Technology Design Selection and Technology Pivots in Digital Startups

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Nicolai Bohn, M. Sc.

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Nicolai Bohn

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Author's Publications Relevant to this Thesis

1. Bohn, N., Kundisch, D. 2019. "All Things Considered? – Technology Design Decision-making Characteristics in Digital Startups", in: *Proceedings of the Fortieth International Conference on Information Systems (ICIS)*, Munich, Germany.
   https://aisel.aisnet.org/icis2019/innov_entre/innov_entre/3/

2. Bohn, N., Kundisch, D. 2020. "What Are We Talking About When We Talk About Technology Pivots? – A Delphi Study", in: *Information & Management*.
   https://doi.org/10.1016/j.im.2020.103319

3. Bohn, N., Kundisch, D. 2018a. "The Role of Technology Pivots in Software Startups: Antecedents and Consequences", in: *Proceedings of the Twenty Fifth European Conference on Information Systems (ECIS)*, Portsmouth, UK.
   https://aisel.aisnet.org/ecis2018_rp/130/

4. Bohn, N., Kundisch, D. 2018b. "An Extended Perspective of Technology Pivots in Software Startups: Towards a Theoretical Model", in: *Proceedings of the Thirty Ninth International Conference on Information Systems (ICIS)*, San Francisco, USA.
   https://aisel.aisnet.org/icis2018/innovation/Presentations/8/

5. Bohn, N. 2019. "Do Digital Startups Prepare for Technology Pivots? – An Initial Analysis of Job Adverts", in: *Proceedings of the Twenty-fifth Americas Conference on Information Systems (AMCIS)*, Cancun, Mexico.
   https://aisel.aisnet.org/amcis2019/ebusiness/ebusiness/6/

Author's Publications not Relevant to this Thesis

6. Hatzijordanou, N., Bohn, N., Terzidis, O. 2019. "A Systematic Literature Review on Competitor Analysis: Status Quo and Start-up Specifics", in: Management Review Quarterly (69:4), pp. 415–458.
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Synopsis

1. Motivation

> *"Let's seek to understand how the new generation of technology companies are doing what they do, what the broader consequences are for businesses and the economy and what we can collectively do to expand the number of innovative new software companies created in the U.S. and around the world."*
>
> *Marc Andreessen (2011), General Partner at Andreessen Horowitz*

Novel digital technologies, which are constantly evolving, provide entrepreneurs with the opportunity to create innovative digital products and services. To name but a few, some of the digital startups founded in recent years, such as Coinbase, Gitlab, Heroku, or Snap, now serve millions of users and customers as a result of seizing these opportunities effectively. Entrepreneurs intent on using these opportunities are faced with fundamental choices which, in turn, have a decisive influence on the development of their endeavors. In particular for digital startups, which aim to build products and services that are entirely digitized, marketed and delivered through digital channels (Steininger 2019), one such fundamental choice involves selecting their first technology design. It is fundamental because the design of the technology provides the technological foundation for their offering in form of building blocks, such as programming languages, components, platforms and development frameworks (IEEE 1990; Schulte-Althoff et al. 2019; Soliman et al. 2015). Once the design is decided, digital startups invest all of their efforts into developing their offering on this technological foundation, with a view to providing a competitive and stand-out product or service of unique value to their users and customers.

Hence, the selection of a technology design represents a significant challenge for digital startups, because of the distinct circumstances they face. First, they may only have a partial understanding of the current needs of their potential customers and the solution required to meet these needs. Consequently, digital startups have to base their technology design decision on a set of assumptions rather than on clear requirements (Klotins et al. 2019). Second, there are many potential technology design options to choose from or to conceptualize (Stackshare 2019), each with its own capabilities, restrictions, and differing degrees of complexity, all of which require time to explore and assess. Third, once a technology design choice has been made and is starting to be implemented, it inherently defines, and even restricts, the space of what can be built, and dependencies among parts of the technology design are created that are not easily resolvable (Giardino et al. 2014; Kraus et al. 2019). Fourth, apart from technological uncertainty, digital startups are also embedded in an environment of high market uncertainty, such as shifting customer needs and upcoming new competitors, adding even more complexity to their technology design decision-making (Mohr et al. 2010; Packard et al. 2017; Steininger 2019). Given the far-reaching implications for the success of their endeavor, and the limited resources available to them at the outset (Klotins et al. 2018; Sutton 2000), it comes as no surprise that digital startups are often concerned about selecting a suitable technology design (Giardino et al. 2015; Wang et al. 2016).

After the selection of their first technology design, digital startups often have to adapt or change their initial design in response to changing circumstances and new learnings generated (van Gurp and Bosch

2002; Klotins et al. 2019). This means, technology design decisions in digital startups are not one-off decisions but may be iterative. Each technology design choice has considerable influence on the feasibility of functionalities and quality attributes of the offerings of digital startups (IEEE 1990), and affects the efficiency of product engineering and the timeliness of product releases – among others (Klotins et al. 2018). Combined, these aspects are able to significantly affect the ability of digital startups to grow into viable and sustainable businesses and, in a worst-case scenario, even negate a digital startup’s efforts, resulting in failure (Giardino et al. 2016; Saukkonen et al. 2016; van der Ven and Bosch 2013).

Given the prevailing uncertainties faced by digital startups surrounding their technology designs and business-related aspects, many digital startups use an iterative and hypothesis-driven approach of venture creation and product development – namely, the Lean Startup Approach – which supports them with reducing uncertainties and generating new learnings (Ghezzi 2019). As part of the Lean Startup Approach, falsifiable hypotheses about the customer needs, technology design, and business model – among others – are created, based on which experiments are designed and performed to engage with customers, collect data points and consequently, accept or reject hypotheses and thus generate new learnings.

If, after having selected and implemented a technology design, new learnings are being generated that require digital startups to adjust their technology design, the Lean Startup Approach facilitates such change by providing the means for structured technological adjustments through so-called technology pivots (Bajwa et al. 2017; Klotins et al. 2018; Unterkalmsteiner et al. 2016). A technology pivot allows to adjust significant parts of the technology design. One well-known example for a digital startup having performed a technology pivot is Twitter. Twitter pivoted from a monolith to a scalable micro-services architecture after experiencing high usage growth. They aimed to provide better performance, reliability and efficiency to their users and customers, as well as gain clearer boundaries between parts of their system and avoid failures to spread across their infrastructure (Aniszczyk 2013). Technology pivots, such as the one performed by Twitter, are an inevitable consequence of the uncertainties associated with starting a new venture, including user and customer expectations and behavior, the required solution and their respective interrelations with a suitable business model. As such, performing one or more technology pivots represents the rule in digital startups rather than an exception (Ries 2011, 2017).

This, however, does not mean that they are an easy to perform measure. Each technology pivot represents a substantial investment in terms of time and resources, requires stakeholder management (Hampel et al. 2019), and must be well planned and executed. Since digital startups act under considerable time pressure and often with limited resources, there are only small margins for errors and delays. Combined with an incomplete understanding about what pivoting entails, and little to no experience in performing them, this leads to a situation in which digital startups “avoid pivot[s] when needed” (Bajwa et al. 2016, p. 170) or “wait until far too late to consider a pivot. [Until] the roof is on fire [and] the walls are caving in” (Ries 2011, p. 110). This suggests that a good education about and deep understanding of technology pivots are extremely valuable for digital startups.

While digital entrepreneurship research has begun to scientifically investigate the Lean Startup Approach, in which Ries draws its arguments mostly from recalling past cases and anecdotal evidence

(Frederiksen and Brem 2017; Ghezzi 2019; Ghezzi and Cavallo 2018), several researchers have started to present digital entrepreneurship-related research agendas focusing on the individual components of the Lean Startup Approach that need further analysis, including technology pivots, and technology designs in digital startups in general (Berg et al. 2018; Steininger 2019; Unterkalmsteiner et al. 2016). First, the question of how technology design decisions are made, and the role of human behavior in this decision-making, are generally under-researched (Razavian et al. 2019; Zaheer et al. 2019). Unterkalmsteiner et al. (2016) particularly stress the need to understand technology design decision-making in the digital startup context, and the considerable impact that the individuals constituting the startup team have on key decisions (Forbes et al. 2006). Second, while first empirical studies have analyzed individual types of pivot (Bajwa, Wang, Nguyen Duc, Matone Chanin, et al. 2017; Khanna et al. 2018; Terho et al. 2015), motivated by the fact that "the boundaries between the different types of pivot can be blurry, and sometimes it may even be difficult to determine into which category a pivot belongs" (Terho et al. 2015, p. 560), no studies have comprehensively and scientifically conceptualized the term technology pivot (Berg et al. 2018; Unterkalmsteiner et al. 2016). Especially for digital startups, for whom technologies form the core of their value creation (Nambisan 2017; Steininger 2019), a clear understanding of what a technology pivot entails is of great importance, particularly for effective decision-making and the ability to grow into a viable and sustainable business. Third, the characteristics of technology pivots, including their antecedents and consequences as well as their business model impact, are widely unknown (Berg et al. 2018; Unterkalmsteiner et al. 2016), making it hard to derive what technology pivots precisely are and what to expect from them. An imprecise conceptualization of technology pivots also hinders the support offered by coaches and investors before, during, and after technology pivots have been conducted. An empirically grounded understanding of the characteristics of technology pivots, including their business model impact, would also allow for theory development explaining the circumstances under which it is beneficial to perform technology pivots, as well as how to prepare for and perform them.

This dissertation contributes to this literature by presenting five research papers. The first investigates decision-making characteristics in the initial technology design selection in digital startups with a view to increasing our understanding of how technology design decisions in digital startups are made and can subsequently be evaluated (Bohn and Kundisch 2019). The second paper explores a contemporary understanding of technology pivots by conducting a Delphi study with an extensive expert panel and creates a scientifically derived conceptualization (Bohn and Kundisch 2020). The third paper investigates the antecedents and consequences that lead up to, and result from, the performance of technology pivots, and their business model impact (Bohn and Kundisch, 2018a). The fourth paper validates and extends these findings by using a quantitative research approach (Bohn and Kundisch, 2018b). The quantitative nature of this study allowed to collect a larger quantity of empirical data on technology pivot instances which, up to this point, had been one of the gaps in the available literature. The fifth and final paper focuses on the composition of the teams needed to successfully perform technology pivots by investigating the extent to which the antecedents of technology pivots form part of the IT job advertisements of digital startups (Bohn 2019). To advance the nascent research in these areas, this dissertation adopts predominantly qualitative and exploratory research designs to collect data and derive findings based on empirical evidence.

This synopsis is structured as follows: Section 2 presents the core concepts that form part of the individual studies of this dissertation. Section 3 reviews the body of literature relevant to the phenomena of interest and presents the identified research gaps. Section 4 includes an elaboration of the methodological approaches adopted in this dissertation. Section 5 provides an overview of the five papers of this dissertation, including a summary with detailed information on the contribution of co-authors and the scientific dissemination undertaken in the form of presentations and publications. Section 6 includes a reflection on the methodological approaches adopted in this dissertation. Finally, Section 7 summarizes the implications of these efforts for research and practice, highlights the limitations of the research conducted, and offers directions for future research.

2. Conceptual Basics[1]

2.1 Digital Startups, Uncertainty and Team Composition

Digital technologies are integrated into an ever-increasing range of business and consumer-focused products and services, expanding the role and relevance of information technology for any innovation (Nambisan 2013; Nambisan et al. 2017; Steininger 2019). As early as the mid-1990s, small software companies were recognized as being remarkably successful in creating and offering innovative products and services by using digital technologies (Carmel 1994). Today, following a recent definition by Steininger (2019), these companies are called digital startups[2]. Digital startups are immature and inexperienced organizations with a short operating history and limited resources (Klotins et al. 2018; Sutton 2000). Their aim is to develop innovative software-based products and services utilizing digital technologies, to create novel offerings that are superior to existing ones in the market, or to address unmet or newly revealed customer needs (Edison et al. 2018). As part of this, a digital startups' value creation and business model rely entirely on digital technologies (Steininger 2019). Utilizing emerging digital technologies lends them a unique technological advantage and helps them realize offerings that have a distinct value proposition. With these offerings, they then aim to reach users and customers globally through digital channels (Tanev 2017). While facing "resource-intensive challenges" (Steininger 2019, p. 369) and obtaining only limited resources themselves, they have to perform under intense time-pressure in a resource-efficient manner (Paternoster et al. 2014).

Digital startups are typically initiated by two or more individuals with an equity stake in the firm (Kamm et al. 1990), constituting the founders or the founding team of a digital startup (Klotz et al. 2013). They leverage their business and technological competencies, domain knowledge and prior experiences to initialize and pursue new ventures (Zaheer et al. 2019). They are responsible for taking all major decisions concerning the digital startup and as such have a significant impact on the strategy, product

[1] The concepts presented in this section represent the foundation for the contributions of Bohn and Kundisch (2018a, 2018b, 2019, 2020), and Bohn (2019). They therefore show similarities and overlaps in content.

[2] In research prior to Steininger (2019), this type of startup was commonly referred to as *software startups* (Bosch et al. 2013; Giardino et al. 2015; Unterkalmsteiner et al. 2016; Wang et al. 2016). But following Steininger (2019), who provides nuanced definitions of different types of IT-related startups, and other recent examples in the literature, I adopted his terminology.

offering, technology design, and overall growth of the firm (Eisenhardt and Schoonhoven 1990). Since the circumstances of digital startups are considerably different from those of established businesses, in terms of the uncertainties surrounding the organization, digital startups need to carefully compose context-specific teams, beyond the founding team, whose members are comfortable with handling uncertainty and capable of responding and adjusting an organization quickly when needed (Kollmann et al., 2009). Consequently, suitable character traits, as well as relevant professional experience prior to joining the venture, are decisive factors – among others – for an individual's suitability for joining a digital startup team (Beckman and Burton 2008; Roach and Sauermann 2015). Given the high level of influence of each individual employee on decisions and the development of digital startups, the selection of employees is a critical task (Giardino et al. 2015; Kollmann et al. 2009) and the recruitment of wrong employees remains a common reason for their failure (CB Insights 2018).

During their endeavor, digital startups are faced with three types of uncertainties (Mohr et al. 2010; Packard et al. 2017). First, they face *market uncertainty*, that is, digital startups begin with an incomplete knowledge about the problem to be solved and the solution required to fulfill customer needs (Ojala 2016; Pantiuchina et al. 2017), which may even change over time (Tatikonda and Rosenthal 2000). Second, they need to handle *technology uncertainty*, that is, be able to understand and evaluate which technologies are suitable to reaching a specific objective, how individual technologies will develop in the future, and follow up on which new technologies are arising (Saukkonen et al. 2016; Schilling 2002). As a result of the unpredictability of technology, digital startups can get "caught up in the wave of technological change" (Unterkalmsteiner et al. 2016, p. 91), in which superior digital technologies emerge or existing technologies become outdated quickly. To technologically address user and customer needs, for which no clear requirements exist yet, and make crucial decisions about the technology design, represents a considerable challenge for digital startups (Giardino et al. 2014, 2015). Finally, *competitive uncertainty*, that is, knowing and understanding which direct and indirect competitors exist and how they might act in the future (Gur and Greckhamer 2019; Hatzijordanou et al. 2019). This aspect is particularly important in consideration of business model creation aspects in digital startups. Digital startups are searching for a "scalable, repeatable, [and] profitable business model" to suit their products and services (Blank and Dorf, 2012, p. xvii). As such, the assessment of viable business model alternatives, and differentiators to existing offerings in the market, play a crucial role for digital startups (Ojala 2016; Standing and Mattsson 2018). Considering the breathtaking pace of today's digital technologies, evolving market demands, and intense competition, the ability to quickly change one's own offerings to keep up with technological changes and to meet emerging customer needs has become of paramount importance not only for large enterprises but also for digital startups (Bianchi et al. 2018; Zott et al. 2011; Zott and Amit 2007). In spite of all the challenges related to their endavors, the success of digital startups continues unabatedly. Today, digital startups account for the bulk of startups valued at US$ 1 billion or more (CB Insights 2019a).

2.2 Technology Designs

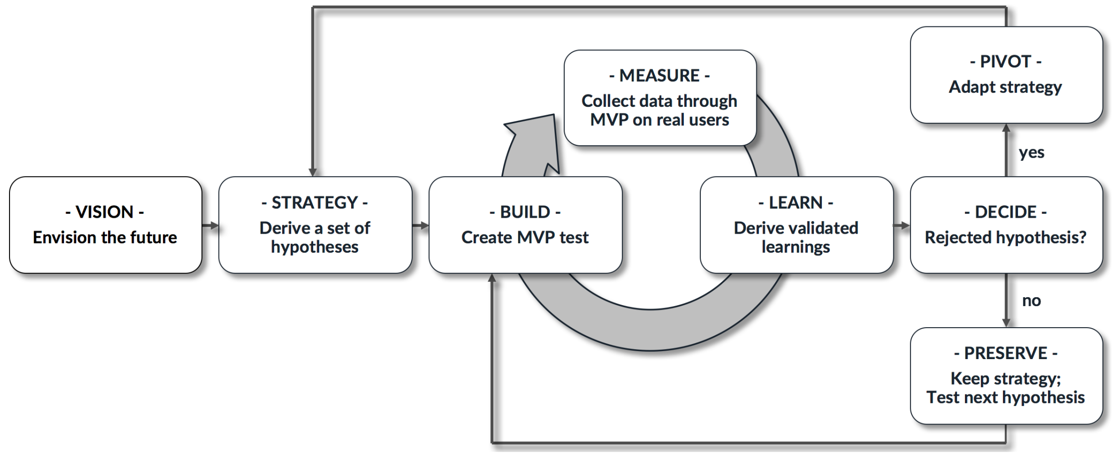
The technology design of digital startups represents the foundation for the development of products and services (Soliman et al. 2015). It provides the technological building blocks to be used during development and includes "concrete technology solutions" (Soliman et al., 2016, p. 128). The design selection itself involves the "process of defining the architecture, components, interfaces, and other characteristics of a system" (IEEE 1990, p. 25) and consists of identifying and selecting individual technologies, programming languages, platforms and development frameworks, among other elements supporting the construction of the product (Klotins et al. 2019; Razavian et al. 2019). In practice, a technology design is commonly referred to as a *technology stack* (Schulte-Althoff et al. 2019; Stackshare 2019).

Digital startups can choose from a variety of technology design alternatives as the basis for creating their own (Stackshare 2019). Evaluating different alternatives requires investigating their respective benefits and drawbacks (e.g., weighing up performance and reliability, development speed and extensibility, Giardino et al. 2016) before deciding on the selection (van der Ven et al. 2011). Design decisions have to take into account not only current goals but also the future evolution of the components and the potential occurrence of technological alternatives (Schlichte et al. 2019). Both aspects are fraught with uncertainty for digital startups (Saukkonen et al. 2016). The ability to assess design options is therefore crucial, and the challenge of defining a technology design which allows to build a first product version often "precedes any market or business-related difficulties" (Klotins et al. 2019, p. 1). Once made, the technology design decision has a huge impact upon – among others – the feasible functionality, performance, and resilience of the final design, and can result in economic as well as technological constraints (Abrahamsson et al. 2010). Technology design decisions typically happen early in the life of digital startups, and the successful development of the product and the business model depend on them (Abrahamsson et al. 2010). Errors made in the technology design generally have a huge impact on a digital startup's ability to grow into a viable business (van der Ven et al. 2011) because if ineffective, the decision may need to be revised, valuable resources might be wasted, and complications created for marketing the product and building a sustainable business (Klotins et al. 2019). Even beyond the initial technology design choices, digital startups are regularly concerned with evaluating their existing technology design as to whether it still fits their needs or whether minor or major adaptations are required (van Gurp and Bosch 2002; Klotins et al. 2019).

2.3 Lean Startup Approach

To build up from scratch a new venture where neither the problem nor the solution might be well understood requires a resource-efficient and discovery-oriented methodology (McGrath 2010). Such a methodology has to help identify which problem to solve and which solution to build, both from a technology and a business strategy perspective (Bosch et al. 2013; Klotins et al. 2018). A methodology to suit this specific context was proposed by Ries (2011) in his book 'The Lean Startup', which received a considerable amount of attention since its publication (Frederiksen and Brem 2017; Mollick 2019). The Lean Startup Approach involves an iterative and hypothesis-driven approach of venture creation and product development (cf. Figure 1), which includes involving potential customers from the very beginning and proposes minimal up-front planning. This approach enables digital startups to transition from opinion-based to data-driven decision-making, whilst allowing for adaptive product and service design (Bianchi et al. 2018). It can be used by a wide range of entrepreneurs with varying degrees of understanding and levels of uncertainty with regards to the customer needs, solution requirements and suitable business models – among others (Carroll and Casselman 2019).

Figure 1. The Lean Startup Approach by Ries (2011), based on Edison et al. (2018)



The Lean Startup Approach starts by envisioning a future on the basis of which a strategy is employed that consists of falsifiable hypotheses about the business model, a problem to be solved and a potential solution (the product). The hypotheses focus on aspects that are critical to venture success and are falsifiable, i.e., they can be validated by means of an experimental method (Klepper and Bruegge 2018). The experiments are designed to understand perceived customer value and derive requirements, and are conducted through an iterative feedback loop – the Build-Measure-Learn cycle. During this cycle, a minimum viable product (MVP) is developed and released, customer interactions are measured, and feedback is collected (Khanna et al. 2018). This allows a quick turn-around of learnings and responding to new information (Eisenmann et al. 2011; Stayton and Mangematin 2018). After the Build-Measure-Learn cycle is completed, startups decide whether they are on the right track ('preserve') or need to conduct adjustments to their strategy ('pivot'). Pivoting in digital startups is described as a "universal consequence of the conditions of extreme uncertainty" (Ries 2017, p. 110) about the problem to be solved, the target customers, and the value proposition of their unique products and services (Mohr et al. 2010; Ojala 2016; Packard et al. 2017). Because of this, pivoting has become "part of the everyday language of many entrepreneurs, the advisors who guide them and the investors who fund them" (Crilly 2018, p. 54). The Lean Startup Approach describes pivoting as "a change in strategy without a change in vision" (Ries 2017, p. 108). It allows to perform "structured course corrections designed to test a new fundamental hypothesis about the product, business model, and engine of growth" (Ries 2011, p. 149). Ries (2011, p.49) highlights the role of learning as "the essential unit of progress for startups". With "each pivot creat[ing] a new series of hypotheses" (Ries 2017, p. 108), digital startups are generating new knowledge. Through fast iterations and "by reducing the time between pivots, it is possible to increase the odds of success" (Bosch et al. 2013, p. 5). Given the uncertainties described above, it is not surprising that many digital startups that grew into viable and sustainable businesses had to pivot (Ries 2017). Pivoting can be required several times during the life of a digital startup (Terho et al. 2015), each of which comes in a particular shape, summarized through so called 'types of pivot'. Ries (2011) initially suggested ten types of pivot (cf. Table 1). Each pivot includes making significant strategic adjustments to a digital startup on different levels, such as on the targeted customer segment (customer segment pivot), the addressed customer need (customer need pivot), or the used technology design (technology pivot). In contrast to a lengthy linear approach, with pre-defined phases and fixed deliverables, using the Lean Startup Approach allows digital startups to change their pursuit strategy quickly (Edison et al. 2018; Richter et al. 2018). As such, pivoting is “inevitable for almost all digital startups to survive, grow and eventually obtain sustainable business models” (Bajwa, Wang, Nguyen Duc and Abrahamsson, 2017, p. 2374).

Table 1. Types of Pivot described by Ries (2011, pp. 172–176)

Types of Pivot	Description
Zoom-In	A single feature in a product becomes the whole product
Zoom-Out	Whole product becomes a single feature of a much larger product
Customer Segment	Change of targeted customer segments
Customer Need	Focusing on another customer need or problem to be solved
Platform	Change from an application to a platform or vice versa
Business Architecture	A switch in business architecture from high margin, low volume to low margin, high volume, or vice versa
Value Capture	Changes to the way how value is captured through monetization or revenue models
Engine of Growth	Changes in growth strategy to seek faster or more profitable growth
Channel	Delivering the same solution through a different channel with greater effectiveness
Technology	Discovering a way to achieve the same solution by using a completely different technology

2.4 Technology Pivots

Technology pivots are particularly important for digital startups, as they heavily rely on digital technologies for their value creation and business model (Steininger 2019). Once they selected a technology design for their products and services, the uncertainties inherent in the entrepreneurial context typically lead to the necessity – or desirability – of undertaking technological readjustments, as validated learnings are generated. For example, it has been found that technological shifts and newly arising technologies can lead to technology pivots (Comberg et al. 2014), as can technological limitations (Bajwa et al. 2016). This is primarily because digital startups aim to be at the cutting edge of technological advancements and subsequently perform technology pivots as new technologies emerge (Bajwa et al. 2016; Bajwa, Wang, Nguyen Duc, and Abrahamsson 2017). Early reported cases of technology pivots include replacing discontinued core-technologies with novel ones (Bajwa et al. 2017) or switching between a mobile-based and a web-based solution (Terho et al. 2015). Technology pivots were initially conceptualized in a seminal contribution by Ries (2011, p. 172):

> *“Occasionally, a company discovers a way to achieve the same solution by using a completely different technology. Technology pivots are much more common in established businesses. In other words, they are a sustaining innovation, an incremental improvement designed to appeal to and retain an existing customer base. Established companies excel at this kind of pivot because so much is not changing. The customer segment is the same, the customer’s problem is the same, the value-capture model is the same, and the channel partners are the same. The only question is whether the new technology can provide superior price and/or performance compared with the existing technology.”*

This conceptualization has since been used to analyze instances of individual technology pivots (Bajwa et al., 2016; Bajwa, Wang, Nguyen Duc and Abrahamsson, 2017; Terho et al., 2015). However, this conceptualization was based on personal experiences and anecdotal evidence (Ries 2011), leading prior research to underline that "in order to ground our research on some basis, we used the pivot types reported in Ries (2011), with the awareness that these types are subject to systematic and scientific validation" (Bajwa, Wang, Nguyen Duc, and Abrahamsson 2017, p. 2379). When researchers analyzed the cases of Android and Paypal, which both performed significant changes to their technology design, applying the conceptualization of "same solution" using a "completely different technology" by Ries (2011) was hardly suitable (Bajwa, Wang, Nguyen Duc, and Abrahamsson 2017). Thus, while being described as an important measure of course correction for digital startups on their journey of growing into a viable and sustainable business (Comberg et al. 2014; Unterkalmsteiner et al. 2016), a great deal of ambiguity remains about when a pivot can justifiably be called a technology pivot. This is not surprising as the conceptualizations for identifying and assigning pivots to certain types were based primarily on the specific experiences described by Ries (2011).

The ability and will to execute technology pivots and, eventually, their success, strongly depend on the composition of the digital startup's team and its individual members (CB Insights 2018, 2019b; Unterkalmsteiner et al. 2018). To put together a suitable team one has to ensure that each team member has the knowledge required to perform pivots and the character traits needed to withstand the stress involved in pivoting (Entrepreneur 2019; Forbes 2015; TechCrunch 2012). Therefore, "attract[ing] and retain[ing] the right people to build the technology" has been described as an essential factor for a startup's chances of success (FastCompany 2015).

3. Body of Literature

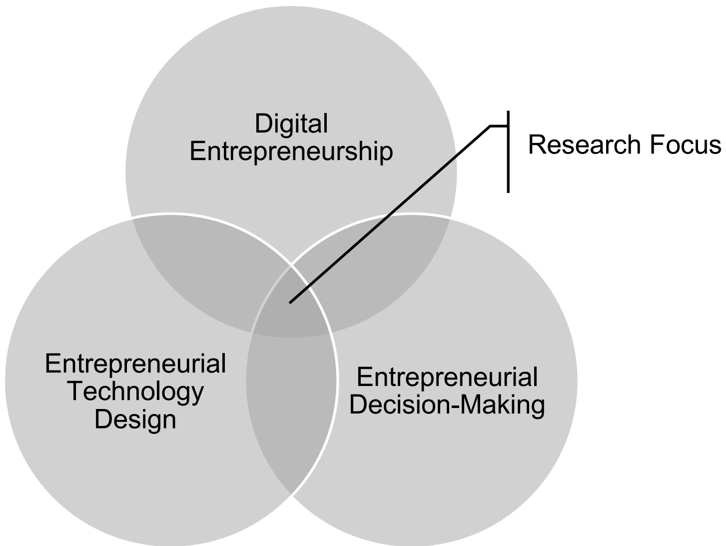
This section starts with an overview of the relevant research streams (cf. Section 3.1), followed by a selection of contributions relevant to the research focus of this dissertation. (cf. Section 3.2) and, finally, ending on the presentation of the identified research gaps (cf. Section 3.3).

3.1 Overview

The literature relevant to the subject of this dissertation is located in three different research streams, namely, (1) Digital Entrepreneurship, (2) Entrepreneurial Technology Design, and (3) Entrepreneurial Decision-Making. At their interface lies the research focus of this dissertation (cf. Figure 2).

First, *digital entrepreneurship literature* is concerned with the utilization of digital technologies as part of entrepreneurship activities, including the discovery, evaluation, and exploitation of opportunities (Nambisan 2017; Recker and von Briel 2019; Shane and Venkataraman 2000). Digital entrepreneurship represents a "reconciliation of traditional entrepreneurship with the new way of creating and doing business in the digital era" (Le Dinh et al. 2018, p. 1). As such, digital entrepreneurship is said to be "not just a research context but an emerging field of research" (Zaheer et al., 2019, p. 4) that requires new concepts and theories about how entrepreneurs form, enact and develop digital startups utilizing digital technologies (Nambisan 2017). Digital technologies such as artificial intelligence, augmented reality, and cloud computing, have the ability to disrupt and transform existing industries and markets (Beliaeva et al. 2019). Yet, they have also "transformed the nature of uncertainty inherent in entrepreneurial processes […] as well as the ways of dealing with such uncertainty" (Nambisan 2017, p. 1029). It is a field that covers, amongst others, phenomena surrounding industries that are "disrupted by startups with no assets or experience in the sector but which use digital applications, requiring no more than a smartphone running the startup's program" (Zaheer et al. 2019, p. 4). As a result, "the traditional ways and forms of pursuing entrepreneurial opportunities are increasingly questioned and refashioned" (Nambisan 2017, p. 1048). This opens up an exciting opportunity for research to develop new theories with which digital entrepreneurship can be explained (Recker and von Briel 2019). Contributions that can shed light on the role of digital technologies for the pursuit of the entrepreneurial endeavor, and the uncertainties associated with them, will help to increase "consensus on the scope, nature, and boundaries of the field [of digital entrepreneurship]" (Zaheer et al. 2019, p. 1).

Figure 2. Venn Diagram illustrating related Literature Streams and Research Focus



Second, *entrepreneurial technology design literature* is concerned with questions surrounding the identification, selection, evaluation, management and adaptation of the technological foundation of new ventures, in essence, their technology design. This literature stream is particularly interested in understanding the engineering practices currently used to perform the afore-mentioned tasks and to develop suitable new engineering practices. It investigates these practices with a particular focus on the characteristics of the entrepreneurial context (Klotins et al. 2019; Kraus et al. 2019; Unterkalmsteiner et al. 2016). It is a research stream that has gained increasing attention in recent years, with research on digital startups becoming more prominent since 2014 (for a detailed overview, see Wang 2019). It is worth noting that, so far, there is no unanimous agreement in the scientific community as to what such research should be called. For the purpose of this dissertation, I refer to this literature stream as entrepreneurial technology design, aiming to align with the most commonly used terms such as "architecture and design process" (Klotins et al. 2019, p. 18), "software design" (Berg et al. 2018), "technology stack" (Schulte-Althoff et al. 2019, p. 3), "architectural and technology decisions" (Kraus et al. 2019, p. 373), or "technology design decision-making" (Soliman et al. 2016, p. 128).

Third, in the entrepreneurial context, the subject of decision-making has preoccupied researchers for some time (Shane and Venkataraman 2000; Shepherd and Patzelt 2017). This is because the context entails that decisions need to be made at a fast pace under complex conditions with regards to uncertainty and ambiguity surrounding the decision basis – among others (Packard et al. 2017). The decisions to be made by entrepreneurs are manifold, ranging from a strategic to an operational level, and starting as early as making a decision whether a "specific situation is (or is not) an opportunity" (Shepherd and Patzelt 2017, p. 17) to be exploited. This literature stream analyzes how, when, where, and by whom decisions can be made effectively, leading to the desired outcome along the different phases of the entrepreneurial process (Mullins and Forlani 2005; Shepherd et al. 2015). For the purpose of this dissertation, I refer to this literature stream as *entrepreneurial decision-making literature*.

3.2 Literature for Research Focus

Originally, the field of entrepreneurship has been described as being concerned with "the scholarly examination of how, by whom, and with what effects opportunities to create future goods and services are discovered, evaluated, and exploited" (Shane and Venkataraman 2000, p. 218). Recent publications from all three literature streams (cf. Figure 2) have furthered understanding of these aspects from their respective entrepreneurial perspective. Each of these literature streams provides recent literature reviews, research agendas or mapping studies which, individually and collectively, provide a comprehensive overview of the body of literature related to this dissertation (Berg et al. 2018; Ghezzi 2019; Kraus et al. 2019; Paternoster et al. 2014; Razavian et al. 2019; Shepherd et al. 2015; Steininger 2019; Unterkalmsteiner et al. 2016; Zaheer et al. 2019). In the following, a brief overview of contributions relevant to the research focus of this dissertation will be provided.

Digital Startups and the Lean Startup Approach for the Discovery, Evaluation and Exploitation of Opportunities

The key constructs used in digital entrepreneurship research are "digital technologies", "digital startups", "business models", and "new venture teams", with recent contributions starting to focus on the "the lean revolution" (Zaheer et al. 2019, p. 4). Particularly, entrepreneurial methodologies such as the Lean Startup Approach in digital startups were highlighted as a current research focus (Kraus et al. 2019). An investigation into the usage of methodologies applied in digital startups, including 227 digital startups, found that 93% "declared that they had explicitly adopted and implemented [the] Lean Startup Approach with the purpose of driving the launch and development of their startup" (Ghezzi 2019, p. 951), indicating that the Lean Startup Approach is a strongly relevant methodology for how digital startups proceed. Moreover, digital startups, which offer a "completely digitized product or service, digitally sold and delivered" were identified as the central actors in this field, which were separated from other types of startups, such as IT-facilitated startups, IT-mediated startups, or IT-bearing startups based on the degree of using digital technologies for value creation (Steininger 2019, p. 19).

As the Lean Startup Approach was developed, based on the observations and learnings made by practitioners (Ries 2011), Frederiksen and Brem (2017) set out to scrutinize the scientific efficacy of the Lean Startup Approach. Following their analysis, the Lean Startup Approach can be divided into five components, namely, (1) customer and user involvement (2) iterative new product development, (3) experimentation in new product development, (4) early prototyping, and (5) effectual thinking. By further examining the theories and concepts in scientific literature that support these components, they found substantial backing in established scientific theories for each of these five components. They conclude that they are underpinned by a solid theoretical foundation. Through their contribution, Frederiksen and Brem (2017) pave the way for more detailed research on the individual components of the Lean Startup Approach. As “new ventures often need to shift their focus many times on their way to finding a profitable business logic” (Steininger 2019, p. 392), pivoting represents an essential part of the Lean Startup Approach worth investigating (Unterkalmsteiner et al. 2016), with each pivot being a considerable challenge for digital startups in practice (Bajwa et al. 2017; Ries 2011). First studies on the subject of pivoting have picked up the call for more research by analyzing particular aspects of the subject. For example, Grimes (2018) analyzes how psychological ownership of startup ideas by entrepreneurs and external feedback influence the pivoting decision in startups. He found that strong ownership by entrepreneurs combined with external feedback encouraging a pivot in startup ideas can lead to resistance among entrepreneurs, yet, if accepted, can in fact increase the viability of startup ideas. Hampel et al. (2019) investigated how entrepreneurs can maintain positive stakeholder relationships and avoid tensions while pivoting. They argue that it is important for entrepreneurs to openly disclose and discuss the venture’s struggles, while simultaneously highlighting their commitment towards their vision.

Challenges Surrounding Digital Technologies as a Means for Opportunity Exploitation

As digital startups exploit discovered opportunities by means of digital technologies, the selection and implementation of technology designs suitable for their endeavor is essential, as highlighted in recent contributions (Giardino et al. 2014; Klotins et al. 2019; Kraus et al. 2019; Unterkalmsteiner et al. 2016). The vast majority of the new ventures do not survive beyond their second year of business (CB Insights 2019b). One of the main reasons for the short longevity of digital startups, identified in a recent digital startup survey (Giardino et al. 2015), is the considerable challenge they face of operating under great and constant technological uncertainty. As promising as they might appear for innovative product and service development, “new technologies might turn out as failures, whilst others go towards unpredictable directions” (Kraus et al. 2019, p. 372). For example, Java Applets were considered a valuable addition for technology designs but turned out to experience little acceptance in the market and were soon discontinued (Graham 2006; OpenJDK 2016). Similarly, Flash was discontinued after falling into disfavor with users and web browser providers because of performance and security issues (Adobe 2017; Wired 2015). The cases of Android and Tango are examples of technologies turning into unexpected directions. Having started as a camera operating system, Android eventually became an operating system for mobile phones, gaining a major market share quickly and superseding other technologies such as Windows phones (Business Insider 2015), while Tango was an augmented reality computing platform, which was discontinued and replaced by ARcore just three years after its initial release (Google 2017). Creating any dependencies upon third-party technologies in terms of technology design, represents a considerable threat to digital startups, because established dependencies cannot be resolved easily or without considerable resource investments (Kraus et al. 2019). Such dependencies can affect development speed, design flexibility and adaptability which, taken together, significantly impact the ability of digital startups to progress (von Briel et al. 2018).

These circumstances have led to research focusing on how technology design selection and their implementation can be performed under uncertainty in the digital entrepreneurship context (Giardino et al. 2014; Klotins et al. 2018; Packard et al. 2017; Saukkonen et al. 2016). It has been found that existing engineering practices and methodologies are extensively aimed at large enterprises and typically consist of prescriptive processes, which can only hardly be applied in the entrepreneurial context, where “adapting quickly to new requests, while being constrained by limited resources” is a key ingredient towards developing an offering (Paternoster et al. 2014, p. 1201). Thus, it comes as no surprise that Paternoster et al. (2014, p. 1216), in their systematic mapping study (covering the period 1994-2013) on software development in startups, found that existing engineering practices and methodologies are “adopted only partially and mostly in a late stage of the startup life-cycle”. They recommend the development of new practices suitable for digital startups that enable easy adaptability of the technology design and allow alignment with the uncertainties currently prevailing. At any time, the selected technology design “should at a minimum accommodate change” and, ideally, “facilitate change” (Sutton 2000, p. 38). A subsequent systematic mapping study performed by Berg et al. (2018) (covering the period 2013-2017), revealed a lack of research on how software engineering and innovation methods can be supported, specifically in the context of digital startups.

Given the lack of engineering practices and methodologies suitable for usage in digital startups, Klotins et al. (2018) set out to perform an exploratory study on the status quo of technology designs in digital startups based on 88 experience reports. They identify three areas containing shortcomings, namely, (1) requirements engineering, (2) software design and (3) software quality. They highlight that insufficient requirements engineering can lead to products being built without taking into account customer demand and, therefore, resources being wasted. An insufficient software design, on the other hand, will hinder fast progression, flexible adaptability and low effort maintenance. Subsequently, Klotins et al. (2019) create a progression model describing the engineering activities, challenges, and tasks in digital startups across life-cycle phases. They confirm that digital startups are, from early on in their life-cycle, concerned about their internal product structure, i.e. their architecture and design processes, and the selection of components, interfaces and other aspects required for the development of their product or service. As such, they describe the selection of a technology design as an important objective for digital startups.

Additionally, first links between research on technology designs and the methodologies of digital entrepreneurship, that is, the Lean Startup Approach and its core components MVPs and pivoting, have started to appear more recently (Berg et al. 2018). Khanna et al. (2018) investigate the usage of MVPs in digital startups and how the learnings generated through them lead to pivots resulting in significant changes to technology design components. Further instances of technology pivots, in particular their antecedents and consequences, have also been investigated (Bajwa et al. 2016; Bajwa, Wang, Nguyen Duc, Matone Chanin, et al. 2017; Terho et al. 2015). It was found that the emergence of new digital technologies or system performance issues can be reasons for technology pivots. Taken together, these studies began to shed light on a nascent field in which first investigations have been conducted on engineering practices in digital entrepreneurship. They particularly highlight the necessity to understand context-specific methodologies and measures that allow to create and adapt technology designs suitable for digital startup development under the prevailing uncertainties.

Team Composition and Decision-making Surrounding the Lean Startup Approach

Entrepreneurial teams select and apply an approach for the identification of a digital entrepreneurship opportunity, its evaluation and exploitation, as well as the digital technologies they deem suitable for its exploitation. As part of this, they undertake all the activities required to drive forward the development of the startup, and make crucial decisions associated with it. For these reasons, Kraus et al. (2019) discuss entrepreneurial teams as an important aspect in the pursuit of digital entrepreneurship opportunities. They state that digital startup teams “are the essential part of the business in its infancy” (Kraus et al. 2019, p. 365) that needs to be able to handle and gradually reduce the prevailing uncertainties. For this challenge, it is essential to compose digital startup teams “willing to change things […] through the trial-and-error business development phase” (Kraus et al. 2019, p. 365). In this context, Forbes et al. (2006) highlight the aspect of guidance (and the lack thereof) on the subject of team composition in entrepreneurial teams. They particularly focus on the extension of entrepreneurial teams for the goal of resolving bottlenecks encountered during the execution and scaling up of the venture, and tackling challenges for which the right competencies do not yet exist within the team. As part of this, they differentiate between two stages relevant to digital startups. First, the identification of potential team additions, and second, the selection of new team members that can help with attaining the goals. Both of these play an important part in successful team composition.

Furthermore, research has highlighted the relation between the characteristics of the individuals responsible for decision-making and their individual decision-making characteristics. Particularly in the entrepreneurial context, decision-makers benefit from greater managerial discretion and wider latitude of action than teams in other types of organizations, and therefore, their characteristics and behaviors can have decisive influence on the development and growth of startups over time (Klotz et al. 2013). In this context, it is important to note that entrepreneurs are heterogeneous in the amount and nature of their experiences, and these differences have an impact on entrepreneurial decision-making (Shepherd et al. 2015). For example, with regards to decisions surrounding the technology designs of digital startups, Giardino et al. (2016, p. 603) state that digital startups “often rely on clever, but inexperienced developers at the beginning”. Yet, the complex conditions apparent in the early phases of digital startups – in terms of uncertainties, lack of resources, and time-pressure – turn technology design-related decisions “into a difficult trade-off” (Giardino et al. 2016, p. 603) between quality and budget, reliability and development speed, thoroughness and time-to-market. These decisions can then result in choices that are unfavorable for the development of the product or service, lead to low product quality, and thus result in resources being wasted and, in the worst case, lead to venture failure (Klotins et al. 2018; Paternoster et al. 2014). Unsurprisingly, decision-making in this context is accomplished better by some than by others. For this reason, understanding “how individuals make key decisions in the entrepreneurial process” (Shepherd et al. 2015, p. 12), and how they should be made so that they result in choices allowing to achieve the established goals are important objectives. As part of this, behavioral elements such as cognitive biases or decision-making characteristics impacting on how decisions are made, are of keen interest to entrepreneurial decision-making research (Razavian et al. 2019).

3.3 Research Gaps

As part of analyzing the literature relevant for the research focus of this dissertation, a set of interesting research questions became apparent. The identified research gaps are presented in the following, which also build the foundation for and the starting point of this dissertation.

First, although engineering practices and technology designs comprise the core of any digital startup as part of their value creation, research on engineering practices in the context of digital startups is still in its infancy and empirical knowledge about technology designs of digital startups remains very limited (Berg et al. 2018; Klotins et al. 2019; Unterkalmsteiner et al. 2016). Only recently, researchers started to "follow up on the call for [a] digital technology perspective" in the entrepreneurial context (Zaheer et al. 2019). So far, most of the research in the field of technology design was focused on the needs and challenges of established organizations (Berg et al. 2018), which results in a limited understanding of tasks such as the creation, design, testing and verification of technology designs suitable in an entrepreneurial context (Paternoster et al. 2014). Consequently, little guidance can be provided for practice about what a suitable technology design looks like and which engineering practices are favorable for digital startups (Klotins et al. 2015, 2019). In order to resolve this, "researchers must build a more comprehensive, empirical knowledge base" of the status quo (Unterkalmsteiner et al. 2016, p. 92), so that thereafter, research can be built upon and validate frameworks and tools that support the development of favorable technology designs and that apply engineering practices suitable for the entrepreneurial context (Berg et al. 2018). Combined, such efforts would support digital startups to grow into sustainable and viable businesses more effectively, while reducing the resources wasted along their growth paths.

Additionally, while research on decision-making of entrepreneurs has raised scholarly interest for a considerable time (Shane and Venkataraman 2000; Shepherd and Patzelt 2017), and brought to light a substantial amount of contributions improving our understanding of which decisions entrepreneurs need to take and the factors that influence them, "we are far from having a comprehensive and coherent story of this phenomenon" (Shepherd et al. 2015, p. 38). The review by Shepherd et al. (2015) highlights an important gap in existing literature about the decisions lying between two major strategic entrepreneurial decisions, namely, between (1) the decision about exploiting an opportunity, and (2) the entrepreneurial exit decision. Framed by these two key moments in a startup's lifecycle, a large number of operational decisions are made. In particular for digital startups, important technological design decisions need to be made concerning the technological foundation of their products and services. As part of understanding and improving engineering practices and technology designs in digital startups, more effort needs to be put into investigating and understanding operational decision-making with a focus on technologies (Klotins et al. 2019; Nambisan 2017; Saukkonen et al. 2016). These decisions need to be understood explicitly with regards to relevant decision attributes, how decisions are being made and how effective they are to reach the desired objective (Shepherd et al. 2015).

Along the same lines, Razavian et al. (2019) stresses that there currently is limited scholarly interest in analyzing the role of human behavior in technology design decision-making and how this impacts the quality of the chosen technology designs. For the context of larger organizations, they found that technology design decisions are commonly made jointly by engineering teams, rather than by individual team members. Digital startups, however, can hardly boast of an engineering *team* as such, particularly in the early phases, this role being delivered mostly by only one individual, the technical co-founder. This leaves a gap about how this is done in digital startups at the moment. In this context, Klotz et al. (2013) particularly highlighted the decision-making dynamics in entrepreneurial teams and the characteristics of individual members of the team as an open gap. They underline the need to further understand how individual team member characteristics influence digital startup decision-making, including examining the values, beliefs, backgrounds, and decision styles of individual members. As such, characteristics of individuals are suspected to have a considerable bearing on the decision effectiveness and the entrepreneurial outcome (Klotz et al. 2013; Zaheer et al. 2019). From this follows that a gap can be identified on the status quo about engineering practices and technology designs in digital startups, which research would like to see closed (Unterkalmsteiner et al. 2016). As part of this, the decision-making applied by technical co-founders to technology design decisions is of particular interest in the context of digital startups.

Gap 1: *Technology design decision-making in digital startups has not yet been studied*

Second, despite an increasing number of digital startups being founded, "research has lagged far behind practice" (Shen et al. 2018, p. 1125) in understanding digital entrepreneurship, and only recently began to pay attention to this emerging field of research (Beliaeva et al. 2019). In particular, our understanding about the role played by digital technologies in entrepreneurship remains limited (Shen et al. 2018). Existing contributions on digital entrepreneurship consist of several proposals for research. They encourage "novel theorizing of how entrepreneurial opportunities are formed and enacted" (Nambisan et al., 2017, p. 1030), under consideration of the "unique characteristics and aspects of digital technologies" (Nambisan et al., 2017, p. 1030), which shape the field of digital entrepreneurship. Particularly, such research is encouraged to "incorporate digital-technology-related concepts, and constructs" in their efforts (Nambisan 2017, p. 1048; see also Zaheer et al. 2019). As part of this, future research should elaborate on the actors in digital entrepreneurship involved in evaluating technological choices and integrating them for value creation (Steininger 2019). Steininger (2019, p. 385) has revealed that those using digital technologies entirely, that is, digital start-ups, are "one of the least researched types of new ventures", which have also "been studied for the shortest period" and for which research "progress is seen only in recent years". He calls for more research on how changes of "digital product[s] or service[s] can induce changes to used IT systems for production" and vice versa, as well as how startups "transition between the different types and roles of IT" (Steininger 2019, p. 385).

Such research should focus on the methodologies applied in digital entrepreneurship (Berg et al. 2018; Steininger 2019; Unterkalmsteiner et al. 2016), the challenges related to them, and their observable outcomes. Although favored by many digital startups (Ghezzi 2019), the concrete application of the Lean Startup Approach in digital entrepreneurship still leaves many questions unanswered (Unterkalmsteiner et al. 2016). The individual components of the Lean Startup Approach need to be investigated further, in order to increase our understanding of the phenomenon as a whole. Only then can we resolve the challenges associated with using the Lean Startup Approach in practice, which in turn can enable entrepreneurs to develop their ventures more sustainably. In particular, our understanding of the main measure of course correction in digital startups, proposed in the Lean Startup Approach, namely, the different types of pivot, is limited (Berg et al. 2018; Unterkalmsteiner et al. 2016). It remains unknown what motivates the different types of pivot, what they entail and what results from them. In this context, Unterkalmsteiner et al. (2016, p. 101) highlight that existing studies on pivoting "lack the sufficient detail to understand different types of pivots and the factors triggering pivots", for which reason they call for "a fundamental framework on [the] reasons for pivoting and their types" (Unterkalmsteiner et al. 2016, p. 101). Furthermore, Berg et al. (2018, p. 258) state that more research is required that "address[es] the consequences and relationship among different pivot types, both from a business and technical perspective". As part of such research, it should be investigated "how pivoting should be performed at different lifecycle stages" (Berg et al. 2018, p. 258) and how this may affect the pivoting decision. Through increasing our understanding of the individual types of pivot, the pivoting phenomenon as a whole can be better understood, which in turn might enable more effective pivot performance. Here, technology pivots represent a particularly important type of pivot for digital startups as their value creation and business model rely entirely on digital technologies, and technology pivots allow them to change the value-creating parts of their fully digitized businesses (Steininger 2019).

Gap 2: *A conceptualization of technology pivots, including their antecedents, consequences, and characteristics is required*

Third, an additional black spot remains about the preparation activities for the engineering challenges occurring in digital startups, with a special focus on effective team composition (Unterkalmsteiner et al. 2016). Zaheer et al. (2019) particularly underline the need for research that identifies the digital technology competencies needed by digital startup teams in the entrepreneurial process, including research on which combinations of team members with regards to their competencies, prior experience and other attributes are effective. Such research on competency needs and team composition in digital startups would broaden our understanding of how digital entrepreneurship opportunities can be seized successfully from a technology perspective (Unterkalmsteiner et al. 2016). As highlighted by Unterkalmsteiner et al. (2016, p. 102) such research should focus "on the early stages and on the growth period of the software startups, when the challenges of software startups are the greatest". In this context, Forbes et al. (2006) also highlight the lack of guidance on the extension of entrepreneurial teams for the goal of resolving bottlenecks in the execution and scaling-up of the venture, and tackling challenges for which the right competencies do not yet exist within the team. Both for the identification and the selection of new team members limited attempts were made so far to understand team composition approaches of digital startups (Bradel et al. 2019). This is surprising, given that existing literature on digital startups has highlighted the importance of composing context-specific and future-oriented startup teams (Baron 2003; Kollmann et al. 2009; Unterkalmsteiner et al. 2016; Zaheer et al. 2019). Moreover, given the complications surrounding a key engineering challenge in digital startups, i.e., the performance of technology pivots (Bajwa et al. 2016; Bajwa, Wang, Nguyen Duc, and Abrahamsson 2017), a better understanding is required about how digital startups (should) prepare for technology pivots, including how entrepreneurial teams should be composed for effectively performing technology pivots in digital startups. This includes how they can be identified and selected (Bradel et al. 2019), and which competencies they should obtain (Berg et al. 2018).

Gap 3: *An understanding of team composition activities for technology pivot preparation is needed*

In summary, more research addressing the outlined three research gaps is required. Table 2 provides an overview of the studies encouraging research on the individual gaps identified, and the questions raised by them.

Table 2. Highlighted Research Gaps (RA = Research Agenda; SLR = Systematic Literature Review; SMS = Systematic Mapping Study)

Source	Type	Literature Stream	Research Gaps Revealed and Research Questions Raised in Literature	Research Gaps Derived for this Dissertation
Unterkalmsteiner et al. (2016)	RA	Digital Entrepreneurship	– What engineering practices are used in the startup context today, and do they work? – Clarify the role of design decisions in software development	Gap 1: *Technology design decision-making in digital startups has not yet been studied*
Shepherd et al. (2015)	RA	Entrepreneurial Decision-Making	– Research exploring the individual factors that magnify or diminish the effect of specific decision-maker characteristics on entrepreneurial decision making is required	
Klotz et al. (2013)	SLR	Digital Entrepreneurship	– Characteristics of decision-makers are suspected to influence the decision effectiveness and entrepreneurial outcome	
Razavian et al. (2019)	SLR	Entrepreneurial Decision-Making	– Software researchers do not pay much attention to the role of human behavior in decision making and how this impacts the quality of software design	
Zaheer et al. 2019)	SLR & RA	Digital Entrepreneurship	– How do professional and entrepreneurial experiences of digital team members affect entrepreneurial processes and outcomes? – How are entrepreneurial process perspectives such as effectuation, and bricolage practiced in digital technology context?	
Steininger (2019)	SLR & RA	Digital Entrepreneurship	– How can changes to digital products or services induce changes to IT systems and vice versa?	Gap 2: *A conceptualization of technology pivots, including their antecedents, consequences, and characteristics is required*
Unterkalmsteiner et al. (2016)	RA	Digital Entrepreneurship	– To what extent is pivoting crucial for software startups? – How do software startups pivot during the entrepreneurial/startup process? – How do pivots occur during different product and customer development life cycles? – What are the existing processes/strategies/methods to make a pivoting decision in a startup context?	
Berg et al. (2018)	SMS	Entrepreneurial Technology Design	– More research is required that addresses the consequences and relationship among different pivot types, both from a business and technical perspective	
Zaheer et al. (2019)	SLR & RA	Digital Entrepreneurship	– What is the role of digital technology capabilities of digital startup team members in the entrepreneurial process?	Gap 3: *An understanding of team composition activities for technology pivot preparation is needed*
Unterkalmsteiner et al. (2016)	RA	Digital Entrepreneurship	– What knowledge and skills are needed to overcome digital startup challenges? – How do the competency needs map onto the roles and responsibilities of the startup teams in digital startups? – How can the growth of software startups be managed in terms of competency needs for engineering practices and processes?	
Berg et al. (2018)	SMS	Entrepreneurial Technology Design	– Future studies dedicated to the role of human capital in startups, investigating capabilities and engineering foundations are required	

4. Methodology

For the investigation of the identified research gaps, and to build theory from empirical evidence, the studies submitted as part of this dissertation have for the most part adopted a qualitative and exploratory research methodology, consisting of case study research (Bohn and Kundisch 2018a, 2019), a Delphi technique (Bohn and Kundisch 2020), and a content analysis (Bohn 2019). As an exception to this series of qualitative research studies is a quantitative study in form of exploratory survey research (Bohn and Kundisch 2018b).

A qualitative research approach is desirable in a setting where it is required to obtain primary data from real-world situations and the individuals that constitute them (Bengtsson 2016; Gehman et al. 2018; Yin 2011). It is based on immersion with the respective real-world situations and commonly entails interacting with the actors in the field to reveal the characteristics of the phenomenon of interest and their meaning for the individuals associated with them (Gehman et al. 2018; Yin 2011). Put differently, qualitative research, defined as any form of research that leads to findings not obtained by statistical means (Yin 2011), aims to extract the meanings given to real-world phenomena by the people who are involved in them, and who themselves contribute to shaping them. It is carried out for the purpose of deriving concepts (from primary data) with which to describe phenomena, and to discover relationships between data. The concepts can then be organized into theoretical explanations (Yin 2011). Qualitative researchers apply rigorous analytical methods to ensure the credibility of their data and interpretations, and the conclusions they derive (Gioia et al. 2012). The purpose of research in an exploratory setting is to better understand a subject and to identify and add new explanations, dimensions and perspectives on the phenomena of interest. This effort can entail the generation of causal models or process theories – among others – that lead to the generation of new theories (Gregor 2016; Rauch et al. 2014). As part of conducting qualitative and exploratory research in this dissertation, an interpretivist view is taken. In interpretive research, which can be linked to Weber's *Verstehen* approach of human behavior (Mason 2002; Munch 1957), the people that form part of certain phenomena and their perceptions, behaviors, and collective understandings, are essential data sources (Mason 2002). As part of this, "interpretive research does not predefine dependent and independent variables", instead it "attempts to understand phenomena through the meanings that people assign to them" (Klein and Myers 1999, p. 69).

Qualitative research is commonly adopted by scholars in digital entrepreneurship (Zaheer et al. 2019). This is because, in an entrepreneurial context, qualitative research is able to pursue open-ended research questions that are not easily addressable by the means of quantitative research (Rauch et al. 2014). For digital startups, for example, there is little quantitative data available, and entrepreneurs rarely document their actions and decisions, which is hardly surprising, given the short operating history of startups, their fast pace, and limited resources. However, if aiming to research specific phenomena in digital startups for which open-ended questions need to be asked, qualitative data about the phenomena of interest can be collected in interaction with the individuals who form part of the organization and thus lead to interesting insights. As such, qualitative research allows to "address and interpret complex and/or unique phenomena embedded in different contexts through an exploratory orientation" (Rauch et al. 2014, p. 335). The collected primary data can then be enriched with additional data, such as press releases and website content – among others.

Moreover, the prevailing usage of qualitative research in digital entrepreneurship (Zaheer et al. 2019) indicates that the research field is still nascent with most researchers exploring and discovering individual phenomena (Unterkalmsteiner et al. 2016), rather than applying, quantifying, or assessing existing knowledge. Therefore, I consider qualitative and exploratory research to be a suitable approach for answering the research questions outlined in the previous section and to advance our understanding of technology designs and technology pivots in digital startups.

For qualitative research to be reliable and convincing, it needs to achieve three objectives (Yin 2011), namely, (1) transparency, (2) methodological rigor, and (3) adherence to evidence. First, while it is difficult to reproduce qualitative research, it is important to be transparent in one's own descriptions of the individual research steps taken, from the design of the study to data collection and the extraction of findings. The research procedure should be comprehensible and scrutinizable by others (Rauch et al. 2014; Yin 2011). Second, research should be conducted rigorously in every step. As part of proceeding in an exploratory fashion, this particularly requires a structured manner, while remaining open-minded, in order to avoid biases and to jump to conclusions prematurely. Third, research should adhere to the evidence collected, and analyze and integrate the various perspectives of the sources included in the data. As part of this, similarities and contradictions should be investigated and discussed.

As part of conducting qualitative and exploratory research, several methods for investigation can be used, among them action research, case study research, Delphi techniques, and grounded theory (Okoli and Pawlowski 2004; Yin 2011). A commonly used method for data collection in qualitative research is semi-structured interviewing (Yin 2011), which offers the advantage of combining the consistency of a topic guide with the flexibility required to ask additional questions in order to understand the participant's world view rather than following a strictly structured interview form. A semi-structured interview itself will aim for a natural conversation, with the flow of the interview individualized to every participant. This is to encourage participants to make statements and give explanations that may reveal extremely important insights into how the participants think and derive their own understanding of their behavior. The topic guide provides a structured interview guideline, to ensures that the interviewer sufficiently focuses on the research questions needing to be answered. In addition, while performing semi-structured interviews, an interpretivist researcher does not aim to control variance but is rather interested in capturing variance and tries to understand where the variances stem from (Gehman et al. 2018). In contrast to artificial research procedures, such as experiments in a lab setting, the social interactions occurring as part of qualitative research include minimal intrusion and enable participants to speak freely rather than respond to a researcher's pre-designed experiment (Yin 2009). At the same time, data collection should, in an ideal world, not be limited to interviewing individuals as the conclusions will otherwise rely entirely on "self-reported behavior, beliefs, and perceptions" (Yin 2011, p. 132) of the participants. Instead, qualitative research should aim, as much as possible, to collect, integrate, and present data from a variety of sources and perspectives. Such combination (or triangulation) of data allows for the interpretation and conclusions to be based on data from different sources, which adds to the credibility of qualitative research.

Once all data is collected, the data analysis in qualitative research is commonly performed in five steps (Yin 2011), consisting of (1) compiling data, (2) disassembling data, (3) reassembling data, (4) interpreting data, and (5) concluding. First, the qualitative data collected are compiled and enriched with secondary field notes. This can entail creating a case database, which enables to keep an overview of the amount of data collected, and usage of qualitative analysis tools, such as Atlas.ti or MaxQDA. Second, during the disassembling step, the compiled data is being broken down into smaller fragments or pieces, frequently accompanied by assigning labels, also called codes, while sticking close to the words used by participants. The disassembling procedure may be revised several times as part of a trial-and-error process, while the researcher scrutinizes the collected data and tries to understand dependencies and relationships. For the majority of qualitative researchers, this step lies at the heart of theory-building (Gehman et al. 2018). Conceptually higher codes, often referred to as secondary level codes, are derived and, while they relate to the initial set of codes, more analytical. At this point the researcher becomes aware of potentially broader patterns in the data and makes first steps towards theorizing, investigating emerging themes and checking for potential explanations of the phenomena of interest. Also, the literature can be consulted and the research process can transition from being purely inductive to a form of abductive research, in which the collected data and existing theories are now considered in parallel (Gehman et al. 2018). It is of particular importance, in this step, to focus on nascent concepts that don’t seem to have theoretical foundations in the existing literature and can represent interesting new findings. Third, as part of the reassembling step, secondary level codes will be taken onto an even higher conceptual level whereby themes or even theoretical concepts start to emerge. The reassembling and recombination of secondary level codes may be facilitated by depicting the data graphically or in a tabulated structure. By progressing through these steps the raw data allows to generate theoretical themes and dimensions, to even higher level of abstractions, which is an important part of demonstrating rigor in qualitative research (Gehman et al. 2018; Yin 2011). Fourth, the emerged theoretical themes and dimensions are then interpreted, which aims to create an understanding of the phenomena analyzed. Initial interpretations may lead the researcher to rearrange the coded data in another way. The narratives supporting the interpretations can consist of exhibits or figures, including tables and lists. Quotes by participants might also be used to support the narrative flow further. The final result can then, for example, be a theoretical model that shows the dynamic relationships among the emerging concepts that explain the phenomena of interest and their interrelationships or a series of constructs that are tied to specific cases (Gehman et al. 2018). Fifth, the conclusion then combines the research objective, the collected data and empirical findings, with the interpretation, and a summary.

5. Overview and Contribution

This dissertation comprises five research papers that expand our understanding of the selection of technology designs in digital startups, the characteristics of technology pivots in digital startups, including the circumstances leading up to technology pivots and the consequences resulting from them. Furthermore, an initial investigation is provided into the team composition activities of digital startups, focusing on teams’ ability to perform technology pivots. Table 3 shows how the studies submitted as part of this dissertation interrelate to the gaps identified in the body of literature (cf. Table 2).

In the following, I dedicate one sub-section to each of the studies included in this dissertation, providing a brief summary of the paper with details on the scientific contributions made by the respective authors, and information on the dissemination of the research findings in the form of presentations and publications. Supplementary information for each study can be found in a separate file attached to this synopsis.

Table 3. Overview of Submitted Studies by Research Gap

Addressed Gap	**Study**	**Methodology**	**Main Data Source**	**Research Question**
Gap 1: *Technology design decision-making in digital startups has not yet been studied*	Bohn and Kundisch (2019)	Multi-Case Study	9 Cases	*How are technology design decisions made in the context of digital startups?*
Gap 2: *A conceptualization of technology pivots, including their antecedents, consequences, and characteristics is required*	Bohn and Kundisch (2020)	Delphi Study	38 Experts	*Which factors advance the conceptualization of the term 'technology pivot'?*
	Bohn and Kundisch (2018a)	Multi-Case Study	20 Cases	*What are the antecedents and consequences of technology pivots in digital startups?* *What is the impact of technology pivots on the business models of digital startups?*
	Bohn and Kundisch (2018b)	Exploratory Survey Research	91 Cases	*What is the nature (antecedents, consequences, interrelations, business model impact, etc.) of technology pivots in digital startups?*
Gap 3: *An understanding of team composition activities for technology pivot preparation is needed*	Bohn (2019)	Content Analysis	510 Job Adverts	*To what extent do the antecedents of technology pivots form part of IT job advertisements published by digital startups?*

5.1 Bohn, N. and Kundisch, D. (2019)

In this paper, we investigate how initial technology design decisions are made in digital startups (cf. Table 4). A technology design defines the foundation of the products and services that digital startups develop, and many subsequent decisions rely on it. However, technology design decisions are fraught with complications, such as, for example, time pressure, an incomplete understanding of the customer problem, or uncertainty about how the developed solution will be received by potential customer groups. As such, choosing an appropriate technology design among the range of available design alternatives is crucial, as the wrong design decision could have severe consequences for product development and quality, and waste valuable resources. Using an exploratory research design, we identify decision-making characteristics, consisting of three decision paradigms and seven decision attributes, based on nine cases. Our empirical evidence suggests that in addition to the decision context, these decision-making characteristics play an important role in enabling digital startups to reach satisfactory technology design decisions.

Table 4. Bohn, N., Kundisch, D. (2019): Joint Work, Presentations, and Scientific Dissemination

Joint Work	Co-Authorship with D. Kundisch (85% N. Bohn, 15% D. Kundisch) • Literature review by N. Bohn • Concretization of the research question jointly with D. Kundisch • Positioning of the paper jointly with D. Kundisch • Research design planned and conducted by N. Bohn • Quantitative analysis performed by N. Bohn • Write-up of paper by N. Bohn. Feedback, comments and corrections by D. Kundisch • Write-up of the revised paper and response to the ICIS reviewers by N. Bohn. Feedback, comments and corrections by D. Kundisch
Presentations	• 12/2019: Bohn, N., Kundisch, D. (2019). All Things Considered? – Technology Design Decision-making Characteristics in Digital Startups, in: Proceedings of the **Fortieth International Conference on Information Systems (ICIS)**, Munich, Germany. Presented by N. Bohn.
Scientific Dissemination	• The work on this paper started in January 2019. • The paper is published in the proceedings of the **International Conference on Information Systems (ICIS)**, 2019 (VHB Jourqual 3 ranking[3]: A).

[3] VHB Jourqual 3 is a journal ranking published by the German Academic Association for Business Research (Verband der Hochschullehrer für Betriebswirtschaft e.V.).

5.2 Bohn, N. and Kundisch, D. (2020)

In this paper, we conduct a Delphi study with a panel of 38 experts drawn from academia and practice to explore a contemporary understanding of the term ‘*technology pivot’* and scientifically derive a comprehensive conceptualization (cf. Table 5). Technology pivots were initially conceptualized in a seminal contribution by Eric Ries (2011) in his book ‘The Lean Startup’. Whilst academia and the media make liberal use of the term technology pivot, they rarely align themselves to Ries’ foundational conceptualization. Recent academic contributions allow first conclusions that important adaptations of the seminal contributions made by Ries (2011) are required, while ambiguity remains about what technology pivots actually represent. The result of our study is a scientifically derived meaning of technology pivots in digital startups based on an expert panel drawn from a broad range of expertise and experiences in entrepreneurship and the Lean Startup approach.

Table 5. Bohn, N., Kundisch, D. (2020): Joint Work, Presentations, and Scientific Dissemination

Joint Work	Co-Authorship with D. Kundisch (75% N. Bohn, 25% D. Kundisch) • Literature review by N. Bohn • Concretization of the research question jointly with D. Kundisch • Positioning of the paper jointly with D. Kundisch • Delphi study planned jointly with D. Kundisch • Delphi study conducted by N. Bohn • Write-up of paper for submission by N. Bohn. Feedback, comments and corrections by D. Kundisch • Revision of the paper and write-up of the response to the Information & Management reviewers by N. Bohn. Feedback, comments and corrections by D. Kundisch
Presentations	• This work has not been presented so far.
Scientific Dissemination	• The work on this paper started in February 2018. • The paper was initially submitted to **Information & Management** (VHB Jourqual 3 ranking: B) in October 2018. • The paper was accepted for publication in **Information & Management** in April 2020.

5.3 Bohn, N. and Kundisch, D. (2018a)

In this paper, we empirically investigate the circumstances under which it is beneficial for digital startups to perform technology pivots and what to expect from them with regards to business model development and the business environment complications (cf. Table 6). The decision to perform technology pivots is notoriously hard to make, especially as a startup's future business viability will depend on it. Failing to pivot at the right time and for the right reasons can substantially jeopardize a startup's chance of developing into a viable business. Given the alleged importance of pivots, surprisingly little is known about the events leading up to and resulting from pivots. We use an embedded inductive multi-case study approach based on 20 technology pivot cases to propose a preliminary model that identifies three prerequisites, five antecedent and nine consequence categories of technology pivots. Our results also include a discussion about the impact of technology pivots on individual business model dimensions.

Table 6. Bohn, N., Kundisch, D. (2018a): Joint Work, Presentations, and Scientific Dissemination

Joint Work	Co-Authorship with D. Kundisch (67% N. Bohn, 33% D. Kundisch) • Literature review by N. Bohn • Concretization of the research question jointly with D. Kundisch • Positioning of the paper jointly with D. Kundisch • Multi-case study planned jointly with D. Kundisch • Multi-case study conducted by N. Bohn • Qualitative analysis performed by N. Bohn • Write-up of paper by N. Bohn. Feedback, comments and corrections by D. Kundisch • Write-up of the revised paper and response to the MKWI & ECIS reviewers by N. Bohn. Feedback, comments and corrections by D. Kundisch
Presentations	• 02/2018: Bohn, N., Kundisch, D. (2018a). Much more than "same solution using a different technology": Antecedents and Consequences of Technology Pivots in Software Startups, in: Proceedings of the **Multikonferenz Wirtschaftsinformatik 2018 (MKWI)**, Lüneburg, Germany. Presented by N. Bohn. • 06/2018: Bohn, N., Kundisch, D. (2018a). The Role of Technology Pivots in Software Startups: Antecedents and Consequences, in: Proceedings of the **Twenty Fifth European Conference on Information Systems (ECIS)**, Portsmouth, UK. Presented by N. Bohn.
Scientific Dissemination	• The work on this paper started in April 2017. • A preliminary version of this paper is published in the proceedings of the **Multikonferenz Wirtschaftsinformatik (MKWI)** 2018 (VHB Jourqual 3 ranking: D) and an extended version in the proceedings of the **European Conference on Information Systems (ECIS)**, 2018 (VHB Jourqual 3 ranking: B).

5.4 Bohn, N. and Kundisch, D. (2018b)

In this paper, we validate and extend our understanding of technology pivots in digital startups drawn from a previous paper (Bohn and Kundisch, 2018a) by collating a uniquely large dataset of 91 technology pivots through survey research (cf. Table 7). Based on the empirical data collected, we provide a quantitative analysis of technology pivots in digital startups, which reveals new insights on the antecedents and consequences of technology pivots, the occurring business environment complications and the interrelations between technology pivots and other types of pivot. Additionally, we split technology pivots into three sub-types based on their antecedents. We summarize our findings in a preliminary theoretical model which includes eight antecedent and eleven consequence categories of technology pivots. In a second preliminary theoretical model, we summarize our analysis of the business model impact of technology pivots. Our findings both substantiate existing knowledge and create new avenues for much needed theory development in this area.

Table 7. Bohn, N., Kundisch, D. (2018b): Joint Work, Presentations, and Scientific Dissemination

Joint Work	Co-Authorship with D. Kundisch (75% N. Bohn, 25% D. Kundisch) • Literature review by N. Bohn • Concretization of the research question jointly with D. Kundisch • Positioning of the paper jointly with D. Kundisch • Research design planned and conducted by N. Bohn • Quantitative analysis performed by N. Bohn • Write-up of paper by N. Bohn. Feedback, comments and corrections by D. Kundisch • Write-up of the revised paper and response to the ICIS reviewers by N. Bohn. Feedback, comments and corrections by D. Kundisch
Presentations	• 11/2018: Bohn, N., Kundisch, D. (2018b). An Extended Perspective of Technology Pivots in Software Startups: Towards a Theoretical Model, contribution at: **INFORMS Conference on Information Systems and Technology (CIST)**, Phoenix, USA. Presented by D. Kundisch. • 12/2018: Bohn, N., Kundisch, D. (2018b). An Extended Perspective of Technology Pivots in Software Startups: Towards a Theoretical Model, in: Proceedings of the Thirty Ninth **International Conference on Information Systems (ICIS),** San Francisco, USA. Presented by N. Bohn.
Scientific Dissemination	• The work on this paper started in January 2018. • The paper is published in the proceedings of the **International Conference on Information Systems (ICIS)**, 2018 (VHB Jourqual 3 ranking: A).

5.5 Bohn, N. (2019)

In this paper, I analyze the extent to which the antecedents of technology pivots form part of job advertisements published by digital startups (cf. Table 8). Technology pivots are resource-intensive and risky endeavors, especially in the early stages of growing into viable and sustainable businesses, and require a team with the competencies needed to perform technology pivots effectively. Throughout the performance of a content analysis on 510 IT job advertisements, I find very limited references to the (non-) technical antecedents of technology pivots. This casts a light on whether digital startups apply anticipatory mindsets throughout team composition, starting with the formulation of job advertisements. This study provides the basis for further research on technology pivots with regards to team composition in digital startups, extending beyond the analysis of antecedences and consequences of technology pivots.

Table 8. Bohn, N. (2019): Joint Work, Presentations, and Scientific Dissemination

Joint Work	Single authored paper • Student assistance by I. Bozhilova
Presentations	• 08/2019: Bohn, N. (2019). Do Digital Startups Prepare for Technology Pivots? – An Initial Analysis of Job Adverts, in: Proceedings of the Twenty-fifth **Americas Conference on Information Systems (AMCIS)**, Cancun, Mexico. Presented by N. Bohn.
Scientific Dissemination	• The work on this paper started in July 2018. • The paper is published in the proceedings of the **Americas Conference on Information Systems (AMCIS)**, 2019 (VHB Jourqual 3 ranking: D).

6. Reflections on Methodology

As part of conducting research for this dissertation, I reflected about the chosen research approach in general, and the individual contributions in particular.

Among my initial concerns was whether I would be able to collect sufficient amounts of qualitative primary data, which can be challenging in any qualitative research (Yin 2011). Particularly among digital startups and for the practitioners associated with them, time is of the essence and participation in research is hardly a priority for an entrepreneur concerned with building a viable and sustainable business. Therefore, such data might not be easy to collect if potential informants have limited or no interest in sharing their experiences or knowledge. Fortunately, I was able to identify a sufficient number of informants from and experts working with digital startups willing to participate in my research, by creating new and making use of existing local network connections in and beyond the Berlin region.

The phenomena of interest are best understood and commonly dealt with by individuals with a technical background in digital startups. As a result of their deep knowledge these individuals also represent a key data source for this research. Their statements, however, could theoretically reflect a one-sided perspective (Yin 2011). This potential bias, however, should have been mitigated by the decision to involve individuals from different areas of the organization, in order to obtain different perspectives on the phenomenon of interest, but limitations arose from the difficulty of recruiting multiple individuals for each case. To address this issue, a quantitative study was performed that allowed to collect data on a larger number of technology pivot instances, thus lending additional external validity to the findings on technology pivots (Bohn and Kundisch, 2018a, 2018b).

Furthermore, this dissertation relies on qualitative data retrieved about situations that had already been concluded (ex-post). When collecting data ex-post there is the chance that the participant may, intentionally or unintentionally, omit some information, or merely forget to mention it. This might particularly be the case when the participants have to admit that they may have made wrong decisions or false assumptions. This means that further relevant information on the phenomenon studied possibly exists, but which was not possible to collect at the time or by the chosen approach, but could still be gathered via other data collection approaches (such as own observations). Therefore, as part of qualitative research, primary data should ideally be enhanced with additional data from further sources (if feasible) (Gehman et al. 2018; Yin 2011). However, in an entrepreneurial context, and particularly in answer to the research questions of this dissertation, little information was available because entrepreneurs tend not to document their processes, decision-making approach and final choices. Instead, decisions are often reached in an unstructured manner, based on the results of internal (undocumented) discussions.

While conducting the individual studies I also reflected on the generalizability of my findings based on the data collected, which can be limited as a consequence of the subjective interpretations inherent in qualitative research. As part of conducting qualitative research, different researchers might come to different conclusions while aiming to answer the same research question (Sandberg 2005). This is because interpretivists aim to describe their observations and understanding, but refrain from making absolute truth claims. However, researchers with a more positivistic and quantitative research philosophy may struggle to accept this approach (Gehman et al. 2018). To address potential concerns, it is therefore important to achieve the three objectives described in Section 4 (i.e., transparency, rigor, adherence to evidence) justifying the knowledge produced through an interpretive approach (Sandberg 2005).

For *transparency*, the following measures were applied. To make the data collection transparent, detailed information is provided on the type of data, the approaches that were used for its collection (such as semi-structured interviews) and the amount of data collected. Furthermore, the sources are described for each part of collected data, such as the startup's founding year, development stage of the organization, product type, and the informant's role in the organization. With regards to the data analysis, each step of the analysis is described in detail including illustrative examples and supplementary materials. For *rigor*, each study follows the guidelines of well-established research methods (e.g., Gioia et al. 2012; Krippendorff 2013; Yin 2011) and applies evaluation criteria for rigorous research such as those suggested by Lincoln and Guba (1985), covering construct, internal and external validity, reliability, and neutrality. Table 9 illustrates the measures that were applied to each of the individual studies that form part of this dissertation, and how they ensure that these evaluation criteria were fulfilled. As can be observed for each evaluation criterion, multiple measures were applied per study. Yet, some gaps also remain. For example, internal validity, for some of the studies, could have been improved further by increasing data-triangulation through additional data points. Overall, considering that well-established methods were applied and multiple measures taken to address all the evaluation criteria, the overall confidence in the rigor of the conducted studies should not be in doubt. Concerning *adherence to evidence*, the findings made as part of this research were derived by retaining a chain of evidence on the primary data collected (e.g. via multi-level coding). Consequently, the elements that were developed as part of each paper's contribution (such as models or definitions) can directly be linked to an explicit set of evidence. Moreover, references are presented as part of the findings, indicating the individual participant's perspectives, for example in the form of verbatim quotes from participants. In addition, to reduce potential biases, both the data analysis and the conclusions were discussed and reviewed with researchers not involved in the studies.

Table 9. Overview on Evaluation Criteria and Measures applied per Study (grey field = not applicable)

Evaluation Criteria	**Measure**	**Bohn and Kundisch (2019)**	**Bohn and Kundisch (2020)**	**Bohn and Kundisch (2018a)**	**Bohn and Kundisch (2018b)**	**Bohn (2019)**
Construct Validity	Maintain chain of evidence (Yin 2009, 2011)	x	x	x		x
	Indication of data collection circumstances (Gibbert et al. 2008; Grover et al. 1993; Krippendorff 2013)	x	x	x	x	x
	Explanation of data analysis procedure (Gibbert et al. 2008; Krippendorff 2013; Pinsonneault and Kraemer 1993)	x	x	x	x	x
	Deductive codes based on literature (Krippendorff 2013; Neuendorf 2016)					x
	Deductive codes validated by other researchers (Krippendorff 2013; Neuendorf 2016)					x
Internal Validity	Literature review (Eisenhardt 1989; Yin 2009)	x	x	x	x	x
	Peer debriefing (Lincoln and Guba 1985)	x	x	x		x
	Data structure creation (Gioia et al. 2012)	x		x		
	Deductive coding protocol evaluated by independent parties (Krippendorff 2013)					x
	Expert or participant validation of researcher's interpretation (Okoli and Pawlowski 2004)		x			
	Data-triangulation (Eisenhardt 1989; Yin 2009)			x		
	Constant comparison technique (Corbin and Strauss 1990)	x				
	Open and closed questions, with optional free text combined (Fowler 2009)				x	
External Validity	Detailed descriptions of the participants, contexts or cases (Paré et al. 2013; Yin 2009, Fowler 2009)	x	x	x	x	x
	Embedded units of analysis (different instances studied in one organization) (Gibbert et al. 2008; Krippendorff 2013; Yin 2011)			x	x	x
	Multiple instances studied (of different organizations) (Gibbert et al. 2008; Yin 2011)	x		x	x	x
	Multiple data collection approaches (Grover et al. 1993)				x	
	Experts from multiple disciplines (Paré et al. 2013)		x			
	Response rate reported (Okoli and Pawlowski 2004)		x		x	
Reliability	Pre-testing of research design (Harper 2012; Okoli and Pawlowski 2004; Paré et al. 2013)	x	x		x	x
	Case study protocol creation (Yin 2009)			x		
	Interview guide creation and review (Gioia et al. 2012; Yin 2009)	x		x		
	Case study database creation (Yin 2009)	x		x		
	Memoing (Wiesche et al. 2017)	x	x	x		
	Intercoder reliability evaluated and applied (Krippendorff 2013)					x
	Anonymity of the participants (Okoli and Pawlowski 2004)	x	x	x	x	
	Purposive sampling criteria explained (Harper 2012; Pinsonneault and Kraemer 1993)		x		x	x
	Theoretical sampling (Corbin and Strauss 1990)	x		x		
Neutrality	Separation of 1st and 2nd order codes (Gioia et al. 2012; Yin 2011)	x	x	x		
	Interviews recorded and fully transcribed Gioia et al. 2012; Yin 2011)	x		x		
	Non-directive interviewing (Yin 2011)	x		x		
	Self-administered questionnaires (Fowler 2009)				x	
	Rules and procedures guided analysis process (Krippendorff 2013; Neuendorf 2016)					x

7. Conclusion

Two of the most essential decisions in digital startups involve (1) choosing an appropriate initial technology design and, subsequently, (2) radically adapting the technology design when necessary. As such, the first decision includes evaluating and selecting an appropriate initial technology design with which to implement a technological foundation for the products and services to be developed. The second decision then involves evaluating which, why, and when fundamental adaptations to an initial technology design are required. This dissertation provides novel insights on the challenges related to both decisions.

The research studies provided as part of this dissertation investigate the decision-making characteristics of initial technology design decisions in digital startups, consisting of decision-paradigms and decision-attributes (Bohn and Kundisch, 2019). This is followed by an investigation about how fundamental adaptations of initial technology design can be made over time, through a particular type of pivot, namely, technology pivots. For these, a contemporary conceptualization is structurally derived, both from the perspective of researchers and practitioners, thus removing existing ambiguities about technology pivots and what changes to technology designs they entail (Bohn and Kundisch, 2020). Further empirical evidence is collected that provides insights on the antecedents that lead to technology pivots and the consequences that result from them, including their impact on the business models of digital startups (Bohn and Kundisch, 2018a). Further, the studies showed that technology pivots can occur in all life-cycle stages of digital startups and even multiple times (Bohn and Kundisch, 2018b). An analysis of the content of IT job advertisements published by digital startups suggests that they invest limited effort into composing IT teams that are able to tackle the challenges that startups can commonly expect to face, first and foremost technology pivots (Bohn, 2019).

7.1 Implications

Our findings carry important implications both for theory and practice.

My main contribution to digital entrepreneurship and entrepreneurial technology design literature arises from transferring one of the methodologies most frequently used by practitioners (entrepreneurs) – namely, the Lean Startup Approach (Ries 2011) and its core measure of course correction, pivoting (Unterkalmsteiner et al., 2016; Bajwa et al., 2017) – from the seminal contribution by Ries (2011) to the theoretical level. The findings from the five studies presented here shed light on the current perspective of academics and practitioners on technology pivots. As the “lean revolution” (Zaheer et al. 2019, p. 4) is still ongoing, current insights about technology pivots might evolve further, which implies that any contributions to this phenomenon should review the understandings shared by participants at the time of conducting the research. Further, the preliminary theoretical models drawn from the studies’ findings contribute to the explanatory level of theory development surrounding technology pivots (Gregor 2016) and can serve as the foundation, and a reference for, further contributions to this phenomenon of interest. This research further contributed to theory by identifying three sub-types of technology pivots, based on their antecedents, namely, technically motivated, non-technically motivated pivots, and full scope technology pivots, each with its own characteristics and consequences. Future theoretical contributions on technology pivots should include this differentiation into their analyses, in order to derive meaningful and nuanced findings.

This research also contributes to entrepreneurial technology design and entrepreneurial decision-making literature (Bohn and Kundisch 2019). The insights provided on the initial technology design decision-making of digital startups enhances our understanding of the selection of individual technologies (Klotins et al. 2019; Nambisan 2017; Saukkonen et al. 2016) and the role of human behavior in that process (Razavian et al. 2019). The empirical evidence presented reveals relevant decision-making characteristics and their configuration during initial technology design decisions in digital startups. By providing the first reference on relevant decision-making characteristics and their applied configurations, future research can use it as a basis for analyzing individual characteristics in more detail. Additionally, this research contributes to our understanding about how digital startups manage their team composition in terms of the competencies needed to meet the engineering challenges (Unterkalmsteiner et al. 2016; Zaheer et al. 2019). The relevant study (Bohn 2019) provides first insights on the preparation activities for the performance of technology pivots, with regards to team composition in digital startups, derived from IT job adverts. The study's findings concerning the low occurrence of content relating to the antecedents of technology pivots in job adverts imply that direct interaction with digital startups is required to better understand whether digital startups undertake any preparation for technology pivots, in terms of team composition, and if so, what they do in this regard.

Finally, the studies' findings presented here also carry important implications for practice. First, as part of initial technology design decisions, several configurations of design decision-making characteristics can be chosen by digital startups. Among their chosen configurations, several have been found to be perceived by them to be unfavorable, in hindsight. Also, the configurations might not be in line with the suggestions made in the literature. I therefore recommend that digital startups schedule dedicated technology design selection time frames, as well as explicitly and visually conceptualize technology design alternatives throughout their decision-making. Each of the technology design alternatives considered in this context should account for the prevailing uncertainties and be aligned with the objectives of continuous customer feedback collection and iterative product development, following the Lean Startup Approach.

Once a technology pivot is deemed necessary, all stakeholders concerned with the decision (e.g., users and customers, startup employees, startup coaches, and venture capital investors) should be informed and managed. It is recommended to build a common understanding of what the planned technology pivot entails, the objectives it pursues, and the potential complications that might occur during its performance. None of the stakeholders wants to be in the dark about a technology pivot during decision making and its performance. The involved parties should also develop an understanding of the consequences they can expect from a technology pivot, not least of which of how the pivot impacts on the business model. Furthermore, digital startups should assess whether they fulfill the prerequisites for the performance of technology pivots and prepare themselves for complications arising in their business environment. Because of its criticality, I recommend that support services (at universities) and structured programs (such as incubators) add to and enhance their technical guidance to digital startups by providing sparring partners (e.g., former CTOs and serial entrepreneurs). Through this, learnings could be transferred from experienced entrepreneurs and startup engineers to first-time entrepreneurs and thus, common mistakes potentially be reduced.

7.2 Limitations

This research about technology design selection and technology pivots in digital startups is hardly exhaustive but provides first contributions to the nascent state of research on the subject. From this also follows that this dissertation has certain limitations which, at the same time, offer potential avenues for future research, including how to conduct future research on the phenomena of interest.

Some limitations stem from methodological concerns as discussed in detail in Section 6, for example in terms of the phenomena of interest being analyzed ex-post, after the relevant situations has been completed, and not being able to triangulate data to the desired extent.

Moreover, the research conducted as part of this dissertation partly relies on data (i.e., press releases and blog entries) that digital startups have published in the public domain. It is possible that this information may represent actual events in an overly positive manner, rather than more truthfully, because digital startups need to present an attractive image of themselves for future employees, investors, and customers. Yet, as part of the data triangulation performed, no notable contradictions between the collected interview data and information published by the startups became apparent.

7.3 Future Research

Given the nascent state of research on technology designs and technology pivots in digital startups and their high relevance to practice, the opportunities to increase our understanding of the phenomena are vast. Therefore, in addition to the limitations outlined above, a selection of avenues for future research is presented in the following.

First, knowing that digital startups, by their very nature, heavily rely on the choice made as part of their technology design decisions (Unterkalmsteiner et al. 2016; van der Ven and Bosch 2013b), it would be worthwhile to better understand the individual decision-making characteristics chosen by digital startups during the initial technology design decision, and beyond. For this, future research could first look for patterns among the decision-making characteristics recognizable in digital startups with differing characteristics (such as product type, business model, or industry). Future research could then also integrate the effect of prior entrepreneurial experiences with regards the decision-making characteristics of initial technology design decisions in digital startups and investigate best practices developed by serial entrepreneurs. Through this, further exploratory and explanatory empirical research could allow more substantive statements about how to improve decision effectiveness of technology design decisions in digital startups for initial technology design decisions. Second, future research could also analyze changes in the decision-making characteristics beyond the initial technology design decision. Over time, some decision-making characteristics might significantly change as the organization matures (e.g., number of involved parties increases or design review approaches become more extensive), while others remain constant. Moreover, future research could then also jointly analyze the combined effects of the decision context and decision-making characteristics on decision effectiveness of initial technology design decisions. Third, it could also be analyzed under which circumstances and for which purposes particular technology designs are favorable to digital startups. Fourth, future research could investigate the specific challenges relating to technology designs for which digital startups could benefit from having external sparring partners and investigate which technical skills and experiences they should bring. Such research could also focus on different approaches about how the exchange with sparring partners can be facilitated and how effective individual processes are. Fifth, future research could further explore technology pivots by enriching our understanding of the phenomenon through longitudinal observations. This would allow to build an understanding of the phenomenon before, during and after its performance in a high level of detail. Such research would reduce the reliance on self-reported behavior and opinions. Additionally, explanatory and predictive research could be performed to test the existing preliminary theoretical models on technology pivots. Sixth, future research could focus on analyzing the preparation and team composition activities required for the effective performance of technology pivots in digital startups, supporting both startup founders and coaches in this endeavor. This could, for example, include approaches to reducing internal complications and conflict surrounding technology pivots, as well as an analysis and recommendation for the hiring efforts performed by digital startups to find employees that are capable of performing technology pivots.

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