitive advantage', *Journal of Management* **17**(1), 99–120.

Barreto, I. (2010), 'Dynamic capabilities: A review of past research and an agenda for the future', *Journal of Management* **36**(1), 256–280.

Bassey, M. (1981), 'Pedagogic research: On the relative merits of search for generalisation and study of single events', *Oxford Review of Education* **7**(1), 73–94.

Becker, W., Staffel, M. and Ulrich, P. (2008), 'Mittelstand und Mittelstandsforschung', *Bamberger Betriebswirtschaftliche Beiträge* **153**, 1–51.

Benner, M. J. (2010), 'Securities analysts and incumbent response to radical technological change: Evidence from digital photography and internet telephony', *Organization Science* **21**(1), 42–62.

Berger, P. L. and Luckmann, T. (1991), *The social construction of reality: A treatise in the sociology of knowledge*, number 10, Penguin Uk.

Berger, R. (2015), 'Die digitale Transformation der Industrie: Was sie bedeutet. Wer gewinnt. Was jetzt zu tun ist'.

Berghoff, H. (2006), 'The end of family business? The Mittelstand and German capitalism in transition, 1949–2000', *Business History Review* **80**(2), 263–295.

Berrone, P., Cruz, C. and Gomez-Mejia, L. R. (2012), 'Socioemotional wealth in family firms: Theoretical dimensions, assessment approaches, and agenda for future research', *Family Business Review* **25**(3), 258–279.

Bharadwaj, A., El Sawy, O. A., Pavlou, P. A. and Venkatraman, N. (2013), 'Digital business strategy: toward a next generation of insights', *MIS Quarterly* **37**(2), 471–482.

Blumer, H. (1954), 'What is wrong with social theory?', *American Sociological Review* **19**(1), 3–10.

Botthof, A. and Hartmann, E. A. (2015), *Zukunft der Arbeit in Industrie 4.0*, Springer.

Bowman, C. and Ambrosini, V. (2003), 'How the resource-based and the dynamic capability views of the firm inform corporate-level strategy', *British Journal of Management* **14**(4), 289–303.

Brady, T. and Davies, A. (2004), 'Building project capabilities: from exploratory to exploitative learning', *Organization Studies* **25**(9), 1601–1621.

Brandenburger, A. M. and Stuart, H. W. (1996), 'Value-based business strategy', *Journal of Economics & Management Strategy* **5**(1), 5–24.

Brennen, J. S. and Kreiss, D. (2014), 'Digitalization and Digitization', Website. last checked: 10/05/2018.
URL: *http://culturedigitally.org/2014/09/digitalization-and-digitization*

Bryman, A. and Bell, E. (2015), *Business Research Methods*, Oxford University Press, USA.

Bughin, J., LaBerge, L. and Mellbye, A. (2017), 'The case for digital reinvention', *McKinsey Quarterly, January* pp. 1–15.

Buhl, H., Röglinger, M., Moser, F., Heidemann, J. et al. (2013), 'Big data', *Business & Information Systems Engineering: The International Journal of Wirtschaftsinformatik* **5**(2), 65–69.

Bundesministerium für Bildung und Forschung (2011), 'Industrie 4.0', Website. last checked: 06/04/2018.
URL: *https://www.bmbf.de/de/zukunftsprojekt-industrie-4-0-848.html*

Burke, L. A. and Miller, M. K. (2001), Phone interviewing as a means of data collection: Lessons learned and practical recommendations, *in* 'Forum Qualitative Sozialforschung/Forum: Qualitative Social Research', Vol. 2.

Buyya, R., Yeo, C. S., Venugopal, S., Broberg, J. and Brandic, I. (2009), 'Cloud computing and emerging it platforms: Vision, hype, and reality for delivering computing as the 5th utility', *Future Generation Computer Systems* **25**(6), 599–616.

Cachia, M. and Millward, L. (2011), 'The telephone medium and semi-structured interviews: a complementary fit', *Qualitative Research in Organizations and Management: An International Journal* **6**(3), 265–277.

Carr, E. C. and Worth, A. (2001), 'The use of the telephone interview for research', *NT research* **6**(1), 511–524.

Chandler, A. D. (1962), 'Strategy and structure: Chapters in the history of the american enterprise', *Massachusetts Institute of Technology Cambridge* .

Chapple, A. (1999), 'The use of telephone interviewing for qualitiative research', *Nurse Researcher* **6**(3), 85–93.

Chen, H., Chiang, R. H. and Storey, V. C. (2012), 'Business intelligence and analytics: from big data to big impact', *MIS Quarterly* **36**(4), 1165–1188.

Christensen, C. (2013), *The innovator's dilemma: when new technologies cause great firms to fail*, Harvard Business Review Press.

Collis, D. J. (1994), 'How valuable are organizational capabilities?', *Strategic Management Journal* **15**(Special Issue), 143–152.

Coltman, T., Tallon, P., Sharma, R. and Queiroz, M. (2015), 'Strategic it alignment: twenty-five years on', *Journal of Information Technology* **30**, 91–100.

Corbin, J. and Strauss, A. (2008), *Basics of qualitative research: Techniques and procedures for developing grounded theory*, Thousand Oaks, CA: Sage.

Coreynen, W., Matthyssens, P. and Van Bockhaven, W. (2017), 'Boosting servitization through digitization: Pathways and dynamic resource configurations for manufacturers', *Industrial Marketing Management* **60**, 42–53.

Creswell, J. W. and Zhang, W. (2009), 'The application of mixed methods designs to trauma research', *Journal of Traumatic Stress* **22**(6), 612–621.

Damken, N. (2007), *Corporate Governance in mittelständischen Kapitalgesellschaften: Bedeutung der Business judgment rule und der D&O-Versicherung für Manager im Mittelstand nach der Novellierung des § 93 AktG durch das UMAG*, OlWIR, Oldenburger Verlag für Wirtschaft, Informatik und Recht.

Danneels, E. (2002), 'The dynamics of product innovation and firm competences', *Strategic Management Journal* **23**(12), 1095–1121.

Danneels, E. (2008), 'Organizational antecedents of second-order competences', *Strategic Management Journal* **29**(5), 519–543.

Danneels, E. (2011), 'Trying to become a different type of company: Dynamic capability at smith corona', *Strategic Management Journal* **32**(1), 1–31.

d'Aveni, R. A. and Gunther, R. E. (1994), *Hypercompetitive Rivalries: Competing in highly dynamic environment*, New York: The Free Press.

De Massis, A., Audretsch, D., Uhlaner, L. and Kammerlander, N. (2018), 'Innovation with limited resources: Management lessons from the German Mittelstand', *Journal of Product Innovation Management* **35**(1), 125–146.

De Mauro, A., Greco, M. and Grimaldi, M. (2016), 'A formal definition of big data based on its essential features', *Library Review* **65**(3), 122–135.

Decker, C. and Günther, C. (2017), 'The impact of family ownership on innovation: evidence from the German machine tool industry', *Small Business Economics* **48**(1), 199–212.

Denzin, N. (1970), 'The research act: A theoretical introduction to sociological methods'.

Dess, G. G. and Davis, P. S. (1984), 'Porter's (1980) generic strategies as determinants of strategic group membership and organizational performance', *Academy of Management Journal* **27**(3), 467–488.

Dess, G. G. and Rasheed, A. (1992), 'Commentary: Generic strategies: classification, combination, and context.', *Advances in Strategic Management* **8**, 409–416.

Dierickx, I. and Cool, K. (1989), 'Asset stock accumulation and sustainability of competitive advantage', *Management Science* **35**(12), 1504–1511.

Dierkes, M., Antal, A. B., Child, J. and Nonaka, I. (2003), *Handbook of organizational learning and knowledge*, Oxford University Press, USA.

Dosi, G., Faillo, M. and Marengo, L. (2008), *Organizational capabilities, patterns of knowledge accumulation and governance structures in business firms: an introduction*, Sage publications, London, England.

Drnevich, P. L. and Kriauciunas, A. P. (2011), 'Clarifying the conditions and limits of the contributions of ordinary and dynamic capabilities to relative firm performance', *Strategic Management Journal* **32**(3), 254–279.

Dubois, A. and Gadde, L.-E. (2002), 'Systematic combining: an abductive approach to case research', *Journal of Business Research* **55**(7), 553–560.

Easterby-Smith, M., Lyles, M. A. and Peteraf, M. A. (2009), 'Dynamic capabilities: Current debates and future directions', *British Journal of Management* **20**(Special Issue 1), 1–8.

Edmondson, A. C. and McManus, S. E. (2007), 'Methodological fit in management field research', *Academy of Management Review* **32**(4), 1246–1264.

Eggers, J. and Kaplan, S. (2013), 'Cognition and capabilities: A multi-level perspective', *Academy of Management Annals* **7**, 295–340.

Eisenhardt, K. M. (1989), 'Building theories from case study research', *Academy of Management Review* **14**(4), 532–550.

Eisenhardt, K. M. and Martin, J. A. (2000), 'Dynamic capabilities: what are they?', *Strategic Management Journal* **21**(10/11), 1105–1121.

Ettlie, J. E. and Pavlou, P. A. (2006), 'Technology-based new product development partnerships', *Decision Sciences* **37**(2), 117–147.

Fidel, R. (1993), 'Qualitative methods in information retrieval research.', *Library and Information Science Research* **15**(3), 219–47.

Figueiredo, P. N. (2003), 'Learning, capability accumulation and firms differences: evidence from latecomer steel', *Industrial and Corporate Change* **12**(3), 607–643.

Firestone, W. A. (1993), 'Alternative arguments for generalizing from data as applied to qualitative research', *Educational Researcher* **22**(4), 16–23.

Flick, U. (2011), Triangulation, *in* 'Empirische Forschung und Soziale Arbeit', Springer, pp. 323–328.

Flick, U. (2014), *An introduction to qualitative research*, Sage publications, London, England.

Florio-Ruane, S. (1986), *Conversation and narrative in collaborative research*, Institute for Research on Teaching, Michigan State University.

Gandomi, A. and Haider, M. (2015), 'Beyond the hype: Big data concepts, methods, and analytics', *International Journal of Information Management* **35**(2), 137–144.

Gartner (2018*a*), 'Gartner it glossary - advanced analytics', Website. last checked: 10/05/2018.
URL: *https://www.gartner.com/it-glossary/advanced-analytics/*

Gartner (2018*b*), 'Gartner it glossary - quantum computer', Website. last checked: 10/05/2018.
URL: *https://www.gartner.com/it-glossary/quantum-computing/*

Gartner (2018*c*), 'Gartner it glossary - social media', Website. last checked: 10/05/2018.
URL: *https://www.gartner.com/it-glossary/social-media/*

Gavetti, G. (2012), 'Perspective—toward a behavioral theory of strategy', *Organization Science* **23**(1), 267–285.

Gawer, A. and Cusumano, M. A. (2014), 'Industry platforms and ecosystem innovation', *Journal of Product Innovation Management* **31**(3), 417–433.

GE (2018), 'What is Edge Computing', Website. last checked: 10/05/2018.
URL: *https://www.ge.com/digital/blog/what-edge-computing*

Gerring, J. (2004), 'What is a case study and what is it good for?', *American Political Science Review* **98**(2), 341–354.

Ghemawat, P. (1991), *Commitment*, Simon and Schuster.

Gibbert, M., Ruigrok, W. and Wicki, B. (2008), 'What passes as a rigorous case study?', *Strategic Management Journal* **29**(13), 1465–1474.

Gioia, D. A., Corley, K. G. and Hamilton, A. L. (2013), 'Seeking qualitative rigor in inductive research: Notes on the gioia methodology', *Organizational Research Methods* **16**(1), 15–31.

Girod, S. J. and Whittington, R. (2017), 'Reconfiguration, restructuring and firm performance: Dynamic capabilities and environmental dynamism', *Strategic Management Journal* **38**(5), 1121–1133.

Glaser, B. G. (1978), *Theoretical sensitivity: Advances in the methodology of grounded theory*, Mill Valley, CA: Sociology Press.

Godfrey, P. C. and Hill, C. W. (1995), 'The problem of unobservables in strategic management research', *Strategic Management Journal* **16**(7), 519–533.

Goffin, K. and Koners, U. (2011), 'Tacit knowledge, lessons learnt, and new product development', *Journal of Product Innovation Management* **28**(2), 300–318.

Gottschalg, O. and Zollo, M. (2007), 'Interest alignment and competitive advantage', *Academy of Management Review* **32**(2), 418–437.

Granovetter, M. (1985), 'Economic action and social structure: The problem of embeddedness', *American Journal of Sociology* **91**(3), 481–510.

Graumann, S., Bertschek, I., Weber, T., Ebert, M., Ettner, K., Speich, A., Weinzierl, M., Ohnemus, J., Niebel, T., Rammer, C. et al. (2016), Monitoring-Report Wirtschaft Digital 2016, Technical report, ZEW-Gutachten und Forschungsberichte.

Groves, R. M. (1990), 'Theories and methods of telephone surveys', *Annual Review of Sociology* **16**(1), 221–240.

Guba, E. G. and Lincoln, Y. S. (1989), *Fourth generation evaluation*, Beverly Hills, CA, Sage.

Gummesson, E. (2000), *Qualitative methods in management research*, Sage.

Habbershon, T. G. and Williams, M. L. (1999), 'A resource-based framework for assessing the strategic advantages of family firms', *Family Business Review* **12**(1), 1–25.

Hagedoorn, J. (1993), 'Understanding the rationale of strategic technology partnering: Nterorganizational modes of cooperation and sectoral differences', *Strategic Management Journal* **14**(5), 371–385.

Hall, R. (1992), 'The strategic analysis of intangible resources', *Strategic Management Journal* **13**(2), 135–144.

Hambrick, D. C. (1983), 'High profit strategies in mature capital goods industries: A contingency approach', *Academy of Management Journal* **26**(4), 687–707.

Hamer, E. (1990), *Mittelständische Unternehmen: Gründung, Führung, Chancen, Risiken (Medium-sized companies: foundation, leadership, opportunities, risks)*, Landsberg am Lech: Deutsches Institut für Mittelstandsökonomie Magdeburg.

Harreld, J. B., O'Reilly III, C. A. and Tushman, M. L. (2007), 'Dynamic capabilities at IBM: Driving strategy into action', *California Management Review* **49**(4), 21–43.

Haveman, H. A. (1992), 'Between a rock and a hard place: Organizational change and performance under conditions of fundamental environmental transformation', *Administrative Science Quarterly* **37**(1), 48–75.

Hayes, R. H. and Pisano, G. P. (1994), 'Beyond world-class: the new manufacturing strategy', *Harvard Business Review* **72**(1), 77–86.

Helfat, C. E. (1997), 'Know-how and asset complementarity and dynamic capability accumulation: The case of R&D', *Strategic Management Journal* **18**(5), 339–360.

Helfat, C. E., Finkelstein, S., Mitchell, W., Peteraf, M., Singh, H., Teece, D. and Winter, S. G. (2007), *Dynamic capabilities: Understanding strategic change in organizations*, Blackwell: Oxford, U.K.

Helfat, C. E. and Peteraf, M. A. (2003), 'The dynamic resource-based view: Capability lifecycles', *Strategic Management Journal* **24**(10), 997–1010.

Helfat, C. E. and Peteraf, M. A. (2015), 'Managerial cognitive capabilities and the microfoundations of dynamic capabilities', *Strategic Management Journal* **36**(6), 831–850.

Henderson, R. and Cockburn, I. (1994), 'Measuring competence? exploring firm effects in pharmaceutical research', *Strategic Management Journal* **15**(S1), 63–84.

Henderson, R. M. and Clark, K. B. (1990), 'Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms', *Administrative Science Quarterly* pp. 9–30.

Hodkinson, P. and Hodkinson, H. (2001), *The Strengths and Limitations of Case Study Research (Paper presented to the Learning and Skills Development Agency Conference).*

Hood, J. C. (2007), 'Orthodoxy vs. power: The defining traits of grounded theory', *The Sage Handbook of Grounded Theory* .

Ishikura, Y. and Porter, M. (1983), 'Canon, inc.: Worldwide copier strategy', *Boston: Harvard Business School Case Services* .

ISO (2012), 'ISO 8373', *International Organization for Standardization* .

Jick, T. D. (1979), 'Mixing qualitative and quantitative methods: Triangulation in action', *Administrative Science Quarterly* **24**(4), 602–611.

Kagermann, H., Helbig, J., Hellinger, A. and Wahlster, W. (2013), *Recommendations for implementing the strategic initiative Industrie 4.0: Securing the future of German manufacturing industry*, Forschungsunion.

Kane, G. C., Palmer, D., Phillips, A. N., Kiron, D. and Buckley, N. (2015), 'Strategy, not technology, drives digital transformation', *MIT Sloan Management Review* **14**.

Kaplan, S., Murray, F. and Henderson, R. (2003), 'Discontinuities and senior management: Assessing the role of recognition in pharmaceutical firm response to biotechnology', *Industrial and Corporate Change* **12**(2), 203–233.

Ketokivi, M. and Choi, T. (2014), 'Renaissance of case research as a scientific method', *Journal of Operations Management* **32**(5), 232–240.

Khadjavi, K. (2005), *Wertmanagement im Mittelstand*.

Kirk, J. and Miller, M. L. (1986), *Reliability and validity in qualitative research*, Sage.

Kotter, J. P. (1996), 'Why transformation efforts fail', *The Journal of Product Innovation Management* **2**(13), 170.

Kraatz, M. S. and Zajac, E. J. (2001), 'How organizational resources affect strategic change and performance in turbulent environments: Theory and evidence', *Organization Science* **12**(5), 632–657.

Lane, P. J. and Lubatkin, M. (1998), 'Relative absorptive capacity and interorganizational learning', *Strategic Management Journal* **19**(5), 461–477.

Lavie, D. (2006), 'Capability reconfiguration: An analysis of incumbent responses to technological change', *Academy of Management Review* **31**(1), 153–174.

Learned, E., Christensen, C., Andrews, K. and Guth, W. (1969), *Business Policy: Text and Cases*, Homewood IL: Richard D. Irwin.

Lee, B., Collier, P. M. and Cullen, J. (2007), 'Reflections on the use of case studies in the accounting, management and organizational disciplines', *Qualitative Research in Organizations and Management: An International Journal* **2**(3), 169–178.

Lehrer, M. and Schmid, S. (2015), 'Germany's industrial family firms: Prospering islands of social capital in a financialized world?', *Competition & Change* **19**(4), 301–316.

Leonard-Barton, D. (1992), 'Core capabilities and core rigidities: A paradox in managing new product development', *Strategic Management Journal* **13**(1), 111–125.

Leuenberger, M. N. and Loss, D. (2001), 'Quantum computing in molecular magnets', *Nature* **410**(6830), 789.

Lieberson, S. and O'Connor, J. F. (1972), 'Leadership and organizational performance: A study of large corporations', *American Sociological Review* pp. 117–130.

Lincoln, Y. S. and Guba, E. G. (1985), *Naturalistic Inquiry*, Sage.

Lukoianova, T. and Rubin, V. L. (2014), 'Veracity roadmap: Is big data objective, truthful and credible?', *Advances in Classification Research Online* **24**(1), 4–15.

Marshall, C. and Rossman, G. B. (2014), *Designing qualitative research*, Sage publications.

McAfee, A., Brynjolfsson, E., Davenport, T. H., Patil, D. and Barton, D. (2012), 'Big data: The management revolution', *Harvard Business Review* **90**(10), 60–68.

McCoyd, J. L. and Kerson, T. S. (2006), 'Conducting intensive interviews using email: A serendipitous comparative opportunity', *Qualitative Social Work* **5**(3), 389–406.

McNamara, G., Vaaler, P. M. and Devers, C. (2003), 'Same as it ever was: the search for evidence of increasing hypercompetition', *Strategic Management Journal* **24**(3), 261–278.

Mell, P. and Grance, T. (2010), 'The NIST definition of cloud computing', *Communications of the ACM* **53**(6), 50.

Merriam, S. B. (1998), *Qualitative Research and Case Study Applications in Education*, ERIC.

Mezger, F. (2014), 'Toward a capability-based conceptualization of business model innovation: insights from an explorative study', *R&D Management* **44**(5), 429–449.

Miles, R. E. and Snow, C. C. (1994), *Fit, Failure, and the Hall of Fame: How Companies Succed or Fail*, New York, Free press.

Mintzberg, H. (1978), 'Patterns in strategy formation', *Management Science* **24**(9), 934–948.

Mohr, N., Morawiak, D., Köster, N. and Saß, B. (2017), 'Die Digitalisierung des deutschen Mittelstands', *Digital McKinsey* .

Mullins, J. W. (2007), 'Discovering "unk-unks"', *MIT Sloan Management Review* **48**(4), 17–21.

Musselwhite, K., Cuff, L., McGregor, L. and King, K. M. (2007), 'The telephone interview is an effective method of data collection in clinical nursing research: a discussion paper', *International Journal of Nursing Studies* **44**(6), 1064–1070.

Negnevitsky, M. (2005), *Artificial intelligence: a guide to intelligent systems*, Pearson Education.

Nelson, R. R. and Winter, S. (1982), 'A theory of economic change'.

Nonaka, I. and Takeuchi, H. (1995), *The knowledge-creating company: How Japanese companies create the dynamics of innovation*, Oxford university press.

Novick, G. (2008), 'Is there a bias against telephone interviews in qualitative research?', *Research in Nursing & Health* **31**(4), 391–398.

Owen-Smith, J. and Powell, W. W. (2004), 'Knowledge networks as channels and conduits: The effects of spillovers in the boston biotechnology community', *Organization Science* **15**(1), 5–21.

Oxford-Dictionary (2018), 'Virtual reality', Website. last checked: 10/05/2018.
URL: *https://en.oxforddictionaries.com/definition/virtual_reality*

O'Reilly, C. A. and Tushman, M. L. (2008), 'Ambidexterity as a dynamic capability: Resolving the innovator's dilemma', *Research in Organizational Behavior* **28**, 185–206.

Pace, S. (2013), 'Looking at innovation through cct glasses: Consumer culture theory and google glass innovation', *Journal of Innovation Management* **1**(1), 38–54.

Patton, M. Q. (1990), *Qualitative evaluation and research methods*, Sage publications.

Peteraf, M. A. and Barney, J. B. (2003), 'Unraveling the resource-based tangle', *Managerial and Decision Economics* **24**(4), 309–323.

Peteraf, M., Di Stefano, G. and Verona, G. (2013), 'The elephant in the room of dynamic capabilities: Bringing two diverging conversations together', *Strategic Management Journal* **34**(12), 1389–1410.

Piller, F. and Schoder, D. (1999), 'Mass customization und electronic commerce', *Zeitschrift für Betriebswirtschaft* **69**, 1111–1136.

Pisano, G. P. (2017), 'Toward a prescriptive theory of dynamic capabilities: connecting strategic choice, learning, and competition', *Industrial and Corporate Change* **26**(5), 747–762.

Ponterotto, J. G. (2005), 'Qualitative research in counseling psychology: A primer on research paradigms and philosophy of science.', *Journal of Counseling Psychology* **52**(2), 126–136.

Poole, D., Mackworth, A. and Goebel, R. (1997), *Computational intelligence: a logical approach*, Oxford University Press.

Porter, M. E. (1979), 'How competitive forces shape strategy', *Harvard Business Review* **57**(2), 137–145.

Porter, M. E. and Millar, V. E. (1985), 'How information gives you competitive advantage', *Harvard Business Review* **6**(4), 149–160.

Powell, W. W., Koput, K. W. and Smith-Doerr, L. (1996), 'Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology', *Administrative Science Quarterly* **41**(1), 116–145.

Prahalad, C. K. and Hamel, G. (1990), 'The core competence of the corporation', *Harvard Business Review* **68**(3), 79–91.

PwC (2016), 'What are the essential eight technologies?', Website. last checked: 10/05/2018.
URL: *http://usblogs.pwc.com/emerging-technology/a-guide-to-the-essential-eight-emerging-technologies/*

Richardson, G. B. (1972), 'The organisation of industry', *The Economic Journal* **82**(327), 883–896.

Romanelli, E. and Tushman, M. L. (1994), 'Organizational transformation as punctuated equilibrium: An empirical test', *Academy of Management Journal* **37**(5), 1141–1166.

Rosenbloom, R. S. (2000), 'Leadership, capabilities, and technological change: The transformation of NCR in the electronic era', *Strategic Management Journal* **21**(10–11), 1083–1103.

Rosenkopf, L. and Nerkar, A. (2001), 'Beyond local search: boundary-spanning, exploration, and impact in the optical disk industry', *Strategic Management Journal* **22**(4), 287–306.

Ross, J. W., Beath, C. M. and Sebastian, I. M. (2017), 'How to develop a great digital strategy', *MIT Sloan Management Review* **58**(2), 7.

Rouse, M. J. and Daellenbach, U. S. (1999), 'Rethinking research methods for the resource-based perspective: Isolating sources of sustainable competitive advantage', *Strategic Management Journal* **20**(5), 487–494.

Rubin, H. J. and Rubin, I. S. (2011), *Qualitative interviewing: The art of hearing data*, Sage.

Rush, P. (2014), *The Metaphysics of Logic*, Cambridge University Press.

Russell, S. J., Norvig, P., Canny, J., Malik, J. and Edwards, D. (2002), *Artificial Intelligence: A Modern Approach (2nd Edition)*, Prentice Hall.

Ryan, P. and Dundon, T. (2008), 'Case research interviews: Eliciting superior quality data', *International Journal of Case Method Research and Application* **4**, 443–450.

Salvato, C. (2003), 'The role of micro-strategies in the engineering of firm evolution', *Journal of Management Studies* **40**(1), 83–108.

Saunders, M., Lewis, P., Thornhill, A. and Wilson, J. (2009), 'Business research methods', *Financial Times, Prentice Hall: London* .

Scheele, B. and Groeben, N. (1988), *Dialog-Konsens-Methoden zur Rekonstruktion Subjektiver Theorien: die Heidelberger Struktur-Lege-Technik (SLT), konsuale Ziel-Mittel-Argumentation und kommunikative Flußdiagramm-Beschreibung von Handlungen*, Francke.

Schwab, K. (2015), 'Are you ready for the technological revolution?', Website. last checked: 03/05/2018.
URL: *https://www.weforum.org/agenda/2015/02/are-you-ready-for-the-technological-revolution/*

SDxCentral (2018), '5G', Website. last checked: 10/05/2018.
URL: *https://www.sdxcentral.com/5g/?c*$_a$*ction = num*$_b$*all*

Shenton, A. K. (2004), 'Strategies for ensuring trustworthiness in qualitative research projects', *Education for information* **22**(2), 63–75.

Skinner, W. (1969), 'Manufacturing - missing link in corporate strategy', *Harvard Business Review* **47**(3), 136–145.

Spanos, Y. E., Zaralis, G. and Lioukas, S. (2004), 'Strategy and industry effects on profitability: evidence from greece', *Strategic Management Journal* **25**(2), 139–165.

Stake, R. E. (1995), *The art of case study research*, Sage.

Strauss, A. L. (1987), *Qualitative analysis for social scientists*, Cambridge University Press.

Sturges, J. E. and Hanrahan, K. J. (2004), 'Comparing telephone and face-to-face qualitative interviewing: A research note', *Qualitative Research* **4**(1), 107–118.

Tashakkori, A. and Creswell, J. W. (2007), *Exploring the nature of research questions in mixed methods research*, Sage publications, Los Angeles, CA.

Taylor, F. W. (1911), 'Principles and methods of scientific management', *Journal of Accountancy* **12**(2), 117–124.

Teece, D. J. (1986), 'Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy', *Research Policy* **15**(6), 285–305.

Teece, D. J. (1998), 'Capturing value from knowledge assets: The new economy, markets for know-how, and intangible assets', *California Management Review* **40**(3), 55–79.

Teece, D. J. (2007), 'Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance', *Strategic Management Journal* **28**(13), 1319–1350.

Teece, D. J., Pisano, G. and Shuen, A. (1997), 'Dynamic capabilities and strategic management', *Strategic Management Journal* **18**(7), 509–533.

Thomas, A. B. (1988), 'Does leadership make a difference to organizational performance?', *Administrative Science Quarterly* **33**(3), 388–400.

Tilson, D., Lyytinen, K. and Sørensen, C. (2010), 'Research commentary—digital infrastructures: The missing is research agenda', *Information Systems Research* **21**(4), 748–759.

Trendexplorer (2018), 'Quantum Computing', Website. last checked: 10/05/2018.
URL: *https://www.trendexplorer.com/en/*

Tripsas, M. and Gavetti, G. (2000), 'Capabilities, cognition, and inertia: Evidence from digital imaging', *Strategic Management Journal* **21**(10–11), 1147–1161.

Trochim, W. M. (1989), 'Outcome pattern matching and program theory', *Evaluation and Program Planning* **12**(4), 355–366.

Tushman, M. L. and Anderson, P. (1986), 'Technological discontinuities and organizational environments', *Administrative Science Quarterly* **31**(3), 439–465.

Uzzi, B. (1997), 'Social structure and competition in interfirm networks: The paradox of embeddedness', *Administrative science quarterly* **42**(1), 35–67.

Vaquero, L. M., Rodero-Merino, L., Caceres, J. and Lindner, M. (2008), 'A break in the clouds: towards a cloud definition', *ACM SIGCOMM Computer Communication Review* **39**(1), 50–55.

Vargo, S. L. and Lusch, R. F. (2004), 'Evolving to a new dominant logic for marketing', *Journal of Marketing* **68**(1), 1–17.

VDMA (2017), *Maschinenbau in Zahl und Bild 2017*.

Vivas López, S. (2005), 'Competitive advantage and strategy formulation: The key role of dynamic capabilities', *Management Decision* **43**(5), 661–669.

Von Hippel, E. (1986), 'Lead users: a source of novel product concepts', *Management Science* **32**(7), 791–805.

Wang, C. L. and Ahmed, P. K. (2007), 'Dynamic capabilities: A review and research agenda', *International Journal of Management Reviews* **9**(1), 31–51.

Wee, D., Kelly, R., Cattel, J. and Breunig, M. (2015), 'Industry 4.0—how to navigate digitization of the manufacturing sector', *McKinsey & Company* **58**.

Weiner, N. (1978), 'Situational and leadership influences on organization performance.', pp. 230–234.

Wernerfelt, B. (1984), 'A resource-based view of the firm', *Strategic Management Journal* **5**(2), 171–180.

White, R. E. (1986), 'Generic business strategies, organizational context and performance: An empirical investigation', *Strategic Management Journal* **7**(3), 217–231.

Williamson, O. E. (1999), 'Strategy research: governance and competence perspectives', *Strategic Management Journal* **20**(12), 1087–1108.

Wilson, J. (2015), 'What Is a Robot, Anyway?', Website. last checked: 10/05/2018.
URL: *https://hbr.org/2015/04/what-is-a-robot-anyway*

Winter, S. G. (2003), 'Understanding dynamic capabilities', *Strategic Management Journal* **24**(10), 991–995.

Wright, P., Kroll, M., Tu, H. and Helms, M. (1991), 'Generic strategies and business performance: an empirical study of the screw machine products industry', *British Journal of Management* **2**(1), 57–65.

Yin, R. K. (2009), *Case study research design and methods*.

Yin, R. K. (2017), *Case study research and applications: Design and methods*, Sage.

Yoo, Y., Henfridsson, O. and Lyytinen, K. (2010), 'Research commentary—the new organizing logic of digital innovation: an agenda for information systems research', *Information Systems Research* **21**(4), 724–735.

Zahra, S. A., Sapienza, H. J. and Davidsson, P. (2006), 'Entrepreneurship and dynamic capabilities: A review, model and research agenda', *Journal of Management Studies* **43**(4), 917–955.

Zander, U. and Kogut, B. (1995), 'Knowledge and the speed of the transfer and imitation of organizational capabilities: An empirical test', *Organization Science* **6**(1), 76–92.

Zollo, M. and Winter, S. G. (2002), 'Deliberate learning and the evolution of dynamic capabilities', *Organization Science* **13**(3), 339–351.

Zott, C. (2003), 'Dynamic capabilities and the emergence of intraindustry differential firm performance: insights from a simulation study', *Strategic Management Journal* **24**(2), 97–125.

Zott, C. and Amit, R. (2007), 'Business model design and the performance of entrepreneurial firms', *Organization Science* **18**(2), 181–199.

Appendices

A Overview of some of the most important technology trends accompanying digitalisation

To shed light on concepts for which little academic research has yet taken place, to demonstrate differences and to highlight links to possible practical applications in a mechanical engineering context, we have compiled an overview on major trends accompanying digitalisation. Following few existing academic insights, we rather seek for a description aiming to capture the core purpose of each and do not claim to provide generalisable definitions.

Category	**Technology**	**Description**	**Mechanical Engineering Use-Case Example**
Data, computational power, and connectivity	Internet of Things	The Internet-of-Things (IoT) is broadly used to refer to the following (Atzori et al. (2010)): • a set of technologies including, e.g., RFIDs, sensor/actuators, machine-to-machine communication devices, etc., • a global network interconnecting smart objects by means of extended internet technologies, • the ensemble of applications and services leveraging such technologies to open new business and market opportunities. From (i) to (iii) the sense of the definitions expands. The term "Industrial IoT (IIoT)" refers to the use of IoT in the mechanical engineering and industrial sectors. IIoT adds sensors to people, places, processes, and products across a value chain to capture and analyze information to advance the goals of the organization (PwC, 2016).	Continuous sensor-based collection of data about the wear of production machines

Category	**Technology**	**Description**	**Mechanical Engineering Use-Case Example**
Data, computational power, and connectivity	Big Data	The development of a all-encompassing definition of "Big Data" is still in a nascent stage. Broadly, "Big Data" can be defined as the information asset characterised by such a high volume, velocity and variety to require specific technology and analytical methods for its transformation into value (De Mauro et al. (2016), Gandomi and Haider (2015), McAfee et al. (2012)). Recently, academics complement this definition by the characteristic of veracity which describes how accurate the data is in predicting business value (Lukoianova and Rubin (2014), Buhl et al. (2013)). In general, big data includes structured as well as unstructured data.	Storage and processing of sensor-based machine data in production facility

Category	**Technology**	**Description**	**Mechanical Engineering Use-Case Example**
Data, computational power, and connectivity	Cloud technology	Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Mell and Grance (2010), Armbrust et al. (2009), Buyya et al. (2009), Vaquero et al. (2008)). This cloud model is composed of five essential characteristics (on-demand self service, broad network access, resource pooling, rapid elasticity, measured service), three service models (Software as a service, platform as a service, infrastructure as a service), and four deployment models (private cloud, community cloud, public cloud, hybrid cloud) (Mell and Grance (2010)).	Cloud-based software-as-a-service business models to complement the sale of tangible machines
Data, computational power, and connectivity	Social Media	Social media is an online environment where content is created, consumed, promoted, distributed, discovered or shared for purposes that are primarily related to communities and social activities rather than to functional, task-oriented objectives. "Media", in this context, represents an environment characterised by storage and transmission, while "social" describes the distinct way these messages propagate in a one-to-many or many-to-many fashion. (Gartner (2018*c*))	New networking, distribution and recruiting channels

Category	**Technology**	**Description**	**Mechanical Engineering Use-Case Example**
Data, computational power, and connectivity	5G	5G is the term used to describe the next-generation of mobile networks beyond the 4G LTE mobile networks of today. It is assumed that 5G networks will not become commercially available until the 2020 timeframe. (SDxCentral (2018))	Better connections to compute resources in the cloud and connectivity among devices, leading to greater reliability and efficiency
Data, computational power, and connectivity	Edge Computing	"Edge Computing" refers to the computing infrastructure that exists close to the sources of data, for example, industrial machines (e.g. wind turbine, magnetic resonance (MR) scanner, undersea blowout preventers), industrial controllers such as SCADA systems, and time series databases aggregating data from a variety of equipment and sensors. These devices typically reside away from the centralized computing available in the cloud. (GE (2018))	Computing infrastructure integrated in automated heavy-lifting machinery to analyse data closest to the source of collection
Data, computational power, and connectivity	Distributed Ledger Technology	An "Electronic Ledger" is a distributed electronic database that uses software algorithms to record and confirm transactions with reliability and anonymity. The record of events is shared between many parties and information once entered cannot be altered, as the downstream chain reinforces upstream transactions. This technology is also often referred to as Blockchain. (PwC (2016))	New forms of supply chain management allow recording of all important product information along throughout the entire delivery process

Category	**Technology**	**Description**	**Mechanical Engineering Use-Case Example**
Data, computational power, and connectivity	Quantum computing	Quantum computer exploit the parallelism of quantum mechanics to effect computation (Leuenberger and Loss (2001)). Data is held in qubits (quantum bits), which have the ability to hold all possible states simultaneously. This property, known as "superposition," gives quantum computers the ability to operate exponentially faster than conventional computers as word length is increased. Data held in qubits is affected by data held in other qubits, even when physically separated. This effect is known as "entanglement." (Gartner (2018*b*)). In the future, the processing power of quantum computer will be accessible via cloud technology (Trendexplorer (2018)).	Data center of D-Wave Systems

Category	**Technology**	**Description**	**Mechanical Engineering Use-Case Example**
Analytics and intelligence	Artificial Intelligence	Artificial intelligence is a science that has defined its goal as making machines do things that would require intelligence if done by humans. A machine is considered intelligent if it can achieve human-level performance in some cognitive task (Negnevitsky (2005), Russell et al. (2002), Poole et al. (1997)). One distinguishes between "Expert Systems" and so-called "Artificial Neural Networks". Expert System which can neither learn nor improve themselves through experience, are individually created and demand large efforts for their development. Artificial Neural Networks are inspired by the biological neural structure and functions of the human brain, are able to learn from historical cases and make it possible to generate rules automatically, and thus avoid the tedious and expensive processes of knowledge acquisition, validation and revision (Negnevitsky (2005)).	Automated evaluation of machine data to predict the necessity of maintenance
Analytics and intelligence	Machine learning	"Machine Learning" is a subset of "Artificial Intelligence" (PwC (2016)). It involves adaptive mechanisms that enable computers to learn from experience, learn by example and learn by analogy. The most popular approaches to machine learning are artificial neural networks and genetic algorithms (Negnevitsky (2005)).	Reassignment of new functions for robots by demonstrating the machine a new task

Category	**Technology**	**Description**	**Mechanical Engineering Use-Case Example**
Analytics and intelligence	Advanced Analytics	Advanced Analytics is the autonomous or semi-autonomous examination of data or content using sophisticated techniques and tools, typically beyond those of traditional business intelligence (BI), to discover deeper insights, make predictions, or generate recommendations. Advanced analytic techniques include those such as data/text mining, machine learning, pattern matching, forecasting, visualization, semantic analysis, sentiment analysis, network and cluster analysis, multivariate statistics, graph analysis, simulation, complex event processing, neural networks. (Gartner (2018*a*))	
Digital-to-physical conversion	Advanced Robotics	Advanced robotics comprises industrial and service robots. They are distinguished depending on the area of application. Industrial robots are defined as an "automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications." (Wilson (2015)) Service robots perform useful tasks for humans or equipment in all sectors excluding industrial automation applications. (ISO (2012))	Welding robot for assembling vehicle bodies in a car production line
Digital-to-physical conversion	Additive Manufacturing	"Additive Manufacturing" (AM) is defined as the "process of joining materials to make objects from three-dimensional (3D) model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies". (ASTM (2010))	3D printing of spare parts at the operating site

Category	**Technology**	**Description**	**Mechanical Engineering Use-Case Example**
Human-machine interaction	Virtual Reality	The computer-generated 3D simulation of a three-dimensional image or environment that can be interacted within a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors. (Oxford-Dictionary (2018))	Digital showroom of a manufacturer to demonstrate the use of machines
Human-machine interaction	Augmented Reality	“Augmented reality” (AR) is a visual and/or audio “overlay” on the physical world that uses contextualized digital information to augment the viewer’s real-world view. (PwC (2016)) AR systems have the following properties (Azuma et al. (2001)): • combine real and virtual objects in a real environment, • run interactively and in real time, and • register (align) real and virtual objects with each other.	AR-enabled smart glasses help service technicians to replace spare parts

B Interview partner

Purpose	Position	Firm	Interview type	Date
Pre-study	CEO	Consulting GmbH	Face-to-face	16/02/2018
Pre-study	Consultant	Consulting GmbH	Face-to-face	16/02/2018
Pre-study	Consultant	Consulting GmbH	Face-to-face	16/02/2018
Pre-study	Consultant	Consulting GmbH	Face-to-face	23/03/2018
Pre-study	Consultant	Consulting GmbH	Face-to-face	23/03/2018
Pre-study	Consultant	Consulting GmbH	Face-to-face	23/03/2018
Main study	CMO	Alpha KG	Telephone	06/04/2018
Main study	CIO	Beta GmbH	Telephone	10/04/2018
Main study	Head of Digitalisation	Gamma GmbH & Co. KG	Telephone	11/04/2018
Main study	Vice President Technology	Delta AG	Telephone	12/04/2018
Main study	CEO	Epsilon GmbH	Telephone	13/04/2018
Main study	Head of Strategy	Zeta AG	Telephone	16/04/2018
Main study	Director Digital Transformation	Eta GmH & Co. KG	Telephone	17/04/2018
Main study	Head of Corporate Strategy	Theta KG	Skype	17/04/2018
Main study	Senior Inhouse Consultant	Iota SE	Telephone	18/04/2018
Main study	Vice President Corporate Development	Kappa AG	Telephone	25/04/2018
Main study	CEO	Lambda GmbH	Face-to-face	26/04/2018
Post study	Senior Director Digitalization & Strategy	Mu GmbH	Telephone	30/04/2018
Post study	CEO	Ny GmbH	Telephone	02/05/2018
Post study	CEO	Xi GmbH	Telephone	03/05/2018
Post study	CEO	Omnikron GmbH	Telephone	07/05/2018

C Interview guide

The questions below were used to guide the conversation. This ensured certain elements of particular interest were covered in more or less detail as the guide was adapted to fit the respondents' background and his firm's context.

1. Digitalisation is on everyone's lips. What do you understand by digitalisation?
2. What is the relevance of digitalisation in your industry and especially in your company?
3. Please describe your function and how you are involved in the digitalisation process of your company.
4. Please describe (if available) an example of a digitalisation project (already implemented / currently being implemented / currently being planned) of your company with the greatest strategic relevance or the greatest influence for the future of your company.
5. What effects does digitalisation has on the strategic orientation of your company (for example: seeking cost leadership, performance leadership or differentiation)?
6. How do you determine if a reorientation of the corporate strategy is necessary and what is the process of reformulation?
7. Where do you currently see your firm's competitive advantage and how does digitalisation help you to strengthen it? Do you see an opportunity to build new forms of competitive advantage through digitalisation (e.g. better meeting customer needs, access to new resources, distribution channels, relationships with other market participants)?
8. To what extent can digitalisation help increase your company's sales and profits?
9. What experiences did you have with the implementation of digitalisation projects and what were the biggest challenges in their implementation?
10. How do your existing skills in the organisation (such as cross-functional collaboration, organisational learning, close customer contact) help you meet the challenges of digitalisation and achieve your strategic goals?
11. What steps do you take to close any capability gaps?
12. Which process supports the anticipation of new opportunities and risks in the context of digitalisation in your company?

13. How do you use new information for your company? How do you draw conclusions from it?

14. Do you see the opportunities of digitalisation more in the development of novel products and services, or in innovation in the field of production methods for manufacturing your machines?

15. How does digitalisation affect the degree of innovation of new products (e.g., incremental optimisation of existing products vs. radical new offerings)?

16. How has digitalisation changed existing production processes?

17. Which role do direct customers and end consumers, suppliers, competitors, complementary suppliers and industry associations play in the new product development process (e.g. cooperation and information exchange)?