Kumulative Dissertation

Managing Complex IT Projects in the Digitalization Era

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Managing Complex IT Projects in the Digitalization Era

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"The secret of getting ahead is getting started.
The secret of getting started is breaking your complex, overwhelming tasks into small manageable tasks, then starting on the first one."

Mark Twain

American Author (1835 - 1910)

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In: Leimeister JM, Brenner W (eds) *Proceedings of the 13th Internationale Tagung Wirtschaftsinformatik (WI)*, St. Gallen, Switzerland, February 2017, p. 484-498.
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P2. Neumeier A (2017) Wert der Digitalisierung – Erfolgreiche Auswahl von Digitalisierungsprojekten.
In: *HMD – Praxis der Wirtschaftsinformatik, 54(3),* p. 338–350.
(VHB-JOURQUAL3: D)

P3. Neumeier A, Wolf T (2017) Getting a Grip on IT Project Complexity – Concluding to Underlying Causes.
Will appear in: Lee YJ, Agarwal R, Lee JK (eds) *Proceedings of the 38th Conference on Information Systems (ICIS),* Seoul, South Korea, December 2017.
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P4. Keller R, Neumeier A, Bilgin S, Fridgen G (2017) A Hybrid Approach for Cost-efficient Cloud Bursting in Rural Regions.
Submitted to: *Business & Information Systems Engineering*
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P5. Müller HV, Neumeier A (2015) Manage your Blind Flight – The Optimal Timing for IT Project Re-Evaluation
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I. Introduction

Digitalization is extensively influencing our private lives and society (Bojanova 2014). Nowadays, smart devices such as smartphones or tablets, social media platforms such as Facebook and Instagram, and e-commerce platforms such as Amazon and eBay have become indispensable to our lives. We use them to communicate, gather information, or purchase goods and services (Esche and Hennig-Thurau 2014). For instance, 82% of German Internet users bought or ordered goods or services via the Internet in 2016 (eurostat 2017). However, digitalization has not only changed our private lives, it also has an enormous impact on business practices (Legner et al. 2017). Disruptive information technology (IT) innovations, such as the Internet, cloud computing, big data, blockchain, and the consumerization of IT are transforming companies across the world towards an age of digitalization (Bojanova 2014; Buhl et al. 2013; Keller and König 2014; Schlatt et al. 2016). Via the Internet of Things (IoT), new ways of interaction between machines and people are becoming possible, and the amount of available information is increasing hugely (Bojanova 2014).

Although digitalization is omnipresent in our daily lives, people are wondering: *What is digitalization? And is digitalization really new?* To address this confusion, Legner et al. (2017, p. 301) have defined digitalization as "the manifold sociotechnical phenomena and processes of adopting and using […] technologies in broader individual, organizational, and societal contexts". They argue that especially the third wave of digitalization, which we are experiencing today, is leading to new opportunities in business, life, and society (Legner et al. 2017).

However, many researchers in the Business and Information Systems Engineering (BISE) and the Information Systems (IS) community argue that digitalization is not a new phenomenon (Legner et al. 2017). IT has been used in business practice for several decades (Legner et al. 2017). Developing from its traditional function as administrative support towards a strategic role within the organization (Henderson and Venkatraman 1993), especially awareness concerning IT's importance in business practice has evolved in the digitalization era. While IT was previously usually considered as an engine to facilitate automation and efficiency increases, during the last years, IT's extensive potential is drawing substantial attention (Legner et al. 2017). Practitioners and researchers recognize IT as a key factor to enrich services or products as well as to change business models in almost every industry (Legner et al. 2017). Thus, the roles of IT and therefore also IT managers in companies are changing. Besides their established functions, IT is expected "to directly contribute to the company's overall success"

(Legner et al. 2017, p. 306) by promoting and implementing innovations in the company. However, besides the large opportunities, digitalization also has negative influences, such as data privacy concerns or even business failures that companies have to overcome (Weill and Woerner 2015).

In this doctoral thesis, I deal with digitalization in an organizational context. In this context, I consider digitalization as the evolution of IT use in business practice. Even though, technologies rapidly evolved during the last years, the basic thought of using IT to increase the profit of a company still remains the same. Establishing the buzzword digitalization in business and society can now help the research community to place a strong focus on the opportunities and challenges of using IT. However, companies will have to learn to take advantage of the opportunities and handle the challenges of new technologies by transforming towards digital business, which will enable collaboration “across boundaries of time, distance, and function” (Bharadwaj et al. 2013, p. 472).

To keep up with the speed of change and enable a digital transformation, companies must ensure a high adaptability level, enabling the required changes and continuous progress. An established way of achieving the required progress is to conduct projects that implement the necessary changes. The literature does not agree on one definition of a *project*. However, most definitions have in common that a project is (1) unique, (2) limited in time, (3) has a clear objective, and (4) has limited resources, e.g., time and cost budgets (Project Management Institute 2008; Turner and Müller 2003). Classical IT projects used to focus on the implementation of IT involving “hardware, software, and networks to create a product, service, or result” from a technological perspective (Schwalbe 2015, p. 4). With the technological development, classical IT projects developed further to digitalization projects which also take sociotechnical aspects, including social aspects and the interaction between human beings and technology, as well as process aspects into account. However, classical IT projects and digitalization projects contribute to a company’s digitalization progress. Thus, in this doctoral thesis, I refer to both as IT projects.

In any case, to contribute to a company’s progress, a project’s objectives should align with the company’s overall objectives (Buhl and Meier 2011). Since the early 1950s, companies have utilized *project management* to ensure successful project completion (Olsen 1971), which is even more important in a digital world (Watson 2012). The British Standard in Project Management (1996) defines project management as “the planning, monitoring and control of all aspects of a project […] to achieve the project objectives safely and within agreed time, cost and performance criteria." They retain the classical characteristics of *project success* defined by the 'Iron Triangle' – cost, time, and quality (Atkinson 1999).

Despite the implementation of project management practices, especially IT projects are prone to failure (Matta and Ashkenas 2003). According to a 2011 study, one out of six IT projects exceeds its planned costs by 200% and the planned time by 70% (Flyvbjerg and Budzier 2011). In 2015, a comprehensive study by the Standish Group reported that only 29% of IT projects are successfully completed (The Standish Group 2015). There are numerous examples of IT project failures in the literature (Keil et al. 2000; Montealegre and Keil 2000; Nelson 2007). McDonalds, for example, started one of the first digitalization projects in 2001. It planned to connect soda dispensers and frying machines via an IT system so that executives at the headquarters could check the devices' performance in real-time (Nelson 2007). After two disastrous years and $170m spent, the company abandoned the project. In this, as in many other cases, managers cite as reasons for failure technological problems, organizational and functional issues, managerial shortcomings, and many others (Al-Ahmad et al. 2009).

In general, a lack of managerial approaches for coping with very complex projects is a main reason for these failures (Jaafari 2003; Vidal and Marle 2008). Since a project's complexity impacts on cost, time, and quality, it can hinder project success (Baccarini 1996). Complexity in projects has permanently increased during the past decades (Nelson 2007). Compared to non-IT-projects, IT projects are particularly affected by high complexity levels (Fridgen et al. 2015b; Jaafari 2003; Vidal and Marle 2008). The intangibility of assets, abstract constraints, difficulty in visualization, uncertainty owing to frequent requirements changes, and the requirement to understand business and IT processes cause complexity (Al-Ahmad et al. 2009; Baccarini et al. 2004; Jaafari 2003). Moreover, projects are increasing in size on average (Nelson 2007). Thus, dependencies, which make managing a project even more complex, can occur within a single IT project (Beer et al. 2013; Fridgen et al. 2015b). Another reason for rising complexity is the increasing number of projects (Nelson 2007). Since a company usually conducts several IT projects at the same time, dependencies can even occur between different projects (Beer et al. 2015; Fridgen et al. 2015b; Zimmermann et al. 2008).

As a response to "the poor track record of previous projects" (Svejvig and Andersen 2015, p. 278), researchers have begun to rethink classical project management approaches (Svejvig and Andersen 2015). Nonetheless, modern project management approaches that are used in practice are usually still based on the classical definition (Svejvig and Andersen 2015). However, focusing on the Iron Triangle leads to an output-oriented management, which may leave project stakeholders unsatisfied (Badewi 2016). Thus, the perspective on project success has been extended by a project value creation and benefits management perspective that investigates "what factors are required to realize the benefits from the projects and how this should be done" (Badewi 2016, p. 762). Further, project-inherent risk should be considered (Remenyi 1999; Wallace et al. 2004). The project management literature states that risk can positively or negatively impact on project progress (Project Management Institute 2008). In any case, risk can lead to a deviation from project goals. Thus, managers should consider risk in their assessments. Overall, modern project management approaches usually regard a project's costs, benefits, risks, and dependencies for evaluation (Beer et al. 2013; Fridgen et al. 2015b).

With these modern project management approaches on the rise, the trend of devastating numbers of IT project failures could reverse in the future. A current study by the Project Management Institute (PMI) recently discovered, for the first time in five years, that more projects are reaching their goals and are not exceeding their budgets (Vaske 2017). Overall, companies wasted 20% less money on project failures (Vaske 2017). According to the study, one key reason for this improvement is that successful companies rely on established project and program management methods (Vaske 2017). This may be a first indication that modern project management methods can help one to reach a higher quota of successfully implemented IT projects. In this doctoral thesis, I address the development and improvement of modern IT project management approaches.

To ensure successful project management, the PMI proposes using a project's lifecycle as the basic framework for managing a project (Project Management Institute 2008). For this purpose, the literature divides the IT project management cycle into three phases: ex ante evaluation (before the project starts), ex nunc steering (during the project), and ex post controlling (after the project ends) – as illustrated in Figure I.1-1 (Beer et al. 2013; Fridgen et al. 2015b; Müller and Neumeier 2015).

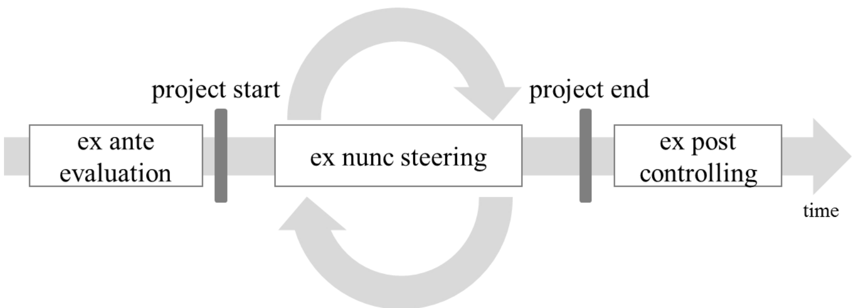

Figure I.1-1. Phases of IT Project Management Cycle

The ex ante evaluation phase brings about a decision for a company if an evaluated IT project is accomplished (Beer et al. 2013). For this purpose, management assesses the project based on qualitative or quantitative measures (Walter and Spitta 2004). The ex nunc steering phase helps a company to ensure positive project progress by continuously evaluating the project during its run-time (Fridgen et al. 2015b). The ex post controlling phase ensures the implementation of project goals in the organization and fosters organizational learning by analyzing positive and negative aspects of the project after its end. The analyses are usually conducted in so-called project post mortems (Pettiway and Lyytinen 2017). This thesis focuses on ex ante evaluation, with a brief look at the ex nunc steering phase.

In chapter I.1, I illustrate the thesis objectives and structure. In chapter I.2, I embed the corresponding research papers in the research context and highlight the key research questions.

I.1. Thesis Objectives and Structure

The main objective in this doctoral thesis is to develop management approaches for the ex ante evaluation phase of a project in the area of digitalization. Further, the doctoral thesis provides an outlook on management approaches for the ex nunc steering phase of a project. Table I.1-1 summarizes the doctoral thesis objectives and structure:

I	**Introduction: Managing Complex IT Projects in the Digitalization Era**
Objective I.1:	Outlining the thesis objectives and structure
Objective I.2:	Embedding the included research papers in the context of the thesis and formulating the key research questions
II	**Ex Ante Evaluation of a Project (Research Papers P1, P2, P3, and P4)**
Objective II.1:	Developing ex ante evaluation approaches for projects (P1, P2, P3, P4)
Objective II.2:	Discovering the value contribution of digitalization for companies (P1, P2)
Objective II.3:	Choosing an adequate project portfolio that helps to implement digitalization’s value (P2)
Objective II.4:	Providing conceptual clarity regarding the IT project complexity construct (P3)
Objective II.5:	Considering the special requirements of hidden champions in rural regions in the decision for a hybrid cloud service model in an IT infrastructure project (P4)
III	**Ex Nunc Steering of a Project (Research Paper P5)**
Objective III.1:	Providing an outlook on the ex nunc steering of a project (P5)
Objective III.2:	Developing an economic decision model that considers the tradeoff between management being in a blind flight and management spending too much money on evaluation (P5)
IV	**Results and Future Research**
Objective IV.1:	Presenting the thesis’ key findings
Objective IV.2:	Identifying and highlighting areas for future research

Table I.1-1 Doctoral thesis objectives and structure

I.2. The Research Context and Research Questions

I will now motivate the research questions of chapters II & III including P1 to P5. Depending on the project scope, projects' characteristics differ. This doctoral thesis, distinguishes between different levels of a project in the ex ante evaluation and the ex nunc steering phases and doesn't focus on ex post controlling.

Research paper P1 is set up on the most general level and deals with the overall value of digitalization and the benefits that can be gained due to the use of new technologies. Research papers P2, P3, and P5 address the evaluation of a single project without focusing on a specific project type. Research paper P5 addresses the most specific topic. It deals with the evaluation of a specific IT infrastructure project in the context of cloud computing. Figure I.2-1 provides an overview of the included papers embedded in the research context.

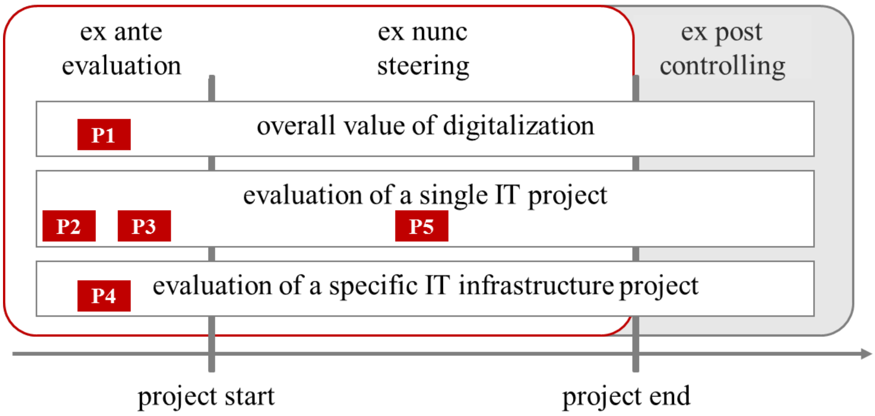

Figure I.2-1. Research Papers Embedded in the Research Context

I.2.1. Chapter II: Ex Ante Evaluation of a Project

Projects are conducted to change a company's current state. Project portfolio management must choose the best possible combination of projects to achieve the company's target state (Wehrmann et al. 2006; Zimmermann 2008). To enable a reliable decision, project ideas must be gathered in a step-by-step process. After first selecting projects that can realistically be accomplished, a company must conduct a detailed evaluation based decision process in the ex ante evaluation phase (Beer et al. 2013; Krcmar 2010).

In the evaluation, a project needs to be assessed in terms of its characteristics. Besides defining the project requirements, project scope, estimated timeline, and estimated required resources for the project (Project Management Institute 2008), it is important to qualitatively and/or quantitatively assess a project (Beer et al. 2013; Wehrmann et al. 2006; Willcocks 1994). According to the literature, a comprehensive method to assess a project's value should incorporate costs, benefits, risks, and interdependencies within the project (Beer et al. 2013; Fridgen et al. 2015b).

For this purpose, Beer et al. (2013) develop an ex ante evaluation method that considers costs, benefits, risks, and interdependencies between benefits in IT projects. However, the adoption of formal evaluation methods in practice is still low. If practitioners apply formal evaluation methods at all, they usually focus on the evaluation of project costs and don't consider benefits, risks, and dependencies (Buhl 2012). Further, especially for very complex IT projects, the identification and quantification of the relevant costs and benefits are time-consuming and hard to accomplish (Alshawi et al. 2003; Beer et al. 2013). Chapter II of this thesis develops approaches for IT project evaluation with a solid academic basis that are nonetheless suitable for management.

In a first step, P1 (*The Manifold Fruits of Digitalization – Determining the Literal Value Behind*) focuses on the value perspective of digitalization. Although the expectations of digitalization's value contribution for companies are very high (Gartner 2013; Gutsche 2014a), few companies really understand the exact value digitalization can create in their company (Gottlieb and Willmott 2014). Nonetheless, many companies are already launching digitalization projects without a deeper understanding of the value these projects can create (Gutsche 2014a). P1 seeks to identify the benefits that digitalization can have for companies and the associated value drivers. P1 states the following research question (RQ):

RQ1: What are the benefits and which aspects can be considered as underlying value drivers of digitalization?

To enable the realization of digitalization's value in a company, a general assessment of possible value drivers is insufficient. A company needs to decide which project portfolio can generate the highest value; thus, it requires support for the project selection decision. Based on the identification of customer experience and efficiency as value drivers of digitalization in P1, P2 (*Wert der Digitalisierung – Erfolgreiche Auswahl von Digitalisierungsprojekten*) operationalizes the developed insights for management practice. In a first step, P2's goal is to develop an assessment scheme for digitalization projects. This assessment scheme enables a company to evaluate a project. In a second step, P2 seeks to develop a four-step procedure that enables the identification of an adequate project portfolio that helps to implement digitalization's value. P2 states the following two research questions:

RQ2: How can a company assess a digitalization project's value based on the value drivers of digitalization?

RQ3: How can a company select an adequate project portfolio based on assessing digitalization projects?

As discussed, besides the value created, project complexity impacts on the ex ante decision. Since the lack of managerial approaches for a project's complexity strongly influences a project's success or failure (Jaafari 2003), P3 (*Getting a Grip on IT Project Complexity – Concluding to Underlying Causes*) investigates the phenomenon of IT project complexity. Complexity must always be considered in the context of its appearance. P3's goal is to enable a comprehensive and structured assessment of an IT project in concerns of complexity. Thus, it is necessary to understand the underlying causes of complexity. Based on this assessment, managers can identify the key aspects of complexity that are relevant for the IT project at hand. Thus, P3 states the following question:

RQ4: How can we assess complexity in IT projects concerning their influencing factors?

The last paper in chapter II addresses the most specific project, an IT infrastructure project. Since IT departments increasingly face high cost pressures and the demand for flexibility, new ways to provide IT services are required (Middleton 2013). In the digitalization era, cloud computing with its service forms Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) (Youseff et al. 2008) have proven to be valid and efficient alternatives to traditional service types (Bojanova 2014). However, the realization of cloud computing's full potential is still restricted by a lack of available bandwidth, especially in rural regions. Thus, hidden champions – medium-sized, often family-operated companies with market leadership in a domain (Simon 1996) – need to evaluate whether they can utilize cloud resources in their service model. P4 (*A Hybrid Approach for Cost-efficient Cloud Bursting in Rural Regions*) develops an ex ante decision model for choosing whether and how hidden champions can consider cloud computing in their service models. Since most hidden champions in rural regions still have their own data center, P4 proposes a hybrid cloud approach that incorporates on-premise resources and cloud resources. In P4, we base our investigations on an existing model by Lilienthal (2013) and examine whether the model considers special restrictions for hidden champions in rural regions. P4 has the following two questions:

RQ6: Which special requirements are relevant for hidden champions in rural regions concerning a hybrid cloud service model?

RQ7: Which adjustments to Lilienthal's (2013) model are necessary to consider the special requirements for hidden champions?

I.2.2. Chapter III: Ex Nunc Steering of a Project

After selecting an IT project for the project portfolio, companies often don't observe the single project's economic development (Fridgen et al. 2015b). However, since projects are conducted in a changing environment, the initially evaluated project circumstances, its associated cash-flows, and thus the derived project value can change over time. If these changes are not considered during a project's run-time, the company is in a blind flight about whether or not the project will achieve its goals. If, during this blind flight, there are negative deviations from the originally estimated project value, management will not recognize them, and cannot take the required actions to bring the project back on track. Thus, the company places the project value at risk. Continuous re-evaluation during the project's runtime is therefore required to ensure successful project completion.

Only a few models provide adequate measures and methods to identify deviations in a project; this led Fridgen et al. (2015b) to develop project steering measures. These help companies to identify changes during a project's run-time and enable to take counter-actions (Fridgen et al. 2015b).

However, every evaluation implies cost and time resources. Thus, it is not economically viable to continuously evaluate every project. Thus, companies must trade off financial loss caused by evaluating too early and the project value that may be lost if a project is evaluated too late. P5 (*Manage your Blind Flight – The Optimal Timing for IT Project Re-Evaluation*) develops an economic model that addresses this tradeoff. Thus, P5 states the question:

RQ8: What is the optimal time until re-evaluation for an IT project based on risky cash-flows?

I.2.3. Chapter IV: Results and Future Research

After this introduction, which outlines the objectives and structure of the doctoral thesis, motivates the research context, and formulates the research questions, chapters II & III present the research papers. Subsequently, chapter IV presents the key findings and highlights areas of future research in the field of project management with a focus on ex ante evaluation and ex nunc steering.

II. Ex Ante Evaluation of a Project

This chapter deals with the ex ante evaluation of IT projects. Based on an initial project evaluation, companies can decide which project should be accomplished. Literature states that IT projects should be evaluated based on costs, benefits, risk and dependencies (Beer et al. 2013; Fridgen et al. 2015b). However, only few methods that regard different aspects have been established in business practice. Hence, this chapter includes four research articles that deal with approaches to improve the management of IT projects.

The first research paper P1 (*The Manifold Fruits of Digitalization – Determining the Literal Value Behind*) in chapter II.1 focuses on the value perspective of digitalization. In this context, the benefits within the era of digitalization are discussed. Further, possible value drivers of digitalization are presented.

The second research paper P2 (*Wert der Digitalisierung – Erfolgreiche Auswahl von Digitalisierungsprojekten)* in chapter II.2 operationalizes the insights of research paper P1. An assessment scheme to evaluate digitalization projects based on their value drivers is introduced. Further, a four-step procedure to identify the most valuable projects for a company is developed.

The third research paper P3 (*Getting a Grip on IT Project Complexity – Concluding to Underlying Causes)* in chapter II.3 focuses on the assessment of complexity in IT projects. The aim of this research paper is to identify antecedents of complexity and project areas where complexity can occur within an IT project. Based on the resulting framework, managers can identify possible problems due to complexity in their projects even before project start.

The fourth research paper P4 (*A Hybrid Approach for Cost-Efficient Cloud Bursting in Rural Regions)* in chapter II.4 deals with one specific IT infrastructure project. P4 develops an ex ante decision model for choosing whether and how hidden champions can consider cloud computing in their service models. P4 discovers the shortcomings in current literature concerning the special requirements of hidden champions. Based on these insights, P4 adjusts an existing model towards the new requirements. Further, P4 derives hypothesis concerning the model behavior based on a Monte Carlo simulation and discusses the hypothesis in further expert interviews.

II.1. The Manifold Fruits of Digitalization – Determining the Literal Value Behind

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Abstract:

As digitalization is rewriting the rules of competition, companies need to adapt to external changes or they will be left behind. Indeed, digitalization bears a lot of economic potential and is undoubted to have tremendous impacts on the economy. Many companies already launched digital initiatives. However, most of them lack an understanding of the value digitalization can create. They often neither know the organizational value created, nor define accountability measures or specify targets. Therefore, as a first step this paper aims to provide clarity by relating digital benefits listed in literature and highlighting the underlying value drivers. Our results help companies to identify digital business value, but also lower the hurdles that prevent them from scaling up their digital effort.

Keywords: Digitalization, Benefit, Value driver.

II.1.1. Introduction

Digitalization is on the rise and “is rewriting the rules of competition” (Hirt and Willmott 2014, p. 1). Those companies who are not able or willing to adapt will be left behind (Bharadwaj et al. 2013; Gimpel and Röglinger 2015; Hirt and Willmott 2014). Especially the ability to handle the new challenges that come with digitalization will make the difference in future. The main differences compared to common IT usage lie in the faster speed of change, in the higher level of interconnectedness, and in the willingness of individuals to use technological devices (Gimpel and Röglinger 2015). Those phenomena already have an enormous impact on private lives and the society and will also tremendously impact business practices and success models. Hence, digitalization is considered as the fourth wave of industrialization, which will dramatically change the business world (Bloching and Wege 2014).

Many consultancies provide extensive studies about success stories, trends, challenges, strategies and benefits of digitalization (Gutsche 2014a; Jaubert et al. 2014; Markovitch and Willmott 2014; Olanrewaju and Willmott 2013). The economic potential of the Internet of Things, for instance, is considered to be up to $ 1.9 trillion by 2020 (Gartner 2013). And yet, the Internet of things is only one of the topics considered as digitalization. Cloud computing, big data, social networks, and many other novelties unfold even more prosperous properties. Many companies set up digital initiatives in order to benefit from the supposed fruits of digitalization. A study among 500 company executives by KPMG showed that about 43% of companies already conducted changes in their business model and that about 60% already made adjustments towards digital in their product and service portfolios and their administrative processes (Gutsche 2014a). However, companies mostly lack a deeper understanding of the value digitalization can create within their organization and therefore are mostly not able to determine the gain their digital initiatives actually shall deliver. According to a survey among 850 C-level executives by Gottlieb and Willmott (2014), only 7% of the respondents consider their organization to understand the exact value from digitalization. Furthermore, over 60% admit that their companies do neither have accountability measures nor specified targets for digital initiatives (Gottlieb and Willmott 2014). This emphasizes the necessity for shading light to manifold supposed fruits of digitalization.

Therefore, the goal of our research endeavor is to identify the value of digitalization within an organization. Therefore, we need to clarify the main value drivers of digitalization that can be used as a starting point for developing measures for the value of digitalization. Thus, we state the following research question:

What are the benefits and which aspects can be considered as underlying value drivers of digitalization?

Therefore, we analyze benefits of digitalization that have been identified in existing literature and derive to the underlying value drivers. We contribute to existing literature by analyzing and structuring existing literature to provide the basis for a detailed analysis of measurement approaches for digital value drivers. Furthermore, practitioners can benefit from our approach as we provide an identification of main benefits and propose value drivers to determine the gain of digital initiatives.

The remainder of the paper is organized as follows. After motivating our research and introducing the research question, we explain our research methodology. In section 2, we provide a structured literature review and synthesize the results of the literature review in section 3. In section 4, we derive conclusions, reveal limitations and give an outlook on future research.

II.1.2. Literature Review

This paper sticks to the well-established method for research synthesis of Cooper and Hedges (1994) and adopts the changes towards the seven-step process of Cooper (2010). Accordingly, we formulate the scope including research objective and problem in the introduction section. In this section we outline the procedure of searching literature and define which information about each study is relevant to the previously described research objective. The selection of relevant studies based on their contribution and fit to the research problem is also illustrated. To integrate, condense and combine the results, we analyze the articles and develop an incorporating framework in section 3. Subsequently, the results are summarized and conclusions are drawn in the discussion section with regard to generalization and possible points of contact for further research. Finally, with this paper the results of the research are presented to public.

To ensure transparency and objectivity regarding the research sample selection, we identified relevant literature based on a keyword search of different data bases. As digitalization is a quite young research field, which is extensively discussed in research and practice, we included scientific literature as well as practice studies in our search.

Procedure: To identify relevant practice studies that cope with the value of digitalization initiatives, we draw on google search engine and used ‘digi*’ AND ‘value’ and ‘digi*’ AND ‘benefits’ as keywords. We focused on articles in English and German language. Furthermore, we searched white papers and studies from large management consultancies (e.g., McKinsey & Company, Accenture) and conducted a forward and backward search within the identified practice studies.

Hence, we gained a vast amount of results from our google search. Thus, we searched for publications by management consultancies and other white papers. After identifying the most relevant articles by screening the titles, we analyzed the introduction of the available data set. Thus, we identified 29 articles and studies that deal with the benefits and value of digitalization for companies.

To identify relevant scientific literature, we conducted a structured literature analysis based on established scientific databases that are relevant in the IS field. With new technologies and innovations like cloud computing, big data and many others establishing, the rules of competition have changed. But what is new with the phenomenon of digitalization compared to the usage of IT or digital technology that has been going on for years already? In this context, Gimpel and Röglinger (2015) state, that “the new aspect of digitalization is not the usage of information technology per se but the speed of change and the world´s level of connectedness”. The miniaturization of increasingly powerful computing hardware leads to an omnipresence of technological devices. This is associated as Moore’s law and is considered to be the root cause or underlying driver of the digitalization phenomenon (Gimpel and Röglinger 2015). Additionally, this interpenetrating dissemination of IT combined with innovations like the internet enable all entities of an ecosystem to connect, which boosts an increase in value. Simultaneously to these technological developments, customers are increasingly willing to use technological devices. All in all, digitalization can be described as a situation in which different influence factors interact and thus the usage of digital technology is able to tremendously impact business practices and business models across almost all industries or even the whole ecosystem.

Hence, we searched for articles that cope with digitalization and the value that can be gained for a company due to digitalization. Thus, the keywords ‘digi*’ AND ‘benefits’ as well as ‘value’ in the title and the abstract of the articles were used. Furthermore, we limited the search to articles that were published after 2010, since we want to put new use and omnipresence of digital devices to the center of contemplation. With the release of the first iPhone in 2007 and the first iPad in 2010, there was an enormous increase of smart devices per person (Cisco 2011). In 2010, the ratio of more than one smart device per person (calculated on the basis of the world’s population) was observed for the first time (Cisco 2011). Hence, we chose 2010 as an adequate time limit for our analysis. Table II.1-1 shows the combination of search terms in the selected databases.

Database	*Keywords*
AIS Electronic Library	‘digi*’ AND ‘benefits’, ‘digi*’ AND ‘value’, ‘digitalization’
EbscoHost	‘digi*’ AND ‘benefits’, ‘digi*’ AND ‘value’
IEEEXplore	‘digi*’ AND ‘benefits’, ‘digi*’ AND ‘value’

Table II.1-1 Selected Databases and Search Terms

As digitalization is an extremely broad research field, many articles can be identified that somehow deal with digitalization. Thus, the scientific literature review generated a result of more than 300 articles with duplicates removed. To identify the articles that are relevant for our research topic, we first analyzed the titles of the articles whether they fit the focus of our manuscript to identify the value of digitalization for companies. All articles that obviously cope with another topic were excluded. In a second step, we analyzed the abstracts of the remaining articles and focused on the articles that deal with the value of digitalization for companies. After analyzing all articles, we gained a result of 27 articles which address the identification of the value of digitalization for companies. To complete the literature review, we conducted a forward and backward search recommended by Webster and Watson (2002). The identified articles were analyzed as previously described and if appropriate added to the selected sample. Finally, 31 articles were identified as relevant for further consideration.

Analyses: Concerning management and practice studies, beside almost all big players in the consulting industry, independent research institutes, as well as public institutions address digitalization in various studies. Even though many articles do not focus on a specific industry, most industries (e.g., media, banking, insurance, and manufacturing) are mentioned in the articles.

The influence of digitalization and the implications for companies is one of the major concerns in practice studies (Bloching and Wege 2014; Gartner 2013; Gottlieb and Willmott 2014; Olanrewaju and Willmott 2013). Even though they focus on different aspects like the expectations of companies (Gottlieb and Willmott 2014), influencing factors of digitalization on business and working processes or the effects of digitalization on a special industry, like production industry, the insurance industry, or German mid-sized companies they all agree that digitalization already has changed and will change many aspects of a company (Gutsche 2014a; Reifel et al. 2014; Reker 2013).

This digital transformation comes with several chances and challenges (Büst et al. 2015; Fitzgerald et al. 2013; Gimpel and Röglinger 2015). Therefore, Capgemini set up a study concerning the management practices and benefits of the digital transformation (Westerman et al. 2011). To accomplish successful digital transformation, organizational requirements need to change and classic organizational structures will no longer be adequate (Guest 2014). Thus, transformation management can decide about success or failure of a company in the digital age (Bloching et al. 2015; Fitzgerald et al. 2013; Gimpel and Röglinger 2015). Reactions and requirements to overcome the new challenge are also widely discussed. Furthermore, the success factors and benefits of digitalization for companies are examined (Fitzgerald et al. 2013; Hirt and Willmott 2014; Markovitch and Willmott 2014; Westerman et al. 2011). Accenture conduct a survey among the Top 500 German companies and identify strategies that make the difference for the successful digital players (Riemensperger et al. 2015).

Scientific literature on digitalization also discusses various topics. Currently, the focus of companies changes from developing an IT strategy towards integrating a 'digital business strategy' (Bharadwaj et al. 2013). Digital business strategy sheds light on the possibilities and effects of digitalization on the firm. In general, it provides special attention on making explicit that the new digital technologies go beyond increasing efficiency and productivity towards competitive advantage and strategic differentiation (Bharadwaj et al. 2013). Value creation is not limited to single products or services anymore. It expands opportunities to new dimensions that have not been accessible before (Keen and Williams 2013). Companies in future will not be successful because they once adopted a digital business strategy or business model. They will succeed due to flexibility in adapting to new circumstances and requirements (Keen and Williams 2013). As the modes of collaboration within and beyond ecosystems will change, companies need to adapt and increase flexibility (Markus and Loebbecke 2013; Pagani 2013). Most articles concerning digital business strategy develop theoretical models concerning the digital architecture, digital networks, platforms and processes (Grover and Kohli 2013; [e.g. Keen and Williams 2013; Markus and Loebbecke 2013; Oestreicher-Singer and Zalmanson 2013; Pagani 2013).

Besides digital business strategy, the combination of digital and physical components is discussed in literature. Yoo et al. (2010) define the "carrying out of new combinations of digital and physical components to produce novel products" as digital innovation. According to Barrett et al. (2012, p. 2) "the economy [shifts] from a goods-based to a service-based economy" due to digitalization and digital innovation (Lusch and Nambisan 2015). The integration of digital technologies in traditional products promises increased performance and experience (Hylving et al. 2012). Thus, the combination of digital and physical products is becoming a strategic topic for many companies as the gained flexibility creates novel market offerings and thus benefits

(Hylving and Schultze 2013; Lusch and Nambisan 2015; Yoo et al. 2010). To gain the value that comes with new market offerings, new ways of defining digital services are required as it differs from the traditional logic of services (Chowdhury and Akesson 2011). Furthermore, traditional innovation processes need to change due to the integration of digital technologies (Hylving et al. 2012).

Besides discussing the influence of digital technologies on the strategy of a company, the integration of digital technologies in the operations of companies is a focus topic in literature. Matt et al. (2015) claim that if the four transformational dimensions ‘use of technologies’, ‘changes in value creation’, ‘structural changes’, and ‘financial aspects’ are closely aligned, the potential benefits of digitalization can be realized. This “include[s] increases in sales or productivity, innovations in value creation, as well as novel forms of interaction with customers, among others” (Matt et al. 2015, p. 339). The integration of new technologies into operations can furthermore leverage higher organizational efficiency and thus increase savings in cost and time (Gaskin et al. 2011; Kuehne et al. 2015).

Digitalization can furthermore help to improve the communication within and beyond the company (Ceccagnoli et al. 2014; Dahl et al. 2011; Lu et al. 2015). By building innovation communities companies can enlarge their idea pools and thus gain tangible as well as intangible benefits (Dahl et al. 2011). Due to easy communication in corporate blogs or platform forums the performance of employees can increase due to knowledge spillovers (Ceccagnoli et al. 2014; Lu et al. 2015). Nevertheless, technology needs to be aligned with the business goal to improve overall performance.

Besides literature that deals with digitalization in general, there are several studies that examine digitalization within specific industry sectors, like automotive industry, retail banking, media, and public sector (Hanelt et al. 2015; Mädche 2015; Spann 2013). Even though all articles discuss different aspects and industry specifics, they agree that new business models can create new value-added services (Hanelt et al. 2015). Improved communication with the customer as well as smart data analysis can help to recognize customer needs (Spann 2013) and thus improve customer experience and satisfaction (Mädche 2015). Furthermore, due to virtualization of decision and operating processes and standardization, companies can achieve an increase of efficiency that leads to higher productivity and thus reduced costs (Hanelt et al. 2015; Mädche 2015).

Although various topics have already been discussed, neither in scientific nor in practice literature we can find a structured overview or framework that can help companies to understand the benefits of digitalization. Thus, we will examine the benefits of digitalization and the underlying value drivers in more detail.

II.1.3. Deriving the Value of Digitalization

Despite many studies from business consultancies about implications and possible benefits of digitalization, this topic is still very vague for many companies. They often are not able to grasp this topic in terms of being able to set concrete organizational objectives. Therefore, this section condenses the benefits previously investigated from scientific and practice literature in order to derive the value drivers of digitalization.

To receive a more objective result, we aligned to a structured approach and discussed all results with other researchers. As a first step we carefully screened the 29 practice studies and the 31 scientific articles for benefits of digitalization. We gathered all mentioned aspects in a central database. After having identified a variety of benefits of digitalization, we clustered all benefits independently of each other to get a common understanding of the various terms and notions mentioned. Then we discussed the results within each other and with other researchers. This led us to a result of 38 kinds of benefits. We derived an appropriate wording for each kind of benefit. For example, customer centric, delight customers, customer behavior, customer loyalty, customer trust, citizen-centricity, customer satisfaction, client experience were subsumed to the benefit *customer experience*. Due to space restrictions, we only included the final wording.

Since the identified benefits of digitalization are diverse regarding granularity and sphere of impact, we categorize them to different levels of an information system. Since the different elements of an information system usually are organized in organizational layers (Aier and Winter 2009; Buhl and Kaiser 2008; Winter 2003), we refer to an established model by Buhl and Kaiser (2008) for information and communication systems to allocate them to appropriate layers of organizational information systems. This model has been applied for categorization by other studies before (Huber 2016; Kleindienst 2016). The model classifies an organization in four different intra-organizational layers and is based on the classification by Frank (2002) and Winter and Fischer (2007): *Business Model*, *Business Processes*, *Application Systems & Services (Appl. Sys & Services)*, and *Infrastructure.* The layers are connected and increase in granularity from the lower to the upper ones. Furthermore, the model considers *Customers* as value driver of each organizational endeavor and supposes them as extra-organizational layer, which is however closely connected to the intra-organizational business model.

Infrastructure mainly contains hardware and networks of a company (Winter and Fischer 2007) and describes all kinds of technology that are used within a company. The benefits that can be observed on this layer are caused by technological advances due to digitalization. The *Appl. Sys & Services* layer includes all software, application, and data components (Winter and Fischer 2007). As more and more services are offered online, companies need to deploy IT applications to accomplish their business processes. The benefits that can be achieved within this layer are on a technical operations level but can help the company to accomplish the overall goals. The *Business Processes* layer pictures the procedure of performing service delivery to achieve the desired business goals (Winter and Fischer 2007) and thus this level includes all benefits that result from improvements on an functional operations level due to digitalization. In contrary to the process layer, the *Business Model* depicts the organization from a strategic point of view (Frank 2002; Winter and Fischer 2007) and should be aligned with customer needs. Thus it connects the intra- and extra-organizational level. All strategic benefits that can be observed in literature are assigned to this layer. The *Customer* layer depicts an extra-organizational layer that refers to all interactions between the company and the customer. Thus benefits that result from the interaction with customers can be assigned to this layer. Table II.1-2 gives an overview of the identified benefits. An overview of all references and a detailed assignment of references to the benefits can be found an extra online repository (Neumeier et al. 2016).

Customer	
relevance among customer	product and service quality
innovative products and services	customer experience
customer interaction convenience	customer tailored solution
drive customer behavior	customer conversion
Business Model	
enlarge customer pool	advance to new business fields
profitability	increased sales
increase returns	risk mitigation
expand to digital channels	cost reduction
competitive advantage	enable innovations
enhanced promotion	efficiency
new competitive business models	
Business Processes	
incr. productivity	process flexibility
reduced product time-to market	speed of service proposition
operational excellence	process automation
smart workflow integration	process improvement
gain external network synergies	
Appl. Sys & Services	
improved information base	use of customer data
new delivery model	use of internal data
knowledge management	customer insights
real-time information	
Infrastructure	
smart technologies	

Table II.1-2 Categorization of Digitalization Benefits

Based on this investigation, we recognized in which areas digitalization particularly is supposed to lead to benefits. However, it still was not clear, how these benefits may pay off and how this can be appropriately measured. Furthermore, the benefits of digitalization are partially interlinked and mutually dependent. To depict the first idea of relationships between the identified benefits, we used deductive logic to relate the manifold vague digital benefits and to conclude on measureable value drivers of digitalization. In doing so, we gradually assigned the different kinds of benefits not only to the different intra- and extra-organizational layers, but also to particular levels of granularity. Therefore, we used logic trees on each organizational level which visualize the different levels of granularity. Benefits of similar granularity have been assigned to the same level and differing ones have been assigned to different levels. Furthermore, we incrementally connected benefits on a lower level of granularity (e.g., *speed of service proposition* or *real-time information*) to benefits on higher levels of granularity (e.g., *increased productivity* or *profitability*), since the ones on the lower level logically contribute to corresponding ones on the higher level. Consequently, we derived a model that depicts a top-down and bottom-up perspective on all identified extra- and intra-organizational benefits related to digitalization.

Since the benefit of digitalization is a very vague research topic with only few existing scientific research, the objective of this paper was to open the field of research by structuring and relating different benefits mentioned in literature in a first step, rather than to state one particular hypothesis that needs to be tested. By structuring the existing benefits with logic trees, we used a qualitative, deductive method to actually state several different hypothesis about the relationship of the single benefits. In doing so, we tried to minimize subjective judgment by conducting a discussion group of diverse scientists. We had a core team of three researchers who discussed their findings and suggestions in several rounds with up to 20 other researchers, including five professors and several PhD graduates. Nevertheless, continuation research is still necessary to proof the stated hypothesis. The resulting model for the benefits of digitalization including their linkages and corresponding areas is depicted in Figure II.1-1.

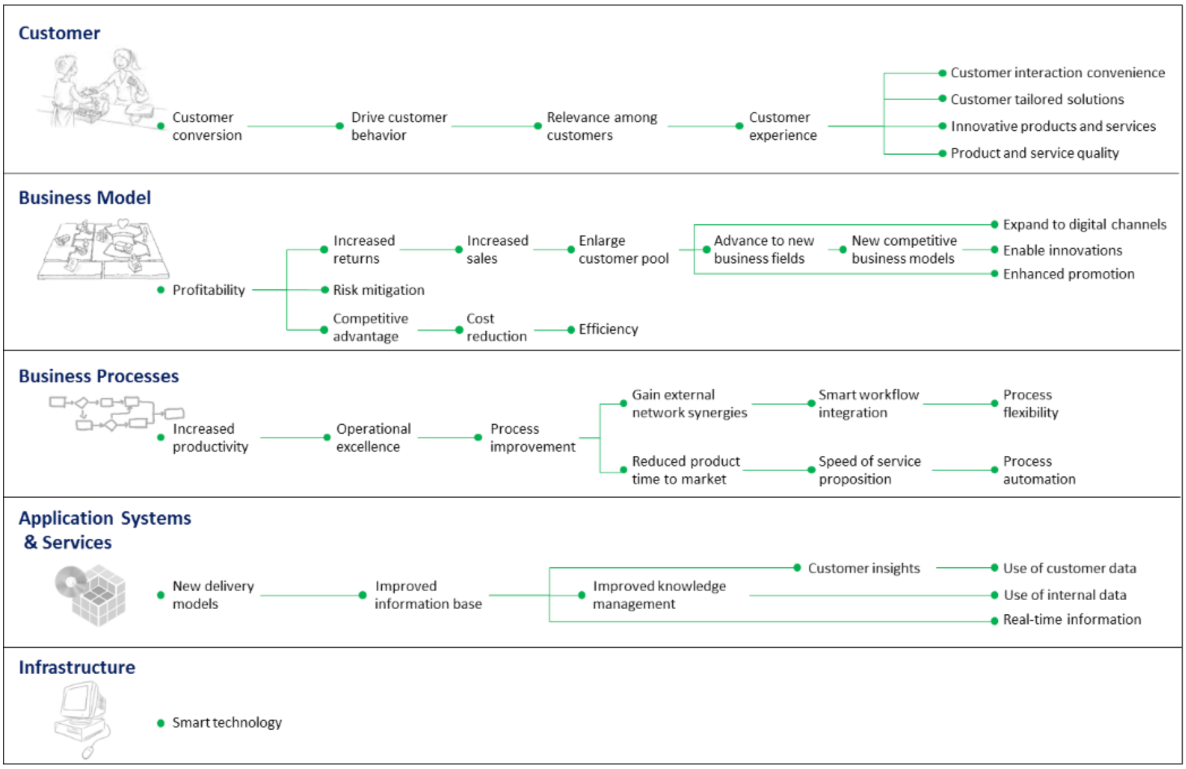

Figure II.1-1 Logic Trees for the Digitalization Benefits on each Organizational Level

For all layers depicted in Figure II.1-1, we exclusively used the benefits that were derived based on the analyzed literature and arranged them within logic trees. On the *Business Model* layer, Figure II.1-1 shows the strategic benefits for an organization where, for instance, the *profitability* is influenced by three components: *increased returns*, *risk mitigation*, and *competitive advantage*. First, we observe higher *profitability* due to *increased returns* that can be caused by *increased sales*. Increased sales depend on an *enlarged customer pool* which can be generated by an *expansion to digital channels*, the *advance to new business fields*, and *enhanced promotion*. The advance to new business fields is enabled by *new competitive business models* that are based on digital *innovations.* Second, the *profitability* of a company can be influenced by risk. If improved *risk mitigation* strategies can be applied due to digitalization, profitability of a company can be increased. Third, profitability is influenced by the *competitive advantage* a company can achieve due to *cost reductions*, which in turn can be gained by improved *efficiency*. According to this example, the logic trees on the other organizational layers can be read similarly. Furthermore, the logic trees are not only connected within but also beyond the organizational layers.

II.1.4. Discussion

To enable a valid assessment of the target state of digitalization within a company, an appropriate measurement is required in future research. Therefore, we need to identify value drivers that can be measured to assess the status of digitalization. On the strategic level (*Business Model),* the overall profitability of the organization could be measured. As the overall profitability of a company is influenced by internal and external factors, one would not be able to obtain whether an increase in profitability would stem from an improved customer interaction (external factor) or an operational improvement (internal factor). Thus, we will not directly draw on the profitability to derive the overall contribution. However, as the *Business Model* layer constitutes the linkage between the intra- and the extra-organizational layer, the interfaces between Business Model & Customer as well as Business Model & Business Processes might offer a starting point for an appropriate measure. By measuring the consequences of digitalization at the intra- and the extra-organizational interfaces of the *Business Model* layer, an overall perspective on the status of digitalization can be gained. Hence, for each interface an appropriate value driver should be identified that (1) is able to depict the overall influence of digitalization on the intra- and extra-organizational layers and (2) can be influenced by the company. Thus, we choose the benefits on the highest granularity level that can be influenced by the company, i.e., as close to the root node of the logic trees as possible.

Intra-organizational perspective: The benefit on the highest granularity level from the intra-organizational perspective is competitive advantage. The competitive advantage of a company cannot easily be measured. Thus, cost reduction should be analyzed for its applicability as a measure for the intra-organizational perspective. Many companies use cost reductions to measure the success of initiatives that are supposed to increase internal competitiveness (Davenport 1993). Nevertheless, cost reduction does not necessarily need to be the consequence of internal improvement. For example, production costs will decrease if less products are produced. In turn, less revenues can be achieved with less products to be sold, which will lead to an overall negative result. Thus, the sole measurement of cost reduction cannot cover particulars on success of digitalization. Thus, we examine *efficiency* as a value driver that can be measured. Efficiency is mainly driven by operational improvements of a company. In this paper, we consider efficiency from an economic perspective and hence suppose an activity to be efficient if there is no other way of performing a particular activity that leads to less cost, delivers the same results, upholds the same quality standards and is economically reasonable to invent. As efficiency, moreover, may be influenced by a company itself, we consider it to be an appropriate value driver for the intra-organizational perspective.

To assess efficiency within the organization established measures like maturity models or similar approaches can be used (Röglinger et al. 2012). Thus, based on different maturity levels the status quo and target state of a company might be determined. A corresponding examination, however, is topic to further research.

Extra-organizational perspective: Within this perspective, there are many starting points for possible measures. For example, increased returns, increased sales, customer conversion and the size of the customer pool can quite easily be measured. However, those benefits are either not necessarily the consequence of external advancement or cannot be influenced directly by the company. Thus, we propose to choose *customer experience,* as this benefit is on the highest level of granularity that can be influenced by the company itself. While the other benefits like customer conversion oftentimes cannot be influenced from an internal point of view, customer experience can be directly changed with the help of appropriate projects.

A measure that might serve to determine a company's digital target state that maximizes the value driver customer experience is the Kano model (Kano et al. 1984). This model measures customer experience through under and over fulfillment of customer expectations (Mette et al. 2013). Based on a respectively designed questionnaire, a company could determine its customers' expectations, which might serve as a basis to determine the digital target state of the company. Another measure that could be used for assessing this perspective is the established American Customer Satisfaction Index (Fornell et al. 1996). A corresponding detailed examination is also in this case topic to further research.

Hence, *efficiency* and *customer experience* are identified as two of the main value drivers within digitalization that might be used as starting point to measure the value of digitalization and hence show the manifold fruits of digitalization. However, concrete measures as well as a reasonable process to assess the value of digitalization should be determined in future research.

II.1.5. Conclusion, Limitations and Outlook

As digitalization is on the rise, the competitive environment of companies in all different industries will change within the next years (Hirt and Willmott 2014). Thus, many companies set up digitalization initiatives to benefit from the promising prospects even though they lack a deeper understanding of the benefits digitalization can literally bring to their company. Furthermore, most companies are not able to assess their status quo as well as their target state concerning digitalization. To address the research question, we conducted a structured literature review within scientific and practice literature to identify the benefits of digitalization and to clarify the underlying value drivers. Thus, we identified 38 kinds of benefits of digitalization which can be categorized into the five areas of the model for organizational information and communication systems *Customer*, *Business Model*, *Business Processes*, *Application Systems*

& Services, and Infrastructure. We used logic trees to relate the manifold vague digital benefits within each layer and to conclude on measureable value drivers of digitalization.

To enable an overall measurement, it is reasonable to consider the internal and the external perspective. Hence, we identified value drivers that enable the measurement at the interfaces between the intra- and extra-organizational perspectives. From the intra-organizational perspective efficiency enables to measure the influence of internal improvements. Measuring customer experience, furthermore, enables to measure digitalization progress from an external view. Each digitalization project should thus target to contribute to the company's profitability in terms of efficiency or customer experience or even both values. Thus, if a company decides to invest in digital initiatives, they should be assessed based on those drivers.

Despite the merits of this paper in terms of clarifying benefits and value drivers of digitalization, it is not without limitations. We base our literature review on scientific and practice literature. While scientific literature sticks to objective research goals and methods, practice literature might inhabit a bias as management consultancies want to position themselves as digitalization experts. Thus, they might exaggerate the positive effects and downplay the risks and challenges to gain new assignments. Nevertheless, management consultancies were able to gain deep insights into the real world application of digitalization during the last years. As the main focus of our research endeavor is to identify the key benefits and value of digitalization, we consider practice studies to be the most fertile source of information. Furthermore, we manually clustered and categorized the identified benefits to different kinds of benefits and layers of the organization. This might lead to subjectivity. However, we tried to reduce subjectivity as far as possible by drawing on a structured research procedure and by discussing our results with other researchers. Moreover, the developed categorization of benefits and the identified value drivers are a first approach to clarify the value of digitalization. However, we did not yet derive an empirical investigation of the underlying hypothesis. This is topic to further research. Furthermore, future research should feel encouraged to analyze different measurement methods for digital value drivers as well as establish a process for the valuation of digitalization projects.

Overall, our study contributes to existing knowledge and approaches the research question raised within this manuscript. Our manuscript can be equally beneficial for research and practice. On the one hand, the approach contributes to future research by analyzing and structuring existing literature and can thus provide the basis for a detailed analysis of measurement approaches for digital value drivers. Furthermore, our results support practice with the identification of the main benefits and value drivers of digitalization. Thus, they can make use of the categorization to determine the gain of their digital initiatives. Thus, all in all, the approach can help practitioners to get a better understanding of the benefits of digitalization, which might lower the hurdles that prevent companies from scaling up their digital effort.

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II.2. Wert der Digitalisierung – Erfolgreiche Auswahl von Digitalisierungsprojekten

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Abstract:

Die Auswirkungen der Digitalisierung sind schon lange sowohl in unserem Privatleben als auch in Unternehmen zu spüren. Die wesentlichen Neuerungen liegen hauptsächlich darin, dass sich Technologien und Prozesse in allen Geschäftsbereichen schneller ändern, die Vernetzung zwischen Unternehmen und Kunden weiter zunimmt und bei Kunden und Mitarbeitern eine höhere Akzeptanz für neue Technologien vorherrscht. Obwohl viele Unternehmen bereits einige Digitalisierungsprojekte umsetzen, wissen die meisten Führungskräfte noch nicht, welchen Wert die Digitalisierung für ihr Unternehmen liefern kann. Auch in der Literatur fehlen noch bewährte Methoden zur Bewertung des Wertbeitrags von Digitalisierungsprojekten. Vor diesem Hintergrund wird im vorliegenden Beitrag ein Bewertungsschema für Digitalisierungsprojekte entwickelt. Dazu werden die Werttreiber Kundenerlebnis sowie Effizienz als Messgrößen im Bereich der Digitalisierung identifiziert und ein vierstufiges Vorgehensmodell zur Identifikation des Projektportfolios, das am besten zur Zielerreichung für ein Unternehmen beiträgt, abgeleitet. In einer Anwendung auf drei Digitalisierungsprojekte im Bereich Online- und Mobile-Banking einer großen deutschen Bank (Online-Kontoeröffnung, Kontozugang durch Fingerabdruck und Postbox) wird das Bewertungsschema im Praxiskontext veranschaulicht.

Keywords: Digitalisierung, Digitale Transformation, Projektportfolio, Projektbewertung, Kundenerlebnis, Effizienz.

II.2.1. Herausforderungen in der Digitalisierung

Die Digitalisierung und deren Auswirkungen auf unser alltägliches Leben sind in aller Munde. Neben den Auswirkungen im privaten Umfeld wie der Verwendung von Smart Devices, sozialer Medien und Online-Shopping haben die meisten Unternehmen erkannt, dass sich die Digitalisierung entscheidend auf ihre Wettbewerbsfähigkeit auswirken wird. Geschäftsmodelle und Erfolgsgeschichten von Unternehmen werden sich grundlegend verändern und die Geschäftswelt massiv beeinflussen (Hirt and Willmott 2014). Nur Unternehmen, die bereit sind, sich diesen Herausforderungen zu stellen, werden in Zukunft mit ihren Wettbewerbern Schritt halten können (Gimpel and Röglinger 2015). Diese Herausforderungen ergeben sich hauptsächlich aus der Tatsache, dass sich Technologien und Prozesse in allen Geschäftsbereichen schneller ändern, die Vernetzung zwischen Unternehmen und Kunden weiter zunimmt und bei Kunden und Mitarbeitern eine höhere Akzeptanz für neue Technologien vorherrscht. Ganz besonders gelten diese Herausforderungen für Dienstleistungsunternehmen, die besonders von Veränderungen an der Kundenschnittstelle betroffen sind.

Die großen Unternehmensberatungen führten in den letzten Jahren bereits zahlreiche Studien durch, die sich mit den Chancen, Erfolgsfaktoren und Nutzeneffekten, aber auch mit den Herausforderungen der Digitalisierung beschäftigen (Gottlieb and Willmott 2014; Gutsche 2014b; Jaubert et al. 2014; Olanrewaju and Willmott 2013). Dabei wurde zum Beispiel das Marktpotential des Internets der Dinge, welches nur einen Bruchteil der als Digitalisierung verstandenen Trends repräsentiert, von Gartner (2013) für das Jahr 2020 auf ca. 1,9 Billionen US-Dollar geschätzt. Und das ist nur der Anfang. Das ökonomische Potential von Cloud Computing, Big Data und vielen weiteren neuen, mit Digitalisierung assoziierten Technologien wird ebenso als sehr hoch eingeschätzt.

Nichtsdestotrotz wissen die meisten Führungskräfte nicht genau, welchen Wert die Digitalisierung in ihren Unternehmen schaffen kann und sind daher meist nicht in der Lage, die erwarteten Gewinne von Digitalisierungsprojekten zu bestimmen. Eine Umfrage unter 850 Befragten auf Geschäftsführungsebene ergab, dass nur 7% der Unternehmen verstehen, welchen Wert Digitalisierung für sie schaffen kann und 60% der Unternehmen sogar zugeben, weder definierte Ziele noch Kennzahlen zur Messung des Digitalisierungsfortschritts zu haben (Gottlieb and Willmott 2014). Auch die wissenschaftliche Literatur beschäftigt sich bereits seit einigen Jahren mit dem Phänomen der Wertschöpfung durch Digitalisierung. Hier werden unterschiedliche Aspekte betrachtet. In einigen Veröffentlichungen liegt der Fokus eher auf der strategischen Weiterentwicklung von Geschäftsmodellen und der Unternehmensstrategie (Grover and Kohli 2013; Keen and Williams 2013). Das Thema digitale Innovationen, das sich mit der Kombination von physischen und digitalen Komponenten beschäftigt, spielt ebenso eine große Rolle in der wissenschaftlichen Literatur (Yoo et al. 2010). Des Weiteren werden von einigen Autoren die Herausforderungen diskutiert, die durch die digitale Transformation in Unternehmen entstehen (Matt et al. 2015). Jedoch bietet auch die wissenschaftliche Literatur auf die Frage nach der Bewertung von Digitalisierungsprojekten noch keine ausreichende Antwort.

Trotzdem hält die Digitalisierung in vielen Unternehmen bereits Einzug. Laut einer Umfrage unter 500 Führungskräften in deutschen Unternehmen führen 43% der Unternehmen bereits Änderungen in ihrem Geschäftsmodell durch und sogar 63% verändern ihre Produkte und Services in Richtung digitaler Leistungen (Gutsche 2014b). Um eine sinnvolle Steuerung des Digitalisierungsfortschritts in Unternehmen sicherzustellen, ist es jedoch notwendig, sowohl den Status quo als auch den Zielzustand in Unternehmen bewerten zu können. Damit lässt sich sicherstellen, dass Projekte durchgeführt werden, die dazu beitragen, den Zielzustand zu erreichen. Daher benötigen Unternehmen ein Rahmenwerk, welches eine Bewertung ermöglicht und somit dazu beiträgt, den Wertbeitrag durch Digitalisierung auch realisieren zu können.

II.2.2. Werttreiber der Digitalisierung

Um eine Bewertung von Digitalisierungsprojekten vornehmen zu können, müssen zunächst Werttreiber festgelegt werden. Hier gilt es zu beachten, dass für die unterschiedliche Ausrichtung von Unternehmen auch unterschiedliche Werttreiber identifiziert werden können. Beispielweise können ein klassischer Handwerker oder ein Produktionsunternehmen, die hauptsächlich im Bereich Business-to-Business (B2B) agieren, eher durch andere Werttreiber beeinflusst werden als ein Dienstleistungsunternehmen mit direkter Endkundenschnittstelle im Bereich Business-to-Consumer (B2C). Der folgende Artikel fokussiert zunächst Dienstleistungsunternehmen. Neumeier et al. (2017) führen zur Identifikation von Nutzenaspekten der Digitalisierung eine strukturierte Literaturrecherche durch. Darauf aufbauend werden die unterschiedlichen Aspekte bestimmt und kategorisiert, die in der Literatur als Nutzen oder Wert der Digitalisierung aufgeführt werden. Dabei werden 38 verschiedene Nutzenaspekte identifiziert, die auf unterschiedlichen Ebenen des in Buhl and Kaiser (2008) definierten Informations- und Kommunikationssystems (IuK) eines Unternehmens auftreten können. Das IuK wird in die vier Ebenen Infrastruktur, Anwendungssysteme & Services (AWS & Services), Geschäftsprozesse und Geschäftsmodell sowie die darüber liegende Ebene Kunde eingeteilt (Buhl and Kaiser 2008). Dabei spiegeln die unteren drei Ebenen (Infrastruktur, AWS & Services und Geschäftsprozesse) unternehmensinterne Abläufe wider. Die obere Ebene (Kunde) spiegelt die externen Einflüsse wider. Die Ebene Geschäftsmodell bildet die Schnittstelle zwischen internen und externen Faktoren. Wie in Abb. II.2-1 sichtbar wird, kann auf Basis der in der Literatur identifizierten Nutzenaspekte auf jeder Ebene des IuK ein Werttreiberbaum aufgestellt werden, der angibt, welche Nutzeneffekte sich gegenseitig beeinflussen (Neumeier et al. 2017).

Die Geschäftsmodellebene beinhaltet beispielsweise die strategischen Nutzenaspekte eines Unternehmens. Die Rentabilität des Unternehmens wird hier durch erhöhte Gewinne beeinflusst. Diese können sich auf Grund von drei Aspekten ergeben: Steigerung des Umsatzes, Risikominderung und Wettbewerbsvorteile. Eine Steigerung des Umsatzes kann durch eine vergrößerte Zielgruppe erreicht werden, die wiederum durch drei Pfade vergrößert werden kann. Erstens spielt die Erweiterung des Geschäfts auf digitale Kanäle eine Rolle. Zweitens kann die Zielgruppe durch eine Erweiterung auf neue Geschäftsfelder vergrößert werden, was meist durch neue wettbewerbsfähige Geschäftsmodelle, die auf Innovationen basieren, ermöglicht wird. Drittens kann durch eine zielgruppenspezifische Werbung der Kundenkreis erweitert werden. Die Gewinne des Unternehmens werden außerdem durch verschiedene Risiken wie beispielsweise das operationelle Risiko beeinflusst. Wenn durch Digitalisierung verbesserte Risikominderungsstrategien angewendet werden können, kann der Gewinn eines Unternehmens steigen. Der Gewinn eines Unternehmens wird durch den Wettbewerbsvorteil, den ein Unternehmen auf Basis von verminderten Kosten erzielen kann, beeinflusst. Dies kann insbesondere durch eine verbesserte Effizienz erreicht werden. Analog zu diesem Beispiel können die Werttreiberbäume in Abb. II.2-1 gelesen werden. Neben den in Abb. II.2-1 dargestellten Verbindungen bestehen außerdem Zusammenhänge zwischen den Ebenen des IuK, auf die im Folgenden jedoch nicht genauer eingegangen werden soll.

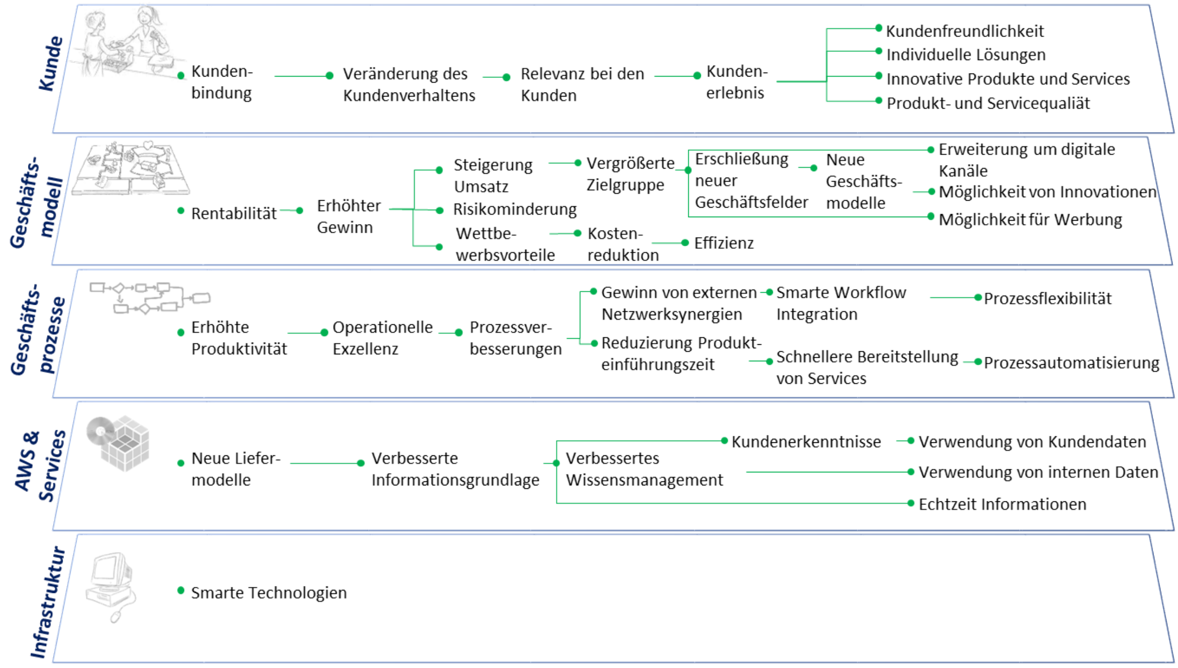

Abb. II.2-1 Werttreiberbäume auf den Ebenen des IuK nach Neumeier et al. (2017)

Um auf dieser Basis eine Messung des Digitalisierungsfortschritts von Unternehmen zu ermöglichen, leiten Neumeier et al. (2017) Ansatzpunkte zur Bewertung von Digitalisierungsprojekten im Dienstleistungsbereich ab. Dazu müssen Werttreiber identifiziert werden, die sich für eine Messung eignen. Auf der strategischen Ebene (Geschäftsmodell) könnte dazu auf die Rentabilität zurückgegriffen werden. Diese eignet sich jedoch in diesem Fall nicht für die Messung, da sie sowohl von internen als auch von externen Faktoren beeinflusst wird. Durch eine reine Messung der Rentabilität könnte somit nicht unterschieden werden, ob eine Verbesserung der Rentabilität durch eine verbesserte Kundeninteraktion (externer Faktor) oder eine Verbesserung im Prozessablauf (interner Faktor) hervorgerufen wurde. Somit sollte insbesondere für Dienstleistungsunternehmen eine Messung des Digitalisierungsfortschritts auf die externe und die interne Perspektive aufgeteilt werden, um den besonderen Stellenwert des Kundenkontakts auch in der Bewertung von Digitalisierungsprojekten berücksichtigen zu können. Daher wird für die interne sowie für die externe Perspektive jeweils ein Werttreiber identifiziert. Hierzu greifen Neumeier et al. (2017) auf die Schnittstellen zwischen der Geschäftsmodellebene und den beiden Ebenen Kunde (externe Perspektive) und Geschäftsprozesse (interne Perspektive) zurück und diskutieren mögliche Alternativen auf Basis der folgenden Kriterien. Die Werttreiber sollten in der Lage sein, den Einfluss der Digitalisierung widerzuspiegeln. Des Weiteren sollte das Unternehmen den Werttreiber selbst beeinflussen können. Somit kann die direkte Wirkung von Projekten auf den Werttreiber betrachtet werden. Um einen ersten Ansatzpunkt zur Messung zu liefern, wählen Neumeier et al. (2017) den Werttreiber mit der höchsten Granularität, der direkt durch das Unternehmen beeinflusst werden kann.

Werttreiber in der internen Perspektive: Auf der höchsten Granularitätsstufe im dargestellten Werttreiberbaum (Abb. II.2-1) findet sich an der Schnittstelle zu den internen Abläufen der Nutzenaspekt Wettbewerbsvorteile. Dieser kann jedoch nur sehr schwierig gemessen werden. Daher wird der Nutzenaspekt Kostenreduktion näher betrachtet. In der Praxis nutzen viele Unternehmen Kostenreduktion als Maß, um den Erfolg ihrer Initiativen zu messen. Allerdings besteht hier die Gefahr, dass durch eine reine Kostenbetrachtung nicht nur interne Verbesserungen abgebildet werden, sondern auch geringere Produktivität. So können geringere Kosten beispielsweise auch durch eine geringere Servicebereitstellung erzielt werden. Allerdings können so auch weniger Umsätze erzielt werden. Insgesamt kann dies sogar zu einer negativen Entwicklung des Unternehmens beitragen. Daher eignet sich auch der Nutzenaspekt Kostenreduktion nicht als Werttreiber. *Effizienz* stellt für Neumeier et al. (2017) den geeignetsten Ansatzpunkt zur Messung aus der internen Perspektive dar. Dieser Nutzenaspekt wird durch die internen Abläufe in einem Unternehmen beeinflusst und liegt somit genau an der Schnittstelle zwischen den Prozessen und dem Geschäftsmodell eines Unternehmens. Eine Aktion wird als effizient betrachtet, wenn es keine Möglichkeit gibt eine Aktivität mit dem gleichen Ergebnis in derselben Qualität zu geringeren Kosten durchzuführen.

Werttreiber in der externen Perspektive: Zur Bewertung der externen Perspektive gibt es eine Vielzahl an Ansatzpunkten. Die Nutzenaspekte wie erhöhter Gewinn, erhöhter Umsatz und die Größe der Zielgruppe werden in einigen Unternehmen bereits gemessen. Jedoch ist oftmals keine eindeutige Zuordnung der Effekte zu bestimmten Projekten möglich. Darüber hinaus können die Nutzenaspekte oftmals nicht durch das Unternehmen direkt beeinflusst werden, sodass Unternehmen ihre Aktionen nicht direkt an den Größen ablesen können. Daher schlagen Neumeier et al. (2017) vor, das *Kundenerlebnis* (im Englischen als customer experience bezeichnet) als Werttreiber zu verwenden. Durch die Durchführung von Projekten wie etwa die Entwicklung eines neuen Produkts oder die Verbesserung einer bestehenden Dienstleistung kann das Kundenerlebnis direkt beeinflusst werden.

II.2.3. Bewertungsschema für Digitalisierungsprojekte

Auf Basis der identifizierten Werttreiber kann ein Bewertungsschema für Digitalisierungsprojekte abgeleitet werden. Jedes Digitalisierungsprojekt, das innerhalb des Unternehmens durchgeführt wird, kann dazu anhand der beiden Werttreiber *Kundenerlebnis* und *Effizienz* bewertet werden. Zur Vereinfachung der Bewertung von Projekten werden beide

Dimensionen anhand einer Skala mit drei Bewertungsstufen (*gering*, *mittel*, *hoch*) bewertet. Auf Basis dieser Skala wird für jede Dimension eine Experteneinschätzung vorgenommen.

Diese Vereinfachung wird aufgrund der verbesserten Anwendbarkeit durchgeführt. Um eine präzisere Quantifizierung der qualitativen Aussagen zu ermöglichen, könnten Unternehmen auch auf komplexere Verfahren zurückgreifen. Für die Bewertung des Kundenerlebnisses könnte beispielsweise auf Kundenbefragungen und eine darauf basierende Bewertung durch das Kano-Modell zurückgegriffen werden (Kano et al. 1984). Die Dimension *Effizienz* könnte zum Beispiel durch die Quantifizierung von Einsparungen im Bereich Personal oder Erhöhungen bei Geschwindigkeit oder Qualität bewertet werden. Eine derartige Quantifizierung wurde bereits zur Operationalisierung der Bewertung von Nutzenaspekten in Projekten angewandt (Beer et al. 2013). Um eine schnelle Umsetzung in der Praxis zu ermöglichen, wird hier jedoch auf das vereinfachte Bewertungsschema zurückgegriffen.

Nachdem ein Projekt in beiden Dimensionen auf Basis von Expertenschätzungen bewertet wurde, kann aus der Kombination der beiden Dimensionen ein Vektor gebildet werden, der den Beitrag des einzelnen Projekts in Bezug auf die Digitalisierung angibt. Abb. II.2-2 zeigt die Darstellung der Projektbewertung in Form von Vektoren. Der Vektor für Projekt 1 gibt an, dass dieses in geringem Maße zum *Kundenerlebnis* und nicht zur Dimension *Effizienz* beiträgt. Projekt 2 trägt im Gegensatz dazu in hohem Maße zur *Effizienz* des Unternehmens bei, leistet jedoch keinen Beitrag zur Dimension *Kundenerlebnis*. Der dritte Vektor gibt den Beitrag von Projekt 3 zur Digitalisierung an. Dieses Projekt trägt in mittlerem Maße zu beiden Dimensionen bei.

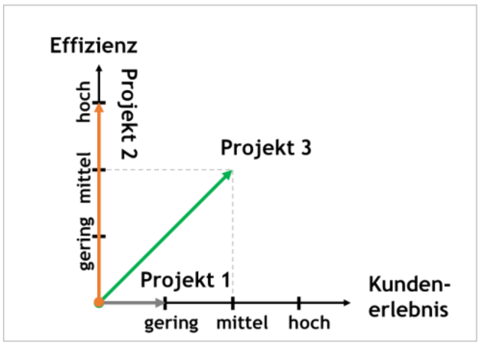

Abb. II.2-2 Bewertung von Einzelprojekten in Form von Vektoren

Um eine sinnvolle Steuerung der Digitalisierungsprojekte in einem Unternehmen zu gewährleisten, ist eine integrierte Betrachtung notwendig. Somit kann entschieden werden, welche Digitalisierungsprojekte unter der Restriktion eines beschränkten Budgets durchgeführt werden sollen. Dabei sollte ein Unternehmen folgende vier Schritte bei der Anwendung des Bewertungsschemas durchführen:

1. Bestimmung des Status quo in beiden Dimensionen

Im ersten Schritt sollte der Betrachtungsbereich definiert werden, auf den das Bewertungsschema angewendet werden soll. Je nach Größe und Ausrichtung des Unternehmens kann das gesamte Unternehmen oder nur ein bestimmter Bereich im Unternehmen betrachtet werden. So kann beispielsweise ein kleines Unternehmen, das nur eine Dienstleistung anbietet, als Betrachtungsbereich das gesamte Unternehmen definieren. Ein großes Unternehmen, das Dienstleistungen in unterschiedlichen, möglicherweise voneinander unabhängigen Bereichen anbietet, sollte die einzelnen Unternehmensbereiche zunächst separat betrachten. Anschließend können die unterschiedlichen Unternehmensbereiche wieder zusammengeführt werden.

Darauf aufbauend sollte für den Betrachtungsbereich der Status quo in Bezug auf die beiden Dimensionen *Kundenerlebnis* und *Effizienz* bestimmt werden. Dazu muss eine Bewertung des aktuellen Status auf Basis der beiden Dimensionen durchgeführt werden. Dieser Schritt ist notwendig, um Transparenz über die aktuelle Situation im Betrachtungsbereich zu schaffen. Viele Unternehmen haben in den letzten Jahren bereits einige Digitalisierungsprojekte durchgeführt. Meist wurde dabei allerdings keine strukturierte Bewertung des projektspezifischen Wertbeitrags vorgenommen. Die Auswirkungen dieser Projekte sollten jedoch im Status quo berücksichtigt werden. Dazu sollte das Unternehmen alle bisher in Bezug auf die beiden Dimensionen durchgeführten Digitalisierungsprojekte bewerten. Die Bewertung kann, analog zur Bewertung eines in Zukunft durchzuführenden Projekts, über Expertenschätzungen und Kundenbefragungen erfolgen. Aus der Kombination der bereits durchgeführten Projekte ergibt sich der Status quo in beiden Dimensionen.

2. Definition des Zielzustands

Als zweiten Schritt muss der angestrebte Zielzustand des Betrachtungsbereichs in Bezug auf beiden Dimensionen bestimmt werden. Dieser leitet sich direkt aus den Unternehmenszielen ab (Bharadwaj et al. 2013) und unterscheidet sich je nach Art des Unternehmens und dessen Entwicklungszielen. Der Zielzustand ergibt sich aus der angestrebten Kombination aus *Kundenerlebnis* und *Effizienz*. Dabei müssen sowohl die externen Prozesse mit Kundenkontakt als auch die internen Prozesse im Betrachtungsbereich analysiert und ein angestrebter Zielzustand abgeleitet werden. Beide Arten von Prozessen sollten auf beide Dimensionen hin untersucht werden. Während bei externen Prozessen beide Dimensionen eine große Rolle spielen, kann bei internen Prozessen der Fokus auf das Thema *Effizienz* gelegt werden. Ex ante ist es für ein Unternehmen jedoch meist nicht möglich, übergreifend für den gesamten Betrachtungsbereich die exakte Kombination aus *Kundenerlebnis* und *Effizienz* zu bestimmen.

Daher sollte ein Zielkorridor festgelegt werden, in dem der Zielzustand für beide Dimensionen liegen soll. Jeder Punkt, der innerhalb des Zielkorridors liegt, stellt ein Ergebnis dar, mit dem das Unternehmen seine Ziele in den beiden Dimensionen erreicht. So entsteht für den Betrachtungsbereich ein Zielkorridor.

3. Auswahl der Digitalisierungsprojekte

Der Zielzustand in beiden Dimensionen kann durch die Durchführung von Digitalisierungsprojekten erreicht werden. Wie bereits oben erläutert, trägt jedes Projekt in unterschiedlicher Ausprägung zu den beiden Dimensionen bei. Durch die Durchführung unterschiedlicher Projekte kann ein Unternehmen näher an seinen angestrebten Zielzustand innerhalb des Zielkorridors heranrücken. Da auch für Digitalisierungsinitiativen Budgetrestriktionen herrschen, kann ein Unternehmen für den Betrachtungsbereich jedoch nicht alle Projekte durchführen, die zur Verfügung stehen und zur Zielerreichung beitragen. Somit müssen Unternehmen auch in diesem Bereich entscheiden, welche Investitionsalternativen sie wählen und die Projekte auswählen, die am besten zur Zielerreichung beitragen.

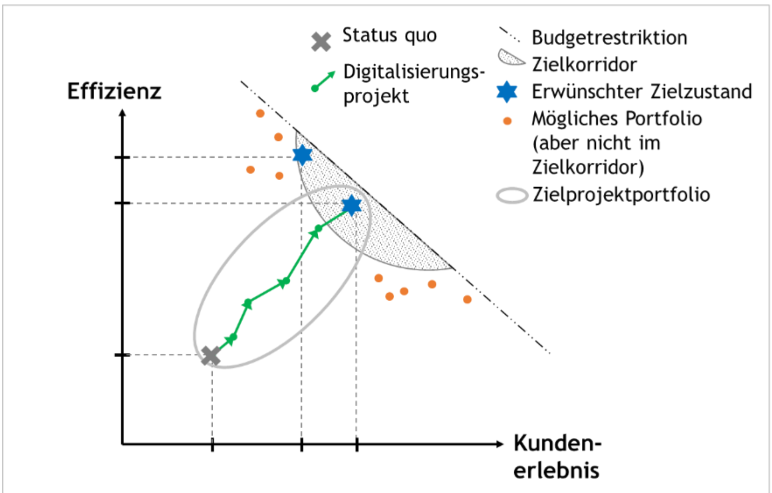

Abb. II.2-3 Erstellung eines Projektportfolios zur Zielerreichung

Abb. II.2-3 zeigt eine beispielhafte Darstellung der Kombination von fünf Digitalisierungsprojekten, die das Unternehmen vom Status quo zu einem möglichen Zielzustand innerhalb des Zielkorridors führen. Das Projektportfolio enthält fünf Projekte, über die Reihenfolge der Projektdurchführung kann jedoch keine Aussage getroffen werden.

4. Regelmäßige Evaluation des Zielkorridors und des Projektportfolios

Nach der initialen Auswahl des Projektportfolios, das am besten zur Zielerreichung beiträgt, ist es unbedingt notwendig, eine regelmäßige Überprüfung des Zielkorridors sowie des aktuellen Projektportfolios durchzuführen. Da die Digitalisierung große Veränderungen und eine stetige

Dynamik mit sich bringt, muss das Unternehmen regelmäßig überprüfen, ob die Anforderungen an den Zielkorridor noch mit den Unternehmenszielen übereinstimmen. Da die Unternehmensstrategie zur Erreichung von Wettbewerbsvorteilen immer stärker zu einer digitalen Geschäftsstrategie wird (Bharadwaj et al. 2013), muss sichergestellt werden, dass sich die Ziele des Unternehmens auch im Zielkorridor für den Betrachtungsbereich widerspiegeln. Unternehmen werden in Zukunft nur dann erfolgreich sein, wenn sie es nicht nur einmalig schaffen eine digitale Geschäftsstrategie zu entwickeln, sondern eine stetige Anpassung der Strategie an die Anforderungen und Veränderungen erreichen (Keen and Williams 2013). Nach der Evaluation des Zielkorridors sollte entsprechend auch eine erneute Evaluation des Projektportfolios, das am besten zur Zielerreichung beiträgt, durchgeführt werden. Somit kann das Portfolio an die neuen Ziele des Unternehmens angepasst werden. Außerdem können neue technologische Entwicklungen berücksichtigt und in das bestehende Portfolio aufgenommen werden.

II.2.4. Anwendung des Bewertungsschemas auf Beispielprojekte

Zur Veranschaulichung des Bewertungsschemas wird im Folgenden die Anwendung auf reale Praxisbeispiele betrachtet. Dabei liegt der Fokus auf Projekten aus dem Bankenbereich, da insbesondere dort im Moment große Umbrüche beobachtet werden können. Die Konkurrenz im Bankenmarkt steigt immer weiter an. Neben reinen Online-Banken, die kein Filialgeschäft mehr betreiben und somit günstigere Produkte und Services am Markt anbieten können, drängen auch immer mehr FinTech (financial technology) Start-Ups in das klassische Bankgeschäft. FinTechs Start-Ups zeichnen sich insbesondere dadurch aus, dass sie schnell Innovationen und neue Technologien für den Finanzsektor in ihren Geschäftsmodellen umsetzen können (Zavolokina et al. 2016). Somit müssen die traditionellen Banken innovative Produkte und Services entwickeln, um ihre Kunden weiter an sich zu binden. Des Weiteren ist eine effiziente Servicebereitstellung notwendig, um gegenüber den hoch kompetitiven Preisen von Konkurrenten wettbewerbsfähig zu bleiben. Eine Weiterentwicklung von traditionellen Banken in Richtung digitaler Geschäftsmodelle, ohne dabei ihre bestehenden Vorteile aufzugeben, kann maßgeblich dazu beitragen, dass traditionelle Banken auch in Zukunft weiterhin bestehen und profitabel wirtschaften können.

Im Folgenden wird das entwickelte Bewertungsschema auf drei Digitalisierungsprojekte, die in den letzten Jahren bei einer großen traditionellen Bank in Deutschland (T-Bank) durchgeführt wurden, angewendet. Alle Projekte beziehen sich auf den Bereich Online- und Mobile-

Banking. Die Einschätzung basiert auf einer vereinfachten Darstellung von realen Projekten und kann als exemplarisch für die meisten traditionellen deutschen Banken betrachtet werden.

Zunächst wird das Projekt **Online-Kontoeröffnung** betrachtet. Die T-Bank will es ihren Kunden ermöglichen, ein Konto vollständig online zu eröffnen. Bisher ist die Eröffnung eines Kontos bei der T-Bank nur teilweise online möglich. Die eindeutige Legitimation muss bisher über das etablierte Postident-Verfahren durchgeführt werden. Der Kunde kann das Konto zwar online beantragen, der Antrag muss jedoch danach zunächst ausgedruckt und unterschrieben werden. Mit den ausgedruckten Unterlagen kann der Kunde zur nächsten Postfiliale gehen, wo er sich mit Hilfe des Postident-Coupons identifiziert und den Antrag postalisch der T-Bank zusendet. Nach Eingang des Antrags gibt die T-Bank das Konto für den Kunden frei. Dies führt dazu, dass die Kontoeröffnung in der Regel mehrere Tage in Anspruch nimmt. Über ein neu entwickeltes Identifikationsverfahren, das mit Hilfe einer elektronischen Signatur den Kunden eindeutig identifizieren kann, soll die Kontoeröffnung in Zukunft vollständig online möglich sein und das Konto am gleichen Tag für den Kunden funktionsfähig zur Verfügung stehen.

Das Projekt **Online-Kontoeröffnung** wirkt sich auf beide Werttreiber im Bewertungsschema aus. Auf der einen Seite kann das *Kundenerlebnis* durch das Angebot verbessert werden. Der Kunde kann sein neues Konto vollständig und ohne zusätzlichen Aufwand online eröffnen. Des Weiteren steht das Konto dem Kunden noch am Tag der Eröffnung zur Verfügung. Somit entstehen keine unnötigen Wartezeiten. Diese beiden Aspekte legen eine hohe Steigerung des *Kundenerlebnisses* nahe. Des Weiteren hat das Verfahren auch eine positive Auswirkung auf die *Effizienz* der T-Bank. Durch eine vollständige Online-Abwicklung der Kontoeröffnung werden Medienbrüche vermieden. Während bisher der postalisch eingesendete Kontoeröffnungsantrag mit dem online erstellten Antrag manuell zusammengeführt werden musste, ermöglicht die Online-Beantragung eine maschinelle Verarbeitung der Information. Eine Ende-zu-Ende Automatisierung des Prozesses wird somit möglich. Daher wird das Kriterium *Effizienz* im Folgenden ebenfalls als hoch angesehen. Abb. II.2-4 zeigt den Vektor, der die Bewertung des Projekts **Online-Kontoeröffnung** abbildet.

Das zweite Projekt erleichtert den Mobile-Banking Zugang für Kunden. Das Projekt **Kontozugang durch Fingerabdruck** ersetzt die PIN und gewährt vollen Zugriff auf das eigene Konto via Mobile-Banking. Die T-Bank verspricht für den Kunden eine komfortable, schnelle und sichere Anmeldung bei dem eigenen Konto. Die Anmeldung via Fingerabdruck kann nur auf Geräten mit Fingerabdrucksensor angewendet werden. Für die Verifizierung wird die bestehende PIN mit dem auf dem Gerät hinterlegten Fingerabdruck des Kontoinhabers verknüpft. Die Freischaltung kann im Onlineportal beantragt werden. Bei Verlust des mobilen Endgeräts kann die PIN einfach über das Onlineportal oder in einer Filiale geändert werden. Somit ist eine Anmeldung über das verlorene Gerät nicht mehr möglich.

Das Projekt **Kontozugang durch Fingerabdruck** wirkt sich vorwiegend auf die Dimension *Kundenerlebnis* aus. Durch die Einschränkung der Verwendbarkeit auf Geräte mit Fingerabdrucksensor ist die Zielgruppe dieses Projekts jedoch wesentlich kleiner als die Zielgruppe des ersten Projekts. Obwohl der Zugang via Fingerabdruck für einige Kunden die Barriere zur Verwendung von Mobile-Banking-Apps reduziert, wird das *Kundenerlebnis* nur in mittlerem Maße beeinflusst. Die *Effizienz* wird durch das Projekt **Kontozugang durch Fingerabdruck** nur in vernachlässigbarem Maße beeinflusst. Trotz Verifizierung in der App mit Hilfe des Fingerabdrucks muss für den Kontozugang weiterhin eine PIN festgelegt werden. Bei Verlust des Geräts muss genau wie bei Konten ohne Kontozugang durch Fingerabdruck eine neue PIN vergeben werden. Auch andere effizienzsteigernde Effekte können nicht festgestellt werden. Abb. II.2-4 zeigt den Vektor, der die Bewertung des Projekts **Kontozugang durch Fingerabdruck** abbildet.

Das dritte Projekt **Postbox** stellt für Kunden der T-Bank ein digitales Postfach zur Verfügung. In diesem Postfach kann der Kunde alle bankbezogenen Dokumente online abspeichern. Dem Kunden werden hier klassischerweise Kontodokumente, Wertpapierdokumente, Kreditkartendokumente und Bankmitteilungen zur Verfügung gestellt.

Dieses Projekt wirkt sich auf beide Bewertungsdimensionen aus. In der **Postbox** werden dem Kunden zentral alle Informationen zur Verfügung gestellt, die er in Bezug auf seine Kontenverwaltung benötigt. Der Kunde muss keine zusätzlichen, sicheren Speicherkapazitäten kaufen, um seine Dokumente sicher ablegen zu können. Außerdem entfällt eine aufwendige physische Lagerung der Unterlagen, die durch das Zusenden der bankbezogenen Unterlagen in der Vergangenheit notwendig war. Da diese Funktionalität jedoch inzwischen durch die meisten Banken zur Verfügung gestellt wird und nicht mehr als Differenzierungsmerkmal verwendet werden kann, hat das Projekt nur einen geringen Einfluss auf das *Kundenerlebnis*. Die Auswirkungen auf die *Effizienz* der T-Bank stellen hier den größeren Beitrag dar. Während Kunden ohne digitales Postfach ihre bankbezogenen Informationen meist noch postalisch zugesendet bekommen, kann über die Verwendung des Postfachs eine wesentlich effizientere Informationsbereitstellung für den Kunden zur Verfügung gestellt werden. Somit kann die T-Bank neben hohen Papier-, Druck- und Portokosten auch einen Großteil an Arbeitsaufwand durch die automatisierte Bereitstellung der Daten im Postfach einsparen. Somit wird der

Einfluss des Projekts **Postbox** auf die *Effizienz* mit der Bewertung mittel versehen. Aus Sicht der T-Bank bietet dieses Projekt noch zusätzliches Potential für Weiterentwicklungen. Das digitale Postfach kann langfristig in eine Kommunikationsplattform weiterentwickelt werden, die auch für einen Dialog zwischen Berater und Kunde genutzt werden kann. So kann sich die einseitige Information in Zukunft zu einer beidseitigen Kommunikation weiterentwickeln. Diese Weiterentwicklung bietet noch hohe Potentiale sowohl im Bereich der *Effizienz* als auch im Bereich des *Kundenerlebnisses*. In Abb. II.2-4 wird der Status quo des Projekts berücksichtigt, jedoch noch nicht die möglichen zukünftigen Potentiale.

Mit Hilfe dieses Bewertungsschemas kann die T-Bank eine Bewertung ihres aktuellen und zukünftigen Projektportfolios im Bereich Online- und Mobile-Banking vornehmen. In dieser beispielhaften Anwendung konnten bereits drei Projekte exemplarisch bewertet werden, die in Abb. II.2-4 aufgezeigt werden.

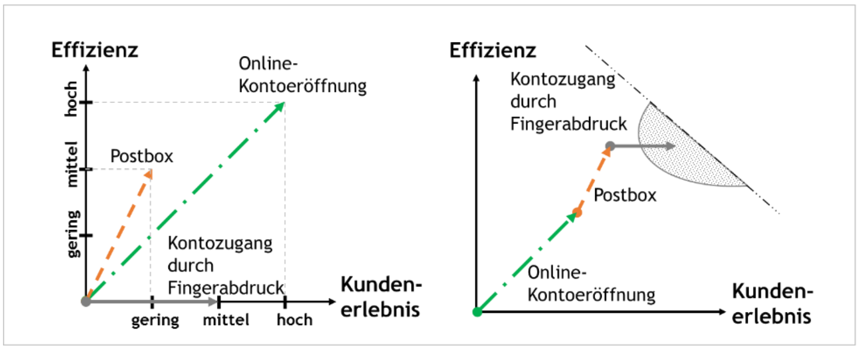

Abb. II.2-4 Einzelbewertung und Portfoliobetrachtung der Beispielprojekte Online-Kontoeröffnung, Kontozugang durch Fingerabdruck und Postbox

Abb. II.2-4 zeigt außerdem die Zusammenstellung der drei Projekte zu einem Projektportfolio. Für eine umfassende Festlegung des Projektportfolios, das am besten zur Zielerreichung beiträgt, sollte die T-Bank alle Schritte des Bewertungskreislaufs durchführen. Dazu muss zunächst eine umfassende Bewertung des Status quo für den Bereich Online- und Mobile-Banking durchgeführt werden. Da die T-Bank bisher keine weiteren Digitalisierungsprojekte in diesem Bereich durchgeführt hat, kann der Status quo auf 0 gesetzt werden. Des Weiteren kann die T-Bank ihren Zielkorridor sowie die Budgetrestriktion für diesen Bereich bestimmen. Der Zielkorridor muss am Geschäftsmodell ausgerichtet sein. Abb. II.2-4 zeigt einen beispielhaften Zielkorridor. Dieser kann mit dem bestehenden Portfolio aus den drei Projekten **Online-Kontoeröffnung**, **Kontozugang durch Fingerabdruck** und **Postbox** erreicht werden. Somit erreicht die T-Bank mit Hilfe der drei Projekte einen erwünschten Zielzustand. Um auch bei der T-Bank sicherzustellen, dass das Projektportfolio ständig an den Unternehmenszielen ausgerichtet ist, sollte der Zielkorridor und das Projektportfolio regelmäßig überprüft werden.

II.2.5. Kritische Würdigung und Ausblick

Im vorliegenden Beitrag wurde ein Bewertungsschema für Dienstleistungsunternehmen entwickelt, das Unternehmen dabei helfen soll, eine strukturierte Bewertung ihrer Digitalisierungsinitiativen sicherzustellen. Hierbei wurden *Kundenerlebnis* und *Effizienz* als Werttreiber für die Digitalisierung identifiziert und als Ansatzpunkt zur Bewertung von Digitalisierungsinitiativen verwendet. Diese beiden Werttreiber können jedoch nicht ohne Einschränkungen auf andere Branchen übertragen werden. Insbesondere der Werttreiber *Kundenerlebnis* ist beispielsweise nur begrenzt im Bereich B2B einsetzbar, da hier kein direkter Endkundenkontakt vorliegt. Daher sollte hier weiter untersucht werden, wie das vorliegende Bewertungsschema weiterentwickelt werden muss, um auch auf andere Branchen angewendet werden zu können. Des Weiteren sollte ein Unternehmen zur Anwendung des Bewertungsschemas in der Lage sein, den Zielzustand des Betrachtungsbereichs zu definieren. Da zwischen den beiden Werttreibern *Kundenerlebnis* und *Effizienz* meist ein Trade-Off vorliegt, der oft nicht sehr einfach durch das Management abgewogen werden kann, bedarf es auch hier weiterer Forschung. Ein erster Ansatzpunkt wäre, eine objektivierte, quantitative Bewertung zu ermöglichen. Diese sollte auf Basis monetärer Bewertungsgrößen eine Entscheidung ermöglichen, welcher Grad an *Kundenerlebnis* und *Effizienz* für das Unternehmen zu einem möglichst hohen langfristigen Wertbeitrag führt. Insgesamt liefert der Beitrag jedoch einen guten Ansatzpunkt für Unternehmen, Digitalisierungsprojekte zu bewerten und die Projekte auszuwählen, die am besten zur Erreichung der Ziele beitragen, sodass eine sinnvolle Steuerung des Digitalisierungsfortschritts erfolgen kann.

II.3. Getting a Grip on IT Project Complexity – Concluding to Underlying Causes

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Abstract:

Research appraises that the substandard management of complexity is one of the common reasons for IT project failure. However, improving the management of complexity requires an unambiguous understanding of what is meant by complexity. In this study, we therefore strive to provide conceptual clarity regarding the construct complexity. We develop a two-dimensional framework. We evaluate its practicability by drawing on semi-structured interviews with IT project management experts. The resulting framework will help researchers and practitioners to understand how complexity can occur in IT projects, as it provides insights into what causes complexity and where it is located within a project.

Keywords: IT project complexity, Complexity determinant, Complexity assessment, Framework.

II.3.1. Introduction

Increasing market competition requires a high level of adaptability to rapidly changing market conditions and customer expectations. This forces companies to continuously progress. Since projects enable change within a company, they are increasingly important (Watson 2012). However, information technology (IT) projects also face a high risk of failure (Matta and Ashkenas 2003). IT projects fail when they do not meet their objectives, concerning schedule, budget, or outputs. The failure can cause devastating problems, and even total business failures for companies (Flyvbjerg and Budzier 2011). With this in mind, managers should aim to manage IT projects properly (Müller and Neumeier 2015).

Although the exact relationship between IT project failure and IT project complexity has not yet been sufficiently investigated, many authors agree that complexity contributes to IT project failure (Daniels and LaMarsh 2007; Fridgen et al. 2015b; Parsons-Hann and Liu 2005). For instance, Vidal and Marle (2008) found that while the relationship needs to be clarified, complexity seems to be one of the main reasons for IT project failure. Xia and Lee (2004) argue that one of the reasons for IT project failure can be a high level of complexity, as there are many different factors that influence a project at the technological and organizational levels. Baccarini (1996) states that since complexity has an impact on cost, time, and quality, it can hamper the achievement of a project's goals (Baccarini 1996; Xia and Lee 2004). Wallace et al. (2004) empirically confirm that complexity risk is one of six risk dimensions that influence the success or failure of software projects. A steady increase in complexity, which has been regularly found in past research, reinforces the effects of this problem (Größler et al. 2006). IT projects are particularly affected by high levels of complexity, as they need to cope with various dependencies within a single project, or between different projects (Beer et al. 2015; Fridgen et al. 2015b; Zimmermann et al. 2008).

The prevalence of IT project failure has been studied in depth. It has been found to be generally related to a lack of managerial approaches for coping with highly-complex projects, rather than to information technology per se (Jaafari 2003). This indicates the need for appropriate means to manage IT project complexity successfully especially for large scale IT projects that cannot be surveyed by one single person. However, IT project complexity is very difficult to understand, and there is no academic consensus about what is behind it or how it should be approached (Vidal et al. 2013). Instead of concluding to the underlying causes of IT project complexity, most researchers have only addressed specific aspects that can be observed within complex IT projects, and which are thus assumed to relate to IT project complexity (Größler et al. 2006; Novak and Eppinger 2001; Tatikonda and Rosenthal 2000). Accordingly, different categorizations of aspects have been proposed in the literature (Baccarini 1996; Vidal et al. 2013; Vidal and Marle 2008). Furthermore, various existing designations of complexity aspects that partly are used even contradictory hamper a clear and unambiguous understanding.

However, the explanation of a phenomenon like IT project complexity, which is crucial to deriving solutions, requires an investigation of underlying causes (Gregor 2006). Hence, a comprehensive and structured assessment of IT project complexity, including causalities of observed aspects, is needed. With this assessment, managers can identify the aspects that influence the complexity of their IT project. With these considerations in mind, we strive to provide conceptual clarity regarding the construct of IT project complexity. We thus aim to answer the following research question:

How can we assess complexity in IT projects concerning their influencing factors?

To do so, we develop a structured and elaborate framework for complexity assessment, which relates manifestations of complexity to generic causes and specific areas of occurrence. We provide an overview of underlying theoretical knowledge. We then explain our research approach. We derive hypotheses about the causalities of complexity by structuring the aspects of complexity identified in literature within a framework. We test and enhance the quality of the derived framework based on manifestations of complexity stated in literature. In terms of evaluation, we conduct five interviews with experts from different industries to validate the comprehensiveness, applicability and utility of the framework. Based on our investigation, future research will be able to propose an appropriate quantification and management of IT project complexity and may thus empower companies to mitigate their overall risk of IT project failure (Größler et al. 2006; Latva-Koivisto 2001). Finally, we discuss the framework's contributions for practice and research, and existing limitations.

II.3.2. Theoretical Background

Complexity is a topic that has been discussed in a variety of research fields, including philosophy, biology, mathematics, and informatics. Accordingly, understanding of complexity tends to vary greatly (Rosen 1977). In general, there are two major streams of literature that analyze "complexity in projects" and "complexity of projects" (Geraldi et al. 2011, p. 968). While the first stream focuses on the integration of complexity theory in projects (e.g. Benbya and McKelvey 2006; Cicmil et al. 2009; Pundir et al. 2007), the second one deals with the characteristics of complex projects (e.g. Geraldi et al. 2011; Jaafari 2003; Jaber et al. 2014; Xia and Lee 2005). In the following, we stick to the second stream. To be more specifically, we focus on the complexity of information system (IS) and IT projects, rather than to complexity of non-IT-projects. Compared to non-IT-projects, IT projects are considered to have specific characteristics that make them even more complex than non-IT-projects. Amongst others, intangibility of assets, immaturity of industry and unpredictability of frequently, not thoroughly documented changes in requirements are mentioned in this context (Baccarini et al. 2004; Jaafari 2003). Thus, in this research, we focus on complexity of IS and IT projects as a specific area of the more general field of project complexity and hereafter simply refer to it as complexity.

We consequently refrain from any specific definitions of computational complexity (Edmonds 1999), software complexity (Wang and Shao 2003), or any other complexity that only concentrates on a specific sub-area of IS/IT projects. Moreover, as a common agreement on a definition of complexity in a general context does not exist (Schlindwein and Ison 2004), we also refrain from simply adopting an existing or introducing a new one. We rather endeavor to proceed to a deeper level of understanding by discovering antecedents of complexity and the project areas where it manifests and might be observed. In the following sections, we thus examine existing literature in order to clarify what is behind complexity and how it can be assessed in a structured and practical way. Thereby, we strive to discover causalities of complexity in general.

Complexity is determined by various circumstances, and is thus very difficult to grasp (Xia and Lee 2004). Hence, related work can be considered as assemblages of different observations within this context, rather than detailed and structured assessments or sharp definitions. The majority of articles addresses influence factors that are supposed to relate somehow to complexity, but which are derived from a narrow subjective perception of the topic. In adopting a more general perspective, we strive to provide conceptual clarity regarding the construct of complexity. Therefore, we introduce a uniform designation and distinguish between aspects, characteristics, and manifestations to facilitate comprehension:

Aspects, as the vaguest category, refer to any kind of influencing factor that somehow relates to complexity.

Characteristics are considered to be aspects of complexity that exist independently of specific areas of occurrence (i.e., characteristics can be observed independently of a specific context).

Manifestations are considered to be aspects that arise from a specific area of occurrence (i.e., manifestations can only be observed within a specific context).

Some approaches to complexity in existing literature primarily describe different manifestations (Edmonds 1999; Edum-Fotwe and McCaffer 2000; Misra 2006; Wang and Shao 2003), whereas others try to determine comprehensive characteristics of complexity (Baccarini 1996; Größler et al. 2006; Tatikonda and Rosenthal 2000). However, the majority of studies address single aspects that are supposed to somehow relate to complexity (Baccarini 1996; Größler et al. 2006; Tatikonda and Rosenthal 2000). Different studies do not treat these aspects consistently, and in some cases, they even use them contradictory. Moreover, since most studies do not address complexity as a whole but rather focus on side issues, they lack a comprehensive and systematic structure or approach concerning this matter.

Since complexity as a cause for IT project failure has attracted greater attention in recent years, researchers increased their effort in providing structured categorizations to complexity, e.g. by dividing complexity aspects "into […] more intuitive groups […], which were cited in several of the references" (Vidal et al. 2013, p. 253). While doing so, Vidal et al. (2013), however, strive to empirically examine several manifestations of complexity found in literature by the means of a Delphi study. Inspired by an initial categorization of Baccarini (1996), who distinguished complexity manifestations on an organizational and a technological level, Lee and Xia (2002) proposed a framework along two dimensions, *locus* and *nature*. *Locus* refers to whether complexity "is associated with *organizational factors* or *IT factors*" (Lee and Xia 2002, p. 4) and thus addresses its areas of occurrence like intended by Baccarini (1996). By contrast, *nature* distinguishes between *structural* and *dynamic complexity*. According to Lee and Xia (2002, p. 3), *structural complexity* pictures "a function of the number of project components and the form and strength of the relationships [in]between". D*ynamic complexity* in contrary "refers to complexity due to changes in business and technological environments" (Lee and Xia 2002, p. 3), which is claimed to be consistent with Wood's definition of dynamic complexity (Wood 1986) and Campbell's notion of uncertainty (Campbell 1988). Continuing their research, Xia and Lee (2005) validated their initial framework with a survey among 541 managers and derived a measurement model for complexity.

As this endeavor was one of the first approaches focusing on complexity assessments, it established and served many researchers as basis for continuing investigations. Gregory and Piccinini (2013), for instance, build upon Xia and Lee (2005) and extend their structure by adding *variety* and *interdependency* as structural and *uncertainty* and *ambiguity* as dynamic "constructs" of complexity in IS projects. To do so, they conducted a literature review and identified several manifestations, which they categorized according to their enhanced structuring. Drawing on a Delphi study, they continued their research by empirically investigating to what extent the identified manifestations influence the complexity of IS projects (Piccinini et al. 2014). Based on a systematic review of complexity literature, Geraldi et al. (2011) propose a contingency framework based on five dimensions of project complexity: *structural complexity*, *uncertainty*, *dynamic*, *pace*, and *socio-political*. However, as *dynamic* complexity might be seen as a concept that addresses "the unpredictable situations and emergent events that occur over time" (Brady and Davies 2014, p. 25), it can be considered to include "different types of uncertainty influencing the progress of a project" (Brady and Davies 2014, p. 25). Consequently, Brady and Davies (2014) propose a conceptualization of project complexity that merely distinguishes between *structural* and *dynamic complexity*, whereas in comparison to Geraldi et al. (2011), *dynamic complexity* comprises the *dynamic*, *uncertainty* and *pace* dimension and *structural complexity* includes the *structural* and *socio-political* dimension. Thus, in contrast to Lee and Xia (2002; 2005), Geraldi et al. (2011) and Brady and Davies (2014) rather focus on the *nature* of complexity and neglect the area within a project where complexity might occur (*locus*).

Despite the undoubted contribution of the previously mentioned investigations, they mostly investigate manifestations of complexity rather than concluding on common characteristics or antecedents. Furthermore, they often lack concrete delimitations between different complexity aspects and consequently lack clarity regarding causalities. The hesitation of researchers to state causes for the phenomena that they investigate is a well-recognized issue in IS research (Avgerou 2013; Bacharach 1989). Yet doing so is crucial, since the explanation of an investigated phenomenon often requires an examination of the underlying causes (Gregor 2006). Conceptual clarity of complexity is further hampered, as different studies came up with various different wordings regarding complexity aspects like dimensions, constructs, groups, areas, etc., which are partly even used contradictory. Therefore, the contribution of existing research on complexity is to provide a structured list of possible aspects of complexity to be thought of when managing an IT project, rather than to provide elaborate guidance on how to assess complexity or explain what is concealed within it. An approach that assesses complexity from a managerial perspective by providing insights about causes for the genesis does not yet exist, to the best of our knowledge.

II.3.3. Research Approach

To develop an approach that is able to assess complexity, we first specify the purpose and scope of our artifact in section 1. After, examining existing descriptive or prescriptive knowledge concerning complexity within section 2 and explaining our research approach in section 3, we move on to the artifact description in section 4. In this section, we provide detailed insights on the iterative design process that led to the development of the final structured and elaborate framework to assess complexity. Since a rigor evaluation regarding multiple criteria requires multiple evaluation techniques, it would exceed the scope of this paper. Thus, we limit the evaluation in section 5 to two criteria: validity and utility. As validity strives to evaluate that the artifact works properly, and utility that it does so even in a real world environment, we draw on expert interviews with practitioners for these evaluation purposes. We are aware that a rigor evaluation of the artifact requires further evaluation regarding additional criteria like quality and efficacy, which also includes an empirical investigation of the hypothesis generate by the proposed framework. Since this, however, is not feasibly within the scope of this paper, it is subject to further research. Finally, we present general learnings in section 6 and conclude in section 7, highlighting limitations and the important findings of the research paper.

II.3.4. Framework for the Assessment of Complexity

Based on common properties of findings from existing literature, we create our initial framework. As indicated, complexity generally depends on observation contexts and its areas of occurrence within an IT project (Lee and Xia 2002). Thus, we consider areas of occurrence as the first dimension of our two-dimensional framework, and henceforth refer to them as project areas. We give a more detailed explanation of the included project areas later.

To indicate how complexity evokes within different project areas, we determine antecedents of complexity. Assuming that antecedents evoke manifestations within specific project areas, and considering them as our second dimension, we come up with a resulting framework, which is supposed to encompass all manifestations evoked by the derived antecedents within the included project areas. Hence, we set up a two-dimensional framework based on generic antecedents and context-specific project areas, with the former describing what causes complexity and the latter describing where complexity is located. We illustrate this approach in Figure II.3-1.

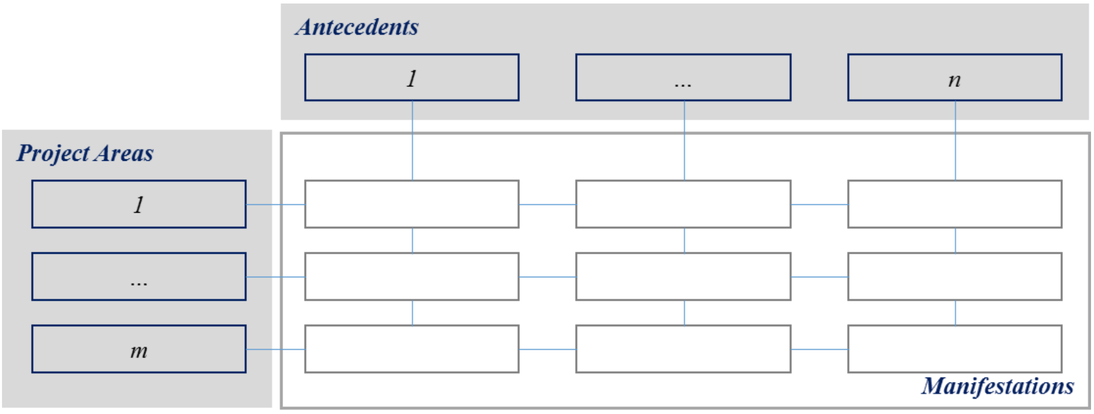

Figure II.3-1 Framework for the assessment of project complexity, including dedicated key terms

To find the antecedents of complexity, as a first step, we focus on the characteristics of complexity that appear in existing literature and that are observable independently of the observation context. Therefore, we examine the different characteristics listed in existing literature and whether they can be considered as antecedents.

II.3.5. Determining Complexity Antecedents

Existing literature mentions several aspects as characteristics of complexity, as they are observable independently of specific project areas. These characteristics mostly appear in studies with diverging and inconsistent definitions of complexity. However, the fact that characteristics seem to be comprehensively observable is not sufficient to consider them antecedents of complexity. Based on existing literature, we derive some requirements that a complexity characteristic specified in literature has to reflect, in order to be considered as a complexity antecedent in the context of this research.

A framework in its proper sense should feature a delineable structure to ensure scientific rigor, comprehensibility, and applicability. Therefore, not only the contained dimensions should be disjoint but also the segmentation within each particular dimension of the framework should be mutually exclusive. To provide clear and reasonable causalities of complexity, we consequently state the following requirement:

Requirement (Req.) 1 – Distinctness: A complexity antecedent should be distinct and easily separable from other complexity antecedents, meaning that it is not listed among others (Bailey 1994).

When people speak of something as being complex, they use "everyday language to express a feeling or impression that [they] dignify with the label complex" (Casti 1994, p. 269). Thus, when two people talk about complexity in the same case, they will not necessarily be talking about the same thing. This is because “like truth, beauty, good and evil, complexity resides […] in the eye of the beholder” (Casti 1994, p. 269). From a subjective point of view, complexity can be influenced by personal “knowledge, experience or intelligence” (Größler et al. 2006, p. 255). This kind of complexity is the result of a particular perception of a situation by a subjective observer (Schlindwein and Ison 2004), and is described as “subjective complexity” in this paper. However, since subjective perceptions are unique to every individual, they do not allow for a generally valid assessment of complexity (Baccarini 1996).

A different perspective is provided by Cilliers and Spurrett (1999, p. 3), who states that “complex systems do have characteristics that are not merely determined by the point of view of the observer.” Schlindwein and Ison (2004, p. 28) also explain that complexity can be “understood as an intrinsic property of a certain kind of system, or as occurring in a certain kind of natural and social phenomena.” This understanding is based on the assumption that there is an objective reality that can be independently assessed and is not influenced by subjective perception (Schlindwein and Ison 2004). Although it is probably impossible to separate the underlying objective reality from its subjective perception, it should be possible to make some conclusions regarding an objective situation by exploring similar properties that different subjective observations have in common. In this paper, we assume that subjective perceptions follow from objectively observable properties. In deciding whether to buy a new car, a customer must use subjective personal judgement, but that judgment is always based on objective properties, like design, features, and price, as well as their relationships to one another. In accordance with this perspective, we focus on properties of objective complexity as the basis of subjective perceptions and state the following requirement:

Requirement (Req.) 2 – Objectivity: A complexity antecedent should not refer to subjective perceptions or cognition, which means it should not depend on human abilities like “knowledge, experience or intelligence” (Größler et al. 2006, p. 255).

The “bounded rationality (Simon 1962) and the constructed nature of complexity (Klir 1985) hampers its definition as a complete, general, ‘perpetual’ and precisely measurable set of characteristics” (Geraldi et al. 2011, p. 982). Thus, the assessment of a transient and alterably construct as complexity by the means of a rather rigid and inflexible framework is a challenging endeavor. Especially, if such a framework is supposed to cover the emergence of unpredictable and random events over time that may influence the progress of a project. Since the assessment of any subject, be it a business case calculation or the appraisal of complexity, is based on information that is available at that specific point in time, future changes that may or may not occur over time cannot be covered anyway. In fact, these imponderables generally are considered vicariously by a risk discount, which is based on possible changes as to the underlying parameters of the assessed subject. Whereas these parameters might be interest rate or different cost factors for a business case calculation, they are antecedents in case of complexity assessment, which means that each antecedent of complexity is prone to changes over time. Hence, we consider changes over time as reinforcing influences to complexity antecedents rather than complexity antecedents themselves. Thus, in contrast to Lee and Xia (2002; 2005) and other research building upon (Gregory and Piccinini 2013; Piccinini et al. 2014, etc.), but in line with Baccarini (1996), Lindemann et al. (2009) and Laufer et al. (1996), we do not include factors that relate to changing circumstances over time into our framework and state the following requirement:

Requirement (Req.) 3 – Robustness: The extent to what an underlying antecedent is able to influence complexity should not depend on the point of time at which it is actually assessed. This means that the influence of an antecedent on complexity must not automatically increase or decrease with the time passing, but just depends on the actual observable value at the specific point of assessment. Although this requirement seems arbitrary and difficult to follow, it is quite intuitive: Imagine you would strive for the complex endeavor of understanding the underlying financial ecosystem of the world economy. In this case, Req. 3 demands, that if internal and external circumstances remain constant, the endeavor will have the same complexity on Monday morning as on Friday evening of the same week.

Literature mentions many aspects that are supposed to be characteristics of complexity. Furthermore, the same characteristic is often described by different expressions. Therefore, we consolidate expressions that describe the same phenomenon and consider these as characteristics only if previous frameworks listed them or if different authors mention them. In doing so, we found uncertainty, difficulty, multiplicity, interdependency, diversity, and ambiguity as characteristics of complexity. Although, the selection of these characteristics features some subjective judgement and they represent a certainly incomplete list, it provides a sound reference point to approach the assessment of complexity. Below, we discuss the identified characteristics and examine whether and how they meet the requirements introduced above, and thus whether we can consider them as complexity antecedents in the sense of this paper.

Uncertainty is the extent to which a project is subject to potential future changes (Xia and Lee 2004). The dynamics of projects can be described as their variability over time (Größler et al.

2006). The probability of varying over time represents the uncertainty of a project. Due to the similarity of the definitions of dynamics and uncertainty, we consider them as equals. Like proposed by Brady and Davies (2014), we furthermore assume pace to be part of uncertainty, since it relates to “changing relationships among components within a system and between the system and its environment over time” (Brady and Davies 2014, p. 24). Numerous researchers refer to uncertainty as a characteristic of complexity (e.g. Frizelle 1998; Jones and Deckro 1993; Sivadasan et al. 2002; Suh 1999; Turner and Cochrane 1993; Williams 1999; Xia and Lee 2004). As uncertainty is not only able to influence any identified antecedent of complexity, but is omnipresent in each planning activity, it cannot be assessed distinctly and thus falls short of *Req. 1*. At the same time, uncertainty can be examined objectively, as an absence of information exists regardless of the concrete abilities of individuals (*Req. 2*). However, it again falls short of *Req. 3.* The uncertainty involved in a project always declines with the project’s progress (for a more detailed explanation, see Boehm’s (1981) “cone of uncertainty” principle). As such, the extent to which uncertainty is able to influence complexity is strongly dependent on the point in time of its assessment. Furthermore, opinions vary as to whether uncertainty is a characteristic of complexity or should be considered separately. Whereas, for instance, Williams (1999) or Xia and Lee (2004) assert that uncertainty is a characteristic, Baccarini (1996), Laufer et al. (1996), and Lindemann et al. (2009) consider uncertainty to be a consequence of complexity, or even a separate concept. We consider uncertainty as a reinforcing influence to any antecedent, rather than an antecedent of complexity itself.

Things that are “difficult” can be defined as hard to achieve, comprehend, handle, or express (Cardoso 2005; Edmonds 1999) and thus **difficulty** refers to something that is “complicated, involved or intricate” (Baccarini 1996, p. 202). Various authors describe difficulty as a characteristic of complexity (e.g. Baccarini 1996; Cardoso 2005; Closs et al. 2008; Edmonds 1999; Gidado 1996). With regard to the distinctness of difficulty from other complexity antecedents, different opinions exist in prior literature. Although some authors argue that difficulty is a characteristic of complexity, others claim that it is just the result of multiplicity and interrelatedness (Closs et al. 2008). Gove (1981) furthermore states that if a project includes many varied project elements, it is difficult to understand as a whole. Thus, difficulty cannot be observed distinctly from other complexity antecedents and falls short of *Req. 1*. Furthermore, since whether something is hard to comprehend strongly depends on subjective perceptions and underlying human abilities, difficulty does not fulfill *Req. 2*. This is confirmed, for instance, by Baccarini (1996), who explains that difficulty as an “interpretation of complexity is in the eyes of the observer” (Baccarini 1996, p. 202). The extent to which difficulty influences complexity however, does not depend on the time of its assessment (*Req. 3*). Based on the previous examination, we consider difficulty to be a subjective consequence of other complexity antecedents, and not an antecedent in itself.

We assume that **multiplicity** is equivalent to multitude and frequency, and refers to the number of project elements that a project involves (e.g., the number of subprojects). Multiplicity is considered to be a characteristic of complexity by numerous authors (Cardoso 2005; Closs et al. 2008; Gidado 1996; Größler et al. 2006; Laufer et al. 1996; Lindemann et al. 2009; Milling 2002; Williams 1999). Multiplicity is distinct from other antecedents (*Req. 1*). As the actual number of project elements is not influenced by human perception, multiplicity can be assessed objectively (*Req. 2*). Furthermore, as quantity is a time-independent measure, the extent to which the number of elements is able to influence complexity is independent of the time of its assessment (*Req. 3*). Since multiplicity thus satisfies all criteria, we consider it to be an antecedent of complexity.

Interdependency is assumed to be equivalent to connectivity and interrelatedness, and is characterized by the relationships and interactions within a project or between different projects (e.g., interaction between a project’s organizational elements). Various authors consider interdependency to be a characteristic of complexity (e.g. Baccarini 1996; Closs et al. 2008; Gidado 1996; Größler et al. 2006; Jones and Deckro 1993; Laufer et al. 1996; Lindemann et al. 2009; Milling 2002; Williams 1999). Interdependency is distinct from other antecedents (*Req. 1*). It can be considered objectively, since relations between technologies, departments, products, or other elements can be assessed without the influence of human abilities (*Req. 2*). Furthermore, the extent to which interdependency influences complexity does not change over time (*Req. 3*). Consequently, since interdependency fulfills all criteria, we consider it to be an antecedent of complexity.

Diversity can be defined as the variety within a project. This implies that a project can have different variants of the elements that define it (e.g., the diversity of the cultures of team members). A large number of authors regard diversity as a characteristic of complexity (e.g. Baccarini 1996; Frizelle 1998; Gidado 1996; Jones and Deckro 1993; Laufer et al. 1996; Lindemann et al. 2009; Sivadasan et al. 2002). In terms of distinctness from other antecedents, it is clear that diversity is related to multiplicity. However, diversity addresses a separate issue, and can thus be considered distinctly from other antecedents (*Req. 1*). The diversity of project elements is quantitatively assessable and therefore independent from the perceptions of the observer (*Req. 2*). Moreover, the extent to which diversity - whether qualitatively or quantitatively assessed - is able to influence a corresponding complexity measure does not depend on the point of time at which it is assessed during a project's life cycle (*Req. 3*). Thus, as diversity fulfills all criteria, we consider it as an antecedent of complexity.

Ambiguity is considered as characteristic by Gregory and Piccinini (2013) and is referred to by manifestations mentioned by several different authors (e.g. Benbya and McKelvey 2006; Cicero et al. 2010; Jiang et al. 2009; Kappelman et al. 2006; Xu and Ramesh 2007). It can be understood as a lack of clarity regarding specifications. Ambiguity can be considered distinctly from other antecedents (*Req. 1*). The objectivity of ambiguity is more doubtful. The perception whether e.g. a task is clearly specified in part certainly depends on the abilities, knowledge, and experience of the perceiving person. However, comparing a very detailed task specification to a poor specification, the former one, in relative terms, is able to reduce complexity independent of the abilities of the task-executing person. Thus, we consider ambiguity as objective with respect to *Req. 2*. Moreover, the extent to which ambiguity is able to influence complexity does not change over time (*Req. 3*). Consequently, we consider ambiguity as antecedent of complexity. To ease the comprehensibility, Figure II.3-2 describes the coherences between the investigated characteristics of complexity.

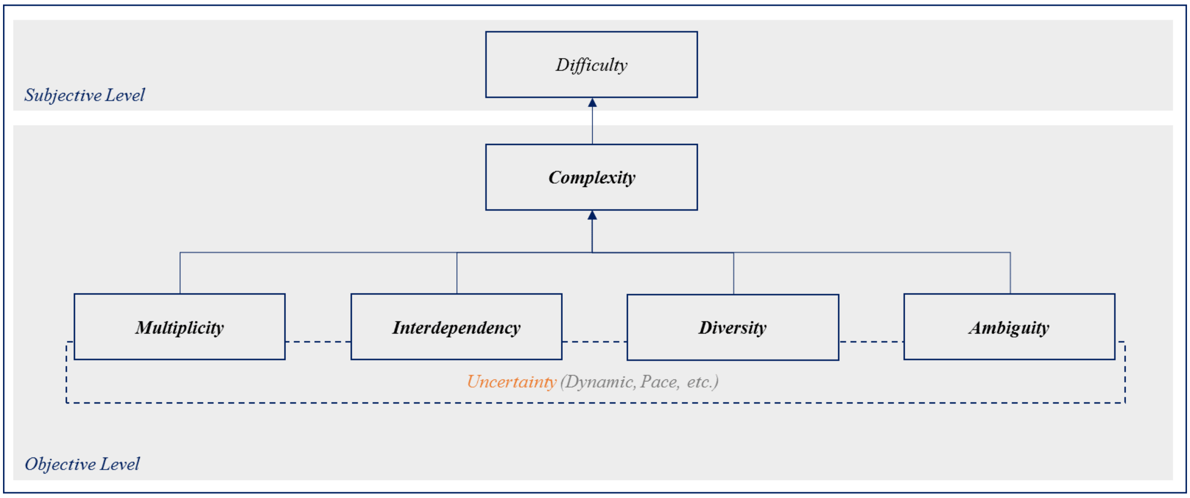

Figure II.3-2 Coherence of complexity characteristics

In conclusion, Table II.3-1 makes clear that only multiplicity, interdependency, diversity, and ambiguity fulfil all criteria for complexity antecedents. They consequently form the horizontal axis of our initial framework.

Characteristics of complexity	Distinctness	Objectivity	Robustness
Uncertainty	-	✓	-
Difficulty	-	-	✓
Multiplicity	✓	✓	✓
Interdependency	✓	✓	✓
Diversity	✓	✓	✓
Ambiguity	✓	✓	✓

Table II.3-1 Complexity characteristics in terms of criteria for complexity antecedents

II.3.6. Identification of Project Areas

Lee and Xia (2002) and Baccarini (1996) already propose to consider the area of occurrence of complexity and thus distinguish "organizational" and "technological" complexity. As this classification is quite rough, we want dive deeper into the project organization in order to understand the project areas in which manifestations of complexity can arise. Further, we want to enable a structured allocation of complexity within a project. Thus, we divide the project organization into different project areas, based on existing project management literature. We do not distinguish organizational and technological aspects as in times of digitalization and beforehand, the importance of IT continuously grows and influences all areas of an organization. Thus, technological aspects can occur in any project area.

To identify an appropriate categorization of project areas, we synthesized several studies. The Project Management Institute (2008) gives an overview of different enterprise environmental factors that surround or influence a project, like e.g. organizational structure, culture, and processes, or marketplace conditions. They give a quite long list of twelve factors, which can be used as a guidance. Since projects are executed within functional organizations, Edum-Fotwe and McCaffer (2000) suggest to use the traditional functions required to manage enterprises, like e.g. finance and accounting, sales and marketing, and operational planning. Nevertheless, both publications point out that additional factors need to be considered. As both categorizations do not incorporate all relevant areas of a project, they do not serve our purpose and thus cannot be used as a categorization scheme for the project areas.

The categorization introduced by Belassi and Tukel (1996) is rather generic and serves as a basis for several other studies. They introduce critical success factors for projects and categorize them according to the four factor groups 'factors related to the project', 'factors related to project manager and team members', 'factors related to organization' and 'factors related to external environment'. Hyvari (2006) further elaborates these areas and differs between 'factors related to project manager' and 'factors related to team members'. She further gives examples of success factors that should be categorized in this area, and thus supports a clear understanding of the scope of the different areas.

Westerveld (2003) uses these areas as a basis and proposes an “overall framework for the management of projects” (Westerveld 2003, p. 411) based on the European Foundation for Quality Management (EFQM) Excellence Model. As the EFQM was developed for “traditional, functionally organised, permanent organisations” (Westerveld 2003, p. 411) it cannot be directly used for project-focused organizations without adjustments. Thus, Westerveld (2003) introduces six organizational areas (contracting, leadership and team, project management, resources, stakeholder management, and policy and strategy) that represent the areas that project managers can work on to “increase the likelihood of achieving a successful outcome of their project” (Westerveld 2003, p. 412). Even though this categorization seems to be more graspable than the ones introduced before, the missing explanation of the concrete scope of the areas lead to a missing distinctness and gives rise to misunderstandings. Hence, for example it stays unclear how the author distinguishes between topics ‘policy and strategy’ and ‘stakeholder management’.

Within complexity literature Jaber et al. (2014) group complexity factors for innovative product development projects into seven categories ‘current product complexity’, ‘project characteristics’, ‘project governance’, ‘project team’, ‘resources’, ‘stakeholder’, and ‘environment complexity’. However, these areas are not based on a literature analysis and are not empirically validated. Hence, to enable an objective, impartial assessment, we adhere to the general and validated areas by Hyvari (2006) based on Belassi and Tukel (1996). Nevertheless, as each project differs from another, it might be useful to incorporate further subcategories within each area. In the following, we stick to the introduced project areas, which form the vertical axis of our initial framework.

Factors related to the project: This area includes all manifestations of complexity that are directly related to the project (Belassi and Tukel 1996). It includes all activities inherent in a project, as well as size, value, project life cycle, resources, project outcome, and planning and scheduling of project activities (Belassi and Tukel 1996; Hyvari 2006).

Factors related to the project manager / leadership: This area covers all aspects concerning the project manager and leadership in the project (Hyvari 2006). We include all aspects that affect the way that a project is led, leadership style, managerial competence, the ability to coordinate, objectively observable relevant past experience of the project manager, required competence, and management commitment in this area (Belassi and Tukel 1996; Hyvari 2006).

Factors related to the project team members: This area comprises the skills and characteristics of the project team members (Hyvari 2006). We include all kinds of competences of the team members, and the way tasks and responsibilities are distributed within a team in this area. We also consider staff constellation, working habits, communication skills, and technical skills, as well as working experience, as these play an important role in this area (Belassi and Tukel 1996; Hyvari 2006).

Factors related to the organization: This area is concerned with the position of the project within the organization (Belassi and Tukel 1996). We include top management support, negotiation and positional power within the organization, as well as the project organization structure in this area (Belassi and Tukel 1996; Hyvari 2006).

Factors related to the environment: This area includes all factors "which are external to the organization but still have an impact on project success or failure" (Belassi and Tukel 1996, p. 145). The environmental factors imply external political, social and economic influences, and even influences by nature. Furthermore, the client is included here. In some IT projects, clients are part of the organization and in this case should be considered in the organization area. Moreover, factors related to competitors and contractors / subcontractors, or external service providers are summarized here (Belassi and Tukel 1996; Hyvari 2006).

II.3.7. Framework Design Validation

After determining the dimensions and designing the framework, we validate the framework against existing literature. This step is supposed to verify if the framework covers all manifestations of complexity that are mentioned in literature and hence gives a hint on the completeness of the framework. However, not all mentioned manifestations have to appear in each IT project.

We examined various studies in our validation phase including but not limited to Baccarini (1996), Geraldi et al. (2011), and Xia and Lee (2005) and thus gained a huge number of aspects concerning complexity. To improve operability, we merged different verbalizations of the same manifestation. As already outlined before, uncertainty is not an antecedent of complexity and needs to be considered as a separate concept. Thus, we excluded all verbalizations concerning uncertainty and change. While several manifestations were only mentioned in literature, certain authors already empirically tested the causality of others. In total, we obtained 166 manifestations and assigned them to the framework.

In the first step, we are able to assign 140 of 166 manifestations to the derived framework. The other 26 either did not fit one of the four antecedents or a specific project area or even both. Thus, the framework in its initial state covers about 84% of the considered manifestations.

We improved the framework based on an iterative procedure. Therefore, after setting up the initial framework, we analyze whether an extension of the dimensions could possibly increase the framework's coverage of context-specific manifestations. Thus, we examined the 26 manifestations that we were not able to assign to the framework, in order to determine whether they exhibit the same properties. As we were able to assign all 26 manifestations to one of the project areas, an adjustment of the project areas does not seem necessary.

However, we further examined the similarities of the 26 manifestations concerning potential antecedents of complexity. The only similarity that we obtained between these manifestations is that 13 of them address the degree of novelty within a project. Novelty addresses whether the organization already knows different aspects of the project, if they have been accomplished before or if best practices are available. To investigate whether we can reasonably consider novelty as a further complexity antecedent, we checked the requirements stated above. Since the 13 manifestations could not yet be assigned to any of the previously stated antecedents, we can consider novelty as distinct in terms of *Req.1*. Considering all people to have the same information of whether something has been done, used, or invented before, the evaluation whether something is new does not depend on human perception or individual experience, but only on the availability of information. Similarly, on a company level the novelty of a project might be evaluated based on the accessible information of the company and is not limited to the subjective experience of one individual project member. Thus, novelty can be assessed objectively *(Req.2)*. The extent to which novelty is able to influence complexity does not depend on the point of time of its assessment. Therefore, as it also fulfils *Req. 3*, we extend our initial framework by considering novelty as a separate antecedent.

Despite the adjustments, we still cannot adequately assign 13 manifestations to the framework. Even though they can be assigned to a project area, they do not adequately fit any antecedent. While five of them cope with the complexity within the "project" like the impact of a fixed deadline for the project or the flexibility of the project budget, seven can be assigned to the project area "environment". Even though those manifestations should be considered, we could not find another cluster to derive a further antecedent. Nevertheless, 92% of the manifestations mentioned in our literature sample fit the revised framework. We consider the framework to cover the most relevant aspects. Figure II.3-3 depicts the final framework.

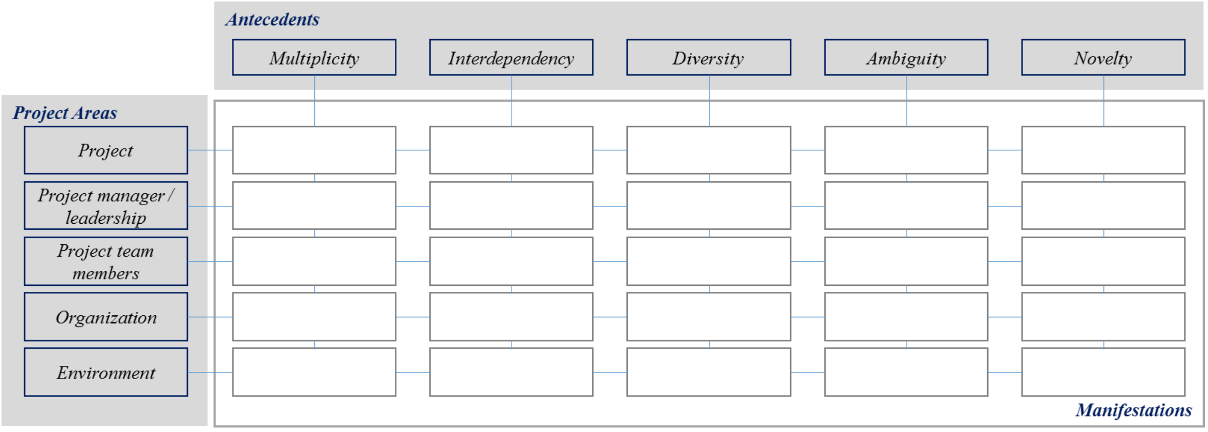

Figure II.3-3 Adjusted framework for the assessment of IT project complexity

II.3.8. Evaluation

The purpose of the evaluation in this section is to examine the validity and utility of the revised framework, using semi-structured interviews with practitioners. The focus of this evaluation is on the adequacy and comprehensibility of the complexity antecedents, the applicability of project areas as holistic and reasonable structures for projects, and the practicability and utility of the framework to assess complexity in real world circumstances. Therefore, we conducted five semi-structured interviews with project management experts from different industries from Mai to September 2016.

We identified potential interview partners based on (i) different industry sectors and (ii) years of experience in the project management field to cover a wide and valid spectrum of knowledge. Three interviewees work for leading strategy consultancies with widespread experience in the field of IS/IT projects within different industries. The other two work as IS/IT project manager within the manufacturing industry. Each interviewee has experience as IS/IT project manager for at least seven to ten years. We contacted our interview partners via e-mail, asking for interviews via telephone or video conference. Each interview lasted approximately 45 to 60 minutes and both authors were participating in all interviews. Due to the global dispersion of the experts, we conducted the interviews via telephone or video conference. However, according to long established evidence, telephone interviews are just as effective as face-to-face interviews (Rogers 1976) and we observed no shortcomings in the data collected for this project. The interviews were audio recorded. Furthermore, one of the authors took notes during the interview to improve spontaneous questions relating to already discussed topics. Table II.3-2 gives an overview of the experts.

No.	Current position	Company	No. of years	Interview conduct
1	Senior consultant	Strategy consultancy with focus on European financial sector	8	Telephone
2	Senior consultant	Strategy consultancy with focus on Swiss financial sector	7	Telephone
3	Junior partner	Strategy consultancy	7	Telephone
4	IT project manager	Global player in the construction industry	7	Video conference
5	Corporate IT coordinator / program manager	Leading supplier of robotics, plants and systems engineering	8	Telephone

Table II.3-2 Overview of interview partners

As a guide for the semi-structured interviews, we divided the inquiry into four phases to gain a common understanding and analyze adequacy and comprehensibility:

- First, to set the stage, the general idea and the purpose of the interview was introduced (Myers and Newman 2007) and the interviewees were asked open questions concerning their understanding of complexity and the related antecedents and manifestations.
- Second, the experts analyzed the distinction between subjective and objective level of complexity (Figure II.3-2), to gain a common understanding of the scope.
- Third, the experts were asked to discuss the actual framework and explicitly criticize the framework (Figure II.3-3).
- Finally, we discussed the practical implications and usability of the framework.

After finishing the interviews, all interviews were systematically analyzed by the authors using initial coding (Saldaña 2015). Initial coding does not restrict the analysis and allows us to break down data into single parts, analyze them and identify similarities and differences. By conducting five interviews, we have been able to gain valuable insights into the benefits and obstacles involved in our concept, from a practical point of view. Nevertheless, before incorporating the annotations to our framework, we critically discussed any feedback received in the interview with other researchers. Furthermore, the evaluation with expert interviews is only a first step in the evaluation cycle. Since the experts did not use the framework in their daily work before the interviews, we can only use the insights as first indication for validity and utility. Future research should include a real-world evaluation in the form of case studies or an action research study.

General understanding of complexity and problem relevance

All interviews had in common that the experts mainly explained their understanding of complexity by describing different manifestations like, for instance, number of people involved (expert 2, 3, 4), interdependencies between systems involved (expert 2, 5), and size of the project (expert 4, 5). Furthermore, they mentioned that they usually consider the project content as well as the environment of the project. Even though the manifestations and general statements did not significantly differ from each other, there was no clear understanding of the overarching aspects of complexity and all experts had difficulties in explaining their concrete perception. Thus, they agreed that it would be useful to gain a common understanding of complexity. Expert 1: *"Complexity is really hard to grasp. I often experience that my colleagues and I have a different understanding of what each of us thinks is complex. It would help us a lot to gain a common understanding."*

General concept

Expert 2, 3, 4, and 5 agree that the personal perception of how difficult a task is differs from one person to another. Expert 3: *"It always depends on your experience and your abilities if something is complex or not. However, to enable a useful discussion, it is necessary to talk about objective criteria."* As this personal feeling is not comparable, the experts agree that a differentiation between the subjective difficulty and the objective (or objectified) complexity is a useful step to enable a graspable and comparable assessment of complexity. Nevertheless, as the management of projects is highly influenced by feelings and perceptions, those subjective influences should be regarded in the process of managing a project. Thus, the experts agree that the assessment of objective complexity is a reasonable procedure to gain comparable assessment of projects, if the subjective component is regarded on the management level. Furthermore, the structuring of complexity in a two-dimensional framework including "antecedents" and "project areas" is a reasonable and useful approach, as it is easily applicable in practice according to all experts.

Complexity antecedents

The most important complexity antecedents from a practical point of view are included in our framework (all experts). In general, the complexity antecedents correspond to reality, especially with regard to interdependency, multiplicity, and diversity. While expert 1 made it clear that an unambiguous distinction between multiplicity and diversity should be maintained, he confirmed that it is possible to understand these distinctions clearly in our framework, due to our definitions of complexity antecedents. However, expert 1 suggested including examples in the descriptions of every complexity antecedent, in order to increase the precision and comprehensibility of the concepts. To follow this advice, we integrated explanatory examples into the definitions for each complexity antecedent.

Even though ambiguity and novelty did not come up in the first thoughts of the experts, they are convinced that it is important to consider those antecedents. While expert 2 was not sure if novelty influences complexity on an objective level, expert 3 and 5 emphasized the influence of novelty on objective complexity especially in case of innovative projects without best practices available. Thus, we decided to remain the antecedent in the framework. Expert 5: *“From my point of view, novelty influences the complexity of a project. If none of the project team members conducted a comparable project before, this can have a large impact on complexity.”*

Furthermore, all experts confirmed the appraisal of uncertainty as a reinforcing factor on complexity antecedents. As changes can occur in each complexity antecedent, according to the experts it should not be considered as an additional antecedent, but as a reinforcing factor.

Applicability of project areas

The experts further confirmed that the introduced project areas are appropriate for dividing a project into different segments. For expert 2 it is especially important to consider all aspects within a project. Thus, all areas of a project need to be covered. Within this context, expert 1 emphasized that the importance of project areas can differ for specific projects, which makes it necessary to specify project areas according to the characteristics of the particular project. In this context, the experts considered the generic level of our project areas advantageous, since it leaves enough latitude to customize them to particular project demands. Nevertheless, all areas need to be clearly delineated, to prevent doubling and overlaps of certain factors.

Validity and utility

The experts generally confirmed that there is a lack of structured methods for the analysis of complexity in practice, although this is a relevant aspect of daily business. By establishing the proposed framework, we strive to provide conceptual clarity regarding the construct of complexity to ease the management of complexity in science and practice. Thus, we discussed with the experts whether the artifact serves these purposes under real-world circumstances. In this context, all experts confirmed that the framework increases the transparency of complexity as it relates the observable manifestations with objective antecedents and project areas and consequently makes complexity more graspable. According to expert 1, it gives structured guidance in considering the relevant aspects, already during project planning, and thus serves as a tool for the ex ante assessment of complexity. Expert 3, furthermore, highlights that this enables a better management of IT projects, as based on an early complexity assessment more experienced project managers might be allocated to more complex IT projects. In terms of assessment, expert 2, 4 and 5 emphasized that the framework eases the identification of aspects that influence the complexity of the project. The provided list of manifestations might serve as a reference list to identify the relevant complexity aspects of particular IT projects more easily. However, it can only be used as a supporting instrument. Since different IT projects comprise different aspects of complexity, the list of manifestations does not have to be used for every project. Based on this initial assessment of complexity, experts 2 to 5 consider the highlighting of particular complex project issues as another opportunity of the proposed framework, which enables to properly allocate resources and take actions to avoid or reduce complexity in those particular areas. Furthermore, expert 1 considered the framework to serve as a steering instrument during the lifecycle of a project or as a continuous controlling measure that detects reasons for project failures, like exceeding time or budget. Consequently, based on the feedback of the business experts, we consider the frameworks appropriate to serve its purposes also under real-world circumstances.

However, as already mentioned in section 3, this evaluation is just a modest first step towards validating the framework. There are several further aspects, which need to be investigated in order to validate the framework. In a first step, we still need empirical support on our hypothesis. Hence, we can show that the items in the framework are complete. Another point that should be further discussed is the interaction of the antecedents in the framework. Further, we need advice on operationalization to enable using the framework in real-world projects and hence also evaluate the usefulness in a practical setting like a case study or an action research study. Although we already made first efforts to proof the validity of the framework, these are currently still topic to further research.

II.3.9. Discussion

Based on the conducted interviews, we can derive the following generalizable insights: Although each of the experts seemed familiar with the topic, they all had difficulties in explaining their understanding of complexity. They used manifestations to describe their experiences and perceptions, but were not able to state the overarching aspects of complexity. Thus, we find that that the axiomatic link between the subjective perceptions of complexity hampers a deeper understanding of what conceals underneath the surface in terms of complexity antecedents. Consequently, there is a lack of structured methods for the analysis of objective complexity, although, according to the interviewed experts, these would help to establish a common understanding of complexity by abstracting from subjective perceptions. Furthermore, we find detailed and example-based explanations of complexity with all its terms and descriptions a necessary condition to enable a common understanding between researchers and practitioners.

We also received the feedback (expert 4) that the compilation of such a comprehensive framework from scratch, based on real world data of a particular project would be very time-consuming. Thus, we conclude that the discovered manifestations should be provided as an optional reference list within the framework, to increase its practicability. Generally, experienced project managers trust on their gut feelings to handle an IT project's complexity. Yet, as complexity comprehends various different aspects, we find that it is quite hard for a project manager to consider all aspects of complexity only by gut feeling especially in large scale project where one manager cannot survey all aspects of the project anymore. In this context, the experts recognized that some of the complexity antecedents, which they considered reasonable, are usually not considered in project planning. Nevertheless, we find that despite the merits of increased transparency, a framework-introducing research should not be limited to just stating the obvious coherences between different complexity aspects. Although the identification and emphasizing of problematic issues is an important first step, the actual value added for practitioners lies in detecting complexity patterns, revealing recommendations for action, and indicating starting points to avoid or reduce complexity.

II.3.10. Conclusion

As complexity can be one reason for the failure of IS/IT projects, companies should strive for a clear and unambiguous understanding of IT project complexity. With this in mind, we introduce a concept for the structured assessment of complexity that is particularly relevant to IS/IT projects, as they are even more complex than usual projects. We initially created the framework based on existing literature in the field of complexity. Our two defined dimensions address complexity antecedents and areas where complexity can occur within an IT project. We assigned manifestations of complexity to those dimensions. Based on this validation, we adjusted our initial framework to account for 92% of all identified manifestations subsequently. Drawing on five semi-structured interviews with experienced project management experts, we evaluate the framework concerning usability and applicability.

Our framework can be equally beneficial for research and practice, as it facilitates comprehension of the concealed aspects of complexity. On one hand, the framework can contribute to future research by analyzing and structuring existing literature to arrive at hypotheses about the causalities of complexity. Since by now, there is no common understanding of complexity within IT projects in literature, this paper gives a structure for the different aspects that influence complexity. By validating the framework against literature and conducting an expert evaluation, we have ensured its quality and utility in practice. However, the validity of the derived hypotheses concerning the causalities of complexity still need to be empirically tested. We encourage other researchers to empirically test and validate our hypotheses in further research.

On the other hand, our framework can help practitioners identify and understand how complexity can occur within an IT project, as the matrix provides insights into the antecedents of complexity and where it is located within the different IT project areas. Additionally, the identification of manifestations from literature can help practitioners to understand the complexity within their IT projects, as the manifestations represent a reference list of aspects that might influence the complexity of a specific application case. Therefore, practitioners can use the framework as an ex ante evaluation tool to identify problems prior to a project's implementation. Overall, our approach provides a framework for assessing complexity with respect to influencing factors, and thus clarifies the IT project complexity's concept. The introduced framework sets a foundation for the development of methods for an active complexity management that includes adequate mitigating actions like, for instance, the adequate allocation of project management capacity. Furthermore, the framework can be used as a basis for a project steering instrument, to determine appropriate strategies for the better management of complexity during a project, and to counteract the risk of IT project failure. However, the developed framework does not include any kind of measurement method. Since the quantification of complexity antecedents could support complexity management, future research should examine the complexity antecedents described in this paper in more detail, considering their quantification and examine what complexity level is most advantageous. Furthermore, future research should cope with complexity patterns and potential recommendations for complexity mitigation. Moreover, future research should theorize more on the coherence between IT project complexity and IT project failure. Hence, the characteristics of IT project complexity could be assessed versus different types of IT project failure.

Despite its limitations, our study contributes to the current body of knowledge regarding complexity assessment by offering a clear and unambiguous structure for complexity. Furthermore, it provides a first glance at the causes of complexity, which have not yet been explored in existing literature.

II.4. A Hybrid Approach for Cost-efficient Cloud Bursting in Rural Regions

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Abstract:

IT departments face the challenge of providing highly flexible IT resources at low costs. The use of cloud bursting within a hybrid infrastructure as a service (IaaS) setting has the potential to reduce IT service provision costs by keeping expensive on-premise resource capacity at a low level while offloading the excess workload into the public cloud. We especially focus on hidden champions who are usually located in rural regions. These regions often lack sufficient bandwidth, restricting the possibility of cloud bursting to a limited threshold. This aspect is not considered by existing approaches. To address this research gap, we conduct a second research cycle for an existing approach for cost-efficient cloud bursting by Lilienthal (2013). After identifying the required adjustments of the model for hidden champions in rural regions in a pre-testing, we conduct all three phases (description, explanation, and post-testing) of the second research cycle, in line with Merredith et al. (1989). Overall, we find that bandwidth restrictions strongly impact on the economies of cloud bursting for hidden champions. We find that bandwidth availability plays a key role in investment decisions and should not be neglected. Both research and practice can benefit from our results. We derive hypotheses that can lead to a deeper understanding of sourcing decisions and load-shifting in rural regions. Further, practitioners can improve their basic understanding of bursting decisions.

Keywords: Cloud computing, Hybrid cloud, Cloud bursting, Cost-efficiency, Bandwidth.

II.4.1. Introduction

Owing to growing competition and customer needs, IT departments increasingly face the challenging demand for greater flexibility and lower IT costs (Deloitte 2015; Ernst & Young 2014; Middleton 2013). To address the demand for flexibility, many companies are planning and turning to shift local load to infrastructure as a service (IaaS) in the public cloud. Thus, fluctuating and hardly predictable workloads that were previously only manageable by providing on-premise resource capacity for the highest possible load situation can now be handled by dynamically lining up supply with demand (Armbrust et al. 2010).

Cloud computing provides an opportunity to reduce fixed capital expenditures of on-premise resources in exchange for usage-dependent costs and to enable almost continuous resources scalability (Ernst & Young 2014). Considering that public cloud providers achieve increasing economies of scale by oversizing their data centers (Marston et al. 2011), there will be few long-term economic rationales for using on-premise resources (Versace and Perry 2013), and most IT demand will be served by the public cloud.

However, the adoption of public cloud resources increases data exchange with various providers, which again increases companies' traffic. Practitioners and the literature point out bandwidth considerations' importance in cloud strategies, since insufficient network capacity may constitute a severe data traffic bottleneck between client and provider (Bittencourt et al. 2012; Bright 2013; Gittlen 2012; Rafique et al. 2011; Weinman 2011; Zhuang et al. 2013). Thus, public cloud services are only continuously scalable if sufficient bandwidth is available. According to Tom Conophy, the CIO of the InterContinental Hotels Group, "the cloud will be nothing more than a pipe dream […] if your employees and your users can't access data fast enough" (Gittlen 2012).

Drawing on public cloud resources may also be a desirable solution for so-called *hidden champions* – medium-sized, often family-operated companies with market leadership in a specific domain (Simon 1996). Nowadays, they usually operate their on-premise resources with few IT staff. These hidden champions are the backbone of Germany's market power. In numbers, they produced about 55% of the net value added in Germany in 2014 (IfM Bonn 2014).

However, hidden champions are often located in rural regions, which suffer from a lack of bandwidth capacity. Most German rural regions are connected to the internet with a maximum of 50 Mbit/s or even only 16 Mbit/s, while cities and urban areas deliver 100 Mbit/s or even fiber-optic connections (Telekom 2016). To overcome those restrictions, enterprises may have to consider upgrades of their dedicated network connectivity. In turn, these upgrades lead to rising public cloud computing costs (Rafique et al. 2011). To overcome this challenge over the next years, the German government has started an initiative to provide sufficient bandwidth in Germany, especially in rural regions, by the end of 2018 (Federal Ministry of Transport and Digital Infrastructure 2017). However, the promised 50 Mbit/s may still not be sufficient for most business needs, since they generally target private households.

Besides this current limitation, companies also have existing on-premise resources, which can be combined with scalable public cloud resources in a hybrid cloud. This concept enables the stepwise migration to public cloud without the need for a big bang solution. Thus, a hybrid cloud may constitute a desirable compromise solution (König 2014; Mell and Grance 2011). The trend towards hybrid cloud solutions is backed by the ongoing improvement of technical prerequisites such as OpenStack or Dasein Cloud, which enable *cloud bursting* (Wright et al. 2011) – the ability to shift the workload into the public cloud on an on-demand basis when the service client runs out of on-premise resources (Mell and Grance 2011). Cloud bursting refers to IaaS – specifically, we decide whether to use on-premise resources or public cloud resources. Cloud bursting promises to cut costs and to enable companies to improve their competitiveness. For readability, in line with Lilienthal (2013), we refer to *public cloud resources*.

The options for IT service provision have extended from building on-premise resources (buying) to renting cloud resources (leasing) (Kleeberg et al. 2014; König 2014). Most cloud resource optimization research deals with scheduling issues, such as Calheiros and Buyya; Keller and König 2014, 2014 (2012), Kailasam et al. (2010), Guo et al. (2014), and Li et al. (2012). Very few articles have considered the optimization of IT capacity while addressing a bursting strategy, such as Strebel and Stage (2010). Further, only a few approaches have dealt with the economic perspective of cloud busting. We particularly emphasize Lilienthal (2013), since he proposes a model that allows one to determine the cost-optimal size of on-premise resources by also considering fluctuating workloads.

However, by discussing Lilienthal’s (2013) initial model with industry experts, we identified the demand for a second research cycle in the sense of Meredith et al. (1989), since Lilienthal’s (2013) model does not consider bandwidth restrictions. We identify required adaptations for the situation of hidden champions in rural regions. We also adapt Lilienthal’s (2013) existing formal deductive model and derive hypotheses on influencing factors. Finally, we test our hypotheses in interviews with industry experts.

II.4.2. Related Literature

Cloud bursting contributes to the context of load-shifting in data centers. In short, load-shifting optimizes the workload shift between data centers for an objective such as cost savings (Li et al. 2012; Qureshi et al. 2009) or ecological goals (Fridgen et al. 2015a; Gmach et al. 2007).

There are two primary streams in shifting load in data centers to address fluctuating demand in regional data centers: *temporal* load-shifting and *spatial* load-shifting (Kong and Liu 2015). Kong and Liu (2015) provide a good overview on current work streams in the load balancing field. Considering spatial load-shifting, many papers have focused on cloud computing, which is grounded in the concept's basis of widespread data centers. For instance, Beloglazov and Buyya (2010) focus on shifting workload between cloud-scale data centers from the perspective of a provider. Since Keller and König (2014) observe a trend towards standardization in cloud computing, there is a growing potential for spatial load-shifting.

In contrast to the general load balancing scenarios between data centers with a general market perspective or a provider perspective, cloud bursting considers a hybrid cloud scenario, in which a company's on-premise IT resources are extended by public cloud resources (Lilienthal 2013). Exploring cloud bursting, several studies address different aspects, such as technical aspects (Cerbelaud et al. 2009; Vecchiola et al. 2011) or economic aspects (Lilienthal 2013; e.g., Mazhelis and Tyrväinen 2012). Lilienthal (2013) already provides an extensive literature review, describing the approaches for instance of Khajeh-Hosseini et al. (2010), Khajeh-Hosseini et al. (2012), Assunçao et al. (2009), Bibi et al. , or Strebel and Stage (2010). In his literature section, Lilienthal (2013) first deals with approaches that consider lease-or-buy decisions concerning public cloud computing, since the decision for cloud bursting relates closely to a classic lease-or-buy decision. However, summarizing his literature review, Lilienthal (2013) remarks that none of the analyzed authors "considers a mixed strategy (cloud bursting) or stochastic demand" (Lilienthal 2013, p. 72) that improves its real-world applicability; nor do most contributions focus on economic aspects. For a more detailed description of the aforementioned approaches, we refer to Lilienthal (2013).

Extending Lilienthal's (2013) literature review, Mazhelis and Tyrväinen (2012) address cost-minimal optimization of hybrid cloud infrastructure. They consider the costs of computing and data communication. They also consider the variable demand for resource capacity and declining unit prices of capacity with demand growth. Laatikainen et al. (2015) further include the interval at which a company reassesses its capacities and may acquire new resources into the sourcing decision. Qanbari et al. (2014) deals with option prices to reduce the risk of fluctuating resource demand for cloud computing. While Weintraub and Cohen (2017) further integrate cost, risk, and utility in a multi-objective optimization approach, they focus on the integration of different service providers, which is not our focus here.

Since Lilienthal's (2013) model generally provides the best extendibility of and fit with our research question, we build on this model.

II.4.3. Research Method

II.4.3.1. Research Approach

Following Meredith et al. (1989), "all research investigations involve a continuous, repetitive cycle of description, explanation, and testing" (Meredith et al. 1989, p. 301). The *description* phase documents and characterizes the subject of interest. The *explanation* phase can capture a situation's dynamics. In this phase, researchers should address "the underlying causal structure of the theory" (Meredith et al. 1989, p. 303) and can therefore generate testable hypotheses. Finally, the *testing* phase examines whether the derived hypotheses can be used to correctly predict the investigated phenomenon in reality. The gained insights can be used as a basis for the step-by-step improvement of explanatory theories as well as guidance to solve real-world problems (Meredith et al. 1989).

In line with Meredith et al. (1989), we start with a testing phase, which examines the applicability of the mathematical model developed by Lilienthal (2013) to the setting of hidden champions in rural regions (hereafter referred to as pre-testing). In the pre-testing, we critically discuss Lilienthal's (2013) approach by conducting six semi-structured, in-depth interviews with industry experts, in line with Myers and Newman (2007). We find that Lilienthal's (2013) model cannot be directly transferred to the situation of hidden champions in rural regions, since it omits bandwidth restrictions. Thus, in line with Meredith et al. (1989), we start a second cycle.

In the second research cycle, we conduct all three phases – description, explanation, and testing. In the description phase, we extend the existing model by parameters that ground on our newly developed insights from the interviews and adapt Lilienthal's (2013) setting, assumptions, and model. In the explanation phase, we analyze the newly added model parameters' effects on the model results. To achieve this, we conduct a Monte Carlo Simulation to examine the model behavior. In the testing phase (hereafter referred to as post-testing), we discuss the derived hypotheses in interviews with five industry experts since, according to Meredith et al. (1989), identified, deductive relationships must be critically tested.

II.4.3.2. Gaining Insights through Interviews

We critically discussed our findings in semi-structured interviews with six industry experts from six companies. We chose potential interview partners (i) from different industry sectors and (ii) based on years of experience in IT service provision to cover a wide and vast spectrum of knowledge. While two interviewees worked for IT service providers, the other four worked in the production and service sector and therefore represented IT service providers' customers. Each interviewee had experience with IT service provision for at least 8 up to 25 years. Each interview lasted approximately 1 to 2 hours and was audio-recorded. Owing to the industry experts' global dispersion, we conducted two interviews via telephone. However, according to long-established evidence, telephone interviews are as effective as face-to-face interviews (Rogers 1976), and we observed no shortcomings in the data collected for this project. Table II.4-1 provides an overview of the interview partners.

No.	Current position	Company	No. of years	Interview type	Pre-testing	Post-testing
I1	Principal IT Architect	Globally acting **IT service provider** with > 150,000 employees	12	Face-to-face	x	
I2	Senior Manager: Corporate Solutions	Globally acting automotive supplier with > 135,000 employees	25	Face-to-face	x	x
I3	Chief Executive	**IT service provider** for laboratory software with around 200 employees	23	Telephone	x	x
I4	Manager: Corporate IT	European energy network operator with around 3,000 employees	8	Face-to-face	x	x
I5	Director: Digital Business and Ecosystems	Globally acting technology company for optics and optoelectronics with around 25,000 employees	10	Face-to-face	x	x
I6	IT Manager	Global glass producer with around 3,000 employees	10	Telephone	x	x

Table II.4-1 Anonymized Overview of Interviews

As proposed by Myers and Newman (2007), we prepared a guide for the semi-structured interviews. In the pre-testing, we addressed the following topics:

- First, in line with Myers and Newman (2007), we introduced the general idea and the context of public cloud and cloud bursting.
- Second, we discussed the main application of cloud computing in that company.
- Third, we discussed the challenges of using public cloud resources for the company. We asked for the reasons to refrain from using public cloud resources as a major provision mode.

- Finally, we explicitly discussed Lilienthal’s (2013) major assumptions. We continuously added the newly gained insights from completed interviews to the subsequent interviews. Thus, as we always discussed the current state of the model with practitioners, we could exclude incorporating viewpoints that were not validated by all industry experts.

The interviews indicated a need for significant adaptions to Lilienthal’s (2013) model. We outline the required modifications in Section 4.3.

In the post-testing, in line with Meredith et al. (1989), we discussed hypotheses derived from the explanation phase with our interview partners:

- We put each hypothesis to the interview partner and asked them to interrogate it. We conducted this procedure with all hypotheses.
- After each interview, we discussed the feedback with other researchers and updated our discussion on the hypotheses.

II.4.4. Pre-testing

We will now first elaborate on Lilienthal’s (2013) model and will describe the pre-testing results, outlining the model’s application for hidden champions in rural regions and illustrating potential improvements.

II.4.4.1. Lilienthal’s Cost-optimization Model

Lilienthal (2013) proposed an approach that minimizes the costs of IT infrastructure on the basis of stochastic workload. Lilienthal (2013) considers the anticipated total costs of service provision per interval. In an ex ante decision, the company conducts investments in new IT resources at the beginning of the budget period. Changes in workload capacity are impossible within one investment period.

On-premise resources depict the internal capacity, which is subject to optimization, while the company can purchase public cloud resources on demand. In the concept of cloud bursting, public cloud resources are used whenever on-premise resources are insufficient. Lilienthal (2013) focuses on IT services that are burstable, are independent from each other, can technically be smoothly shifted between on-premise and public cloud, and are not subject to high latency requirements.

We will now briefly outline Lilienthal’s (2013) basic procedure. For further details, we refer to the original publication.

Lilienthal (2013) grounds his model on five major assumptions (A):

A1: Cloud bursting is technologically and managerially feasible.

A2: The model is based on the most critical underlying resource (e.g., CPU, storage, etc.), and internal and external resources only differ in price.

A3: The supply of public cloud resources is not limited. Since users don't need to fear shortfalls, demand does not depend on supply.

A4: Resources are continuously scaled.

A5: Applications or demand bursts can be horizontally scaled, which means that more resources of the same kind can be applied.

Based on these assumptions, Lilienthal (2013) builds a quantitative decision model based on workload and costs, described as follows:

Workload: Workload is the amount of necessary resources per time interval. The required resources are measured in resource units. Workload is modeled as a random variable and therefore has a stochastic distribution. The workload distribution is "the distribution of the amount of resources needed within one time interval" (Lilienthal 2013, p. 73). The exact distribution depends on the application or service. The amount of available on-premise resource capacity is provided by the company. It is a fixed value that is determined ex ante and is used as a decision variable in the optimization model.

Costs: The model distinguishes four cost types per interval. The total expected costs are the sum of the four cost components, which need to be minimized concerning the internal capacity. On the first level, he distinguishes between on-premise (internal) and public cloud (external) costs. Further, he introduces a distinction between *variable* and *fixed* costs. Fixed on-premise costs depend on the size of the on-premise capacity, but are independent of use. Variable on-premise costs are proportional to the use of on-premise capacity. The public cloud cost structure depends on the underlying tariff. Thus, it can include a fixed component (e.g., monthly fees) and variable costs for the use of each instance. Tariffs can also include a free consumption allowance, which is also displayed in the model.

Lilienthal's (2013) optimization objective is "minimizing the total expected costs as a function of internal capacity" (Lilienthal 2013, p. 74).

II.4.4.2. *Applying the Model to the Context of Hidden Champions in Rural Regions*

II.4.4.2.1. Main Application of Public Cloud Resources

To glean more information about the adoption of public cloud in the interviewees' companies, we briefly outline its recent use.

<u>Service providers</u>

I1 works for a service provider. He observes an increasing adoption of cloud computing for his clients. I1 describes the decline of cloud service prices and the easy calculation of the prevailed pay-per-use models as major drivers for cloud adoption. I3's company provides software as a service (SaaS) products based on three provision models: (1) public cloud provided by a hosting company, (2) public cloud provided by I3's company, and (3) on-premise resources provided by the customer.

<u>Service customers</u>

Until now, I2's company has only used few public cloud resources, since it has several data centers for administration and production facilities. I2's company plans to invest in several applications especially in the analytics field that use public cloud resources as a basis. I4's company cannot use public cloud resources for critical business processes, since in I4's industry, there are special regulatory requirements. I5 states that the use of public cloud resources as well as other cloud service models is prevalent for his company. I5's company also possess on-premise resources. It usually decides about the use of public cloud based on each individual use case. I5 also states that the flexibility of public cloud resources and the absence of high upfront investments are key aspects that must be considered. I6 states that they hardly use public cloud resources. Although I6's company recently outsourced its office and mail services to the public cloud, all other services are provided by its newly built on-premise data center.

II.4.4.2.2. Challenges to the Use of Public Cloud in Rural Regions

According to our interviews, there are three major challenges to the use of public cloud resources:

First, all interviewees (I1 to I6) mentioned data privacy and security issues as well as legal and regulatory concerns. I5 notes that a common understanding of public cloud computing is missing. Many people are scared off by the buzzword. According to our interviewees (especially I2, I4, and I5), traditional German companies usually are fairly conservative in their risk assessment. I2 notes that *"in Germany, we still have difficulties with risk assessment in the* *public cloud. Our American colleagues are more open to the topic. They discuss risk probabilities and risk amount, and compare them to the opportunities, for instance, cost savings, while we are deterred by the existence of risk."*

Second, I5 mentions that a lack of expertise in staff still keeps companies from shifting workload to the public cloud. Thus, it is important to train IT and business staff to make informed economic decisions.

Third, I1 strongly emphasizes the importance of considering bandwidth restrictions in rural regions. According to I1, a primary obstacle for the public cloud in rural regions is high investment costs for bandwidth extensions. I6 even highlights this restriction as the main reason for outsourcing few services to the cloud. I6's headquarters has only been connected to the internet via a single connection from 2014. Although I6's company profited from the German government's broadband expansion program, it still lacks sufficient bandwidth. The risk to outsource business critical services to the cloud is too high. Thus, I6's company built a new data center in 2013. I3 states that huge amounts of data need to be regularly transferred between the company's customers and the platforms it provides. Thus, a lack of bandwidth would considerably harm its business model.

I2, I4, and I5 did not initially mention bandwidth restrictions. Since I1 strongly emphasized the topic, we explicitly addressed bandwidth restrictions after the general discussion about challenges during the discussion of Lilienthal's (2013) model. I2 states that his company only faces bandwidth problems in isolated areas of Germany; he mentioned two major problems: (1) Bandwidth availability is very low in developing and emerging countries such as India and Kazakhstan; these branch offices cannot utilize public cloud resources. (2) Further, I2's company only uses public cloud resources for a small part of its service provision. If larger amounts would be outsourced to the public cloud, I2 expects a significant data traffic increase. I2 also sees problems for bandwidth availability in Germany. To increase bandwidth availability, I2 expects high investment costs. I4 reports his special situation, since network operators are usually equipped with fiber-optic networks added to the regular high-voltage power lines. Thus, I4's company only needs to span short distances to its service providers. Nonetheless, I4 recognizes bandwidth as a problem for companies without their own fiber-optic networks. I5 reported that the company does not currently have problems with bandwidth capacity since, in 2017, its headquarters, which is in a rural area, was equipped with a 1 Gbit/s internet connection. However, I5 also emphasizes bandwidth's relevance, especially for future smart connected products.

To conclude, I1, I3, and I6 were already experiencing bandwidth restrictions. I2, I4, and I5 highlighted the increasing importance of more flexible and more scalable solutions for infrastructure services. Thus, moving resources to the public cloud requires high bandwidth availability to enable data intense services.

II.4.4.2.3. Discussion of Setting and Assumptions

As a last step in the pre-testing, we introduced and discussed the setting and assumptions of Lilienthal's (2013) model. While the interviewees generally understood these, they noted six required adaptations.

Required adaptations for the setting:

1. Lilienthal (2013) built his model using a greenfield approach, in which companies don't have IT resources. Thus, he does not consider existing IT capacity. All interviewees (I1 to I6) agreed that especially hidden champions historically have existing on-premise resources. Most companies need to decide on capacity expansions (e.g., owing to business growth) or renewal (e.g., renewal of hardware, re-licensing of software). Since the infrastructure usually can still be used in parts, a model to calculate the minimum costs of resource provision should include existing on-premise capacity. Further, I3, I4, and I5 explicitly noted that their company needs to consider existing resources' operational lifetime.
2. Lilienthal (2013) incorporated different tariffs, including a basic charge with a free consumption allowance into his model. All interviewees (I1 to I6) agreed that tariffs, including a basic charge, are not common in current pricing models. I1 stated, in accordance with basic cloud literature (e.g., Armbrust et al. 2010; Mell and Grance 2011), that cost models of cloud providers generally follow the originally described pay-per-use model. I2 stated that *"In general, we face pay-per-use conditions."* Pay-per-use is additionally fostered by the occurrence of cloud spot pricing (Li et al. 2016).
3. Lilienthal (2013) does not consider economies of scale. The discussion with all interviewees (I1 to I6) confirmed the relevance of economies of scale for on-premise as well as for public cloud resources. According to I1, economies of scale can be achieved for large investments in on-premise resource; for instance, the IT staff does not grow linearly with investments in hardware. Further, economies of scale can be achieved for public cloud infrastructure regarding bandwidth upgrades. Construction costs for building a new Internet connection only partly depend on the extent of the upgrade.

4. Lilienthal (2013) considered internal costs under high utilization to be lower than external costs. All interviewees (I1 to I6) criticized this setting. During the past few years, the price of public cloud resources has declined. Tremendous economies of scale in huge data centers now enable public cloud providers to offer high-quality public cloud resources at low prices. Thus, especially for hidden champions, still having established employees in their IT department, the price of public cloud resources is lower than the internal costs for on-premise resources (Mohlameane and Ruxwana 2013). I1 stated that, *"no matter how efficiently your on-premise data center works, you will never be able to compete with the huge data farms of Amazon or other large players. Their economies of scale will always beat you."*

In discussion with our interview partners and other researchers, we extended our insights on latency issues for public cloud services. I2 stated that latency is only a key topic for special use cases. Bandwidth is usually the more critical component. Thus, in line with Lilienthal (2013), we did not consider highly latency-critical services, for reasons of simplicity.

Required adaptations for the assumptions:

1. A3: The supply of public cloud resources is not limited. Since users don't need to fear shortfalls, demand does not depend on supply.

   Lilienthal (2013) considers public cloud resources to be unlimited. However, as discussed with all interviewees (I1 to I6), bandwidth limits their availability and thus the supply of public cloud resources.
2. A4: Resources are continuously scaled.

   Lilienthal (2013) assumes that A4 holds true for on-premise as well as for public cloud infrastructure. All interviewees (I1 to I6) questioned this assumption. According to I1, public cloud resources are scalable on a fairly fine-grained level. However, according to all interviewees (I1 to I6), continuously scalable upgrades of on-premise resources are not feasible, owing to technical restrictions and the companies' specific upgrade policies. I1 mentioned that, depending on a company's size, the on-premise IT capacity is usually upgraded on the level of servers, racks, or entire clusters.

II.4.5. Second Research Cycle

This section describes the second research cycle, in line with Meredith et al. (1989), separated into description, explanation, and post-testing.

II.4.5.1. Description Phase

In the description phase, we first outline the required adjustments for the situation of hidden champions in rural regions. Second, we introduce the adjusted setting and assumptions. Third, we illustrate the adjusted decision model.

II.4.5.1.1. Required Adjustments

To transfer Lilienthal's (2013) model to the specific requirements of hidden champions in rural regions, we carved out adjustments grounded in our interviews with six industry experts. We will now outline the proposed adjustments (PA). To get a better overview, Table II.4-2 summarizes all model parameters used in the following sections.

Name	**Variable**	**Name**	**Variable**
workload per time measured in resource units requested per time	x	probability that the maximum workload is sufficient	α
stochastic variable for the workload per time x that follows a continuous distribution F	$\tilde{X}$	quantile for the maximum workload	q_α
number of building blocks for bandwidth	b	number of building blocks for on-premise resources	a
fixed costs for public cloud resources (external)	c_b	fixed costs for on-premise resources (internal)	c_a
variable costs per public cloud resource unit (external)	c_{ex}	variable costs per on-premise resource unit (internal)	c_{in}
existing bandwidth capacity	Cap_b	existing on-premise resource capacity	Cap_a
minimum bandwidth upgrade size	vol_b	minimum upgrade size for on-premise resources	vol_a
economies of scale for bandwidth	δ	economies of scale for on-premise resource capacity	γ

Table II.4-2 Overview of the Model Parameters

PA1: Bandwidth limitations

Our interviews indicated bandwidth limitations as a major challenge for hidden champions in rural regions. To overcome this restriction, the model needs to consider upgrades of on-site bandwidth. There are two primary network connection types: (a) via public internet and (b) via a dedicated network. Thus, the available bandwidth must be determined in terms of the existing bandwidth capacity of the public internet or the dedicated line, if available. Bandwidth can be measured by the amount of data that can be transmitted via a connection within a given time, for instance, bits per second.

We incorporate bandwidth into the model by defining $Cap_b \in \mathbb{R}_0^+$ as the existing network infrastructure mostly provided by the internet service provider, to the public cloud provider. In the context of this optimization model, we consider the number of public cloud instances that can be deployed simultaneously with the use of the prevailing network connectivity. Since we measure an IT service's workload against the workload of its most critical underlying resource, the bandwidth capacity must be transformed to the number of resource units one is able to deploy simultaneously with the use of the network line. Furthermore, we consider the costs for bandwidth extensions in the variable and the fixed costs for public cloud resources in the optimization model.

PA2: Existing on-premise IT capacity

Since all the industry experts agreed that hidden champions usually have on-premise resources, we include $Cap_a \in \mathbb{R}_0^+$ as the existing on-premise resource capacity. We measure Cap_a by the number of resource units that can be deployed from the on-premise resources per period. Downgrading on-premise resource capacity and leveraging with another deployment model is not an economically viable option owing to rapidly declining residual values (Dewan et al. 2007).

PA3: Scalability of on-premise and public cloud resources

As illustrated above, neither on-premise nor public cloud resources are perfectly scalable. Thus, we included the following two aspects in our model:

On-premise resources: A company must first define its minimum upgrade size for on-premise resources $vol_a \in \mathbb{R}_0^+$ (e.g., one rack or one server, depending on the data center's structure). Clusters of low-end servers are the preferred building blocks for on-premise data centers (Barroso et al. 2013). On this basis, companies can decide on the number of building blocks for on-premise resources $a \in \mathbb{N}^0$ that they need to fulfill capacity requirements. The concept of building blocks is intended to reflect the discrete nature of investments in on-premise resource capacity.

Public cloud resources: Although public cloud infrastructure is continuously scalable, bandwidth is not. From economic and technological perspectives, it is not reasonable to upgrade bandwidth connection by a very small amount, since the construction costs would be unreasonably high. Thus, the company must also determine the minimum bandwidth upgrade size $vol_b \in \mathbb{R}_0^+$ and must apply the number of building blocks for bandwidth $b \in \mathbb{N}^0$ to determine the amount of new bandwidth capacity. This amount strongly depends on contracts with bandwidth providers.

Thus, the total on-premise resource capacity for the budget period increases to $(Cap_a + a \cdot vol_a)$. Likewise, the total bandwidth capacity and therewith the total public cloud resource capacity increase to $(Cap_b + b \cdot vol_b)$.

PA4: Incorporation of maximum capacity

PA4 is a result of PA1 and is therefore strongly connected to it. Lilienthal (2013) assumes that the supply of public cloud resources is not limited. Although the general assumption that demand does not depend on supply still holds, the supply of public cloud resource capacity is restricted by bandwidth capacity. While Lilienthal (2013) assumes that no matter how high the workload becomes, it can always be served by public cloud resources. Considering that bandwidth is limited, there will be requests that cannot be served.

Since the workload is subject to fluctuation, which can result in extremely high workload peaks, companies need to determine a capacity that can be guaranteed. Accordingly, companies have to define a maximum workload (as quantile $q_\alpha \in \mathbb{R}_0^+$) with the probability $\alpha \in (0,1)$ for which the hybrid environment must ensure its processing (e.g., with a probability of 99.9%, the workload of 800 virtual clients can be processed). The higher α is, the better even improbable high workload peaks are covered by either the on-premise resource capacity or by the public cloud resources. However, more capacity must be provided, which in turn leads to higher costs.

PA5: Economies of scale

As discussed with the industry experts, we also included economies of scale for on-premise as well as for public cloud resources in the model.

On-premise resources: We transformed the linear scale of fixed costs for on-premise resource capacity used by Lilienthal (2013) into a logarithmic scale. Thus, we defined $\gamma \in (0,1)$ as an exponent of a. The lower γ is, the lower the marginal costs of additional resources are with increasing acquisitions.

Public cloud resources: Analogous to on-premise resources, we defined $\delta \in (0,1)$ as exponent of the number of building blocks for bandwidth b. The lower δ is, the lower the marginal costs of the bandwidth upgrade are with increasing size.

PA6: Dismissing basic charges for public cloud tariff structures

Since according to our industry experts, the pay-per-use model for public cloud resources has been established as a common standard, we excluded different tariffs from our model and only considered fixed and variable costs.

PA7: Extreme decline in prices for public cloud resources

Since one of the key changes concerning the public cloud computing market during the past few years is the extreme decline of prices of public cloud resources, in contrast to Lilienthal (2013), we considered current prices in our simulation.

II.4.5.1.2. Adjusted Setting and Assumptions

With the focus on hidden champions in rural regions, in comparison to Lilienthal (2013), the setting and assumptions of the decision model have changed. Comparing the assumptions of the adjusted model with Lilienthal's (2013) assumptions, the original assumptions A1, A2, and A5 don't require adjustments.

However, we can adjust assumptions A3 and A4 to more realistic assumptions:

A3*: The supply of public cloud resources is limited by the bandwidth capacity. However, besides their bandwidth limitations, and in line with Lilienthal (2013), users can benefit from unlimited public cloud resources.

A4*: Since on-premise and public cloud resources are not continuously scalable, we include customizable building blocks in our model.

II.4.5.1.3. Adjusted Decision Model

To measure IT services' required workload, we defined $x \in \mathbb{R}_0^+$ as the workload per period measured in resource units requested per period. The typical minimum lease time of on-demand public cloud resources is one hour (Amazon 2015). In line with this, workload may be measured in time intervals with a length of one hour.

An IT service's workload, and thus the workload of its most critical resource, may fluctuate heavily concerning the underlying IT service. Accordingly, we defined $\tilde{X}$ as the stochastic variable for the workload per period x that follows a continuous distribution F. The most suitable distribution function F must be determined based on real-world data, since it depends on an IT service's individual factors. Workload distributions generally differ for each case. Lilienthal (2013) proposes different methods to determine the correct distribution function. However, in line with Lilienthal (2013), we consider the workload per time $\tilde{X}$ to be independent and identically distributed (i.i.d.) with the distribution function $F(x)$. The model implies that workload is processed at its time of occurrence.

Since we have already included existing on-premise resource capacity, the total expected workload can be processed either by existing or by additional resources. Additional workload requires additional on-premise or public cloud resources. If existing resources are sufficient for processing the expected workload, no additional resources are required. Figure II.4-1 provides an overview of a workload distribution.

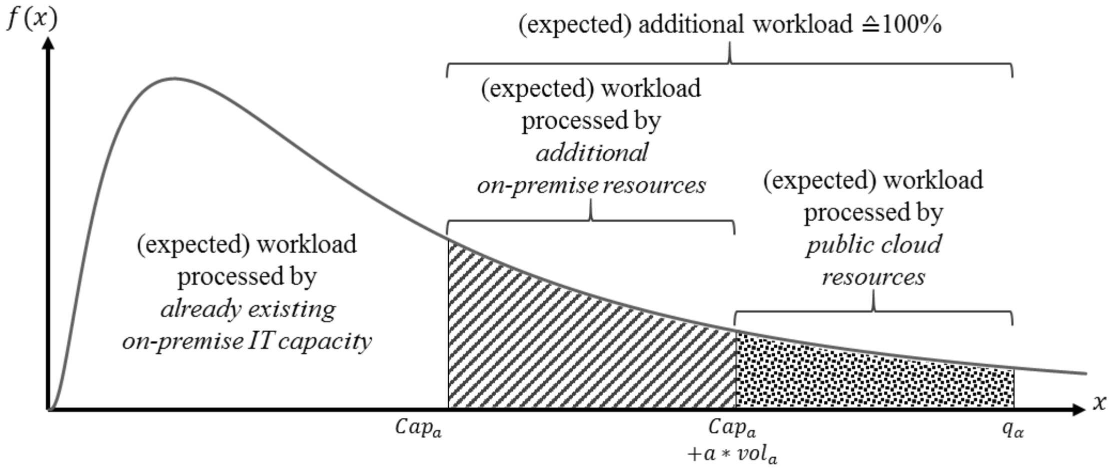

Figure II.4-1 Workload Distribution for On-premise and Public Cloud Resources

In line with Lilienthal (2013), the model's objective function depicts the expected costs of IT service provision per time interval (e.g., one hour) based on the number of building blocks for on-premise IT capacity a. The objective function must be minimized. The optimization for a time interval is equivalent to the optimization for the whole budget period, owing to the identical workload distribution and the constant cost rates. Analogous to Lilienthal (2013), we distinguish four cost types (fixed or variable costs, and on-premise or public cloud).

The *fixed costs (per period) of the on-premise resources* (*FOP*) depend on the number of building blocks for on-premise resources a considering economies of scale and therefore differ from the currently used resources. In line with Lilienthal (2013), these costs include one-time investments in hardware, software, facilities, etc. divided by their depreciation amount per period as a proxy for their lifetime. *FOP* also includes the workload-independent running costs of new acquisitions, such as personnel, energy costs at idle, etc., which we regard as a function of a. We defined $c_a \in \mathbb{R}_0^+$ as the fixed costs of on-premise IT incurred for one building block per period. Thus, we got the term for *FOP* as in Table II.4-3.

The *variable costs (per time) for on-premise resources* (*VOP*) are proportional to the de facto use of resources, for instance, for energy consumption beyond the data center's idle state. We defined $c_{in} \in \mathbb{R}_0^+$ as the variable costs of on-premise resources incurred for one resource unit per period. We multiplied c_{in} with the demand for internal resources up to a maximum of the available on-premise resource capacity $(Cap_a + a \cdot vol_a)$. If the workload demand exceeds the available on-premise resource capacity, the on-premise resources are fully utilized and the maximum amount of variable costs occurs $(c_{in} \cdot [(Cap_a + a \cdot vol_a) \cdot (1 - F(Cap_a + a \cdot vol_a)])$. Further, we subtracted the variable costs incurring for already existing capacity. After slight transformations, we got the term for *VOP* in Table II.4-3. (For the detailed formula, see Appendix II.)

The *fixed costs (per period) for public cloud resources* (*FPC*) depend on the number of building blocks for bandwidth b. In contrast to Lilienthal (2013), we don't consider fixed prices for public cloud resources, including free consumption allowance. However, fixed costs of public cloud resources are comprised of one-time investments in necessary construction works for new conduits divided by their lifetime (depreciation amount per period). Additionally, *FPC* includes workload-independent costs for bandwidth expenditures, which we likewise regard as a function of b. Thus, we define $c_b \in \mathbb{R}_0^+$ as the fixed costs of bandwidth for one building block per period. Further, we considered economies of scales analogously to the economies of scale for on-premise resources.

As noted above, we used the number of on-premise building blocks a as our decision variable. Depending on the chosen number of building blocks for on-premise resources a, the total bandwidth $(Cap_b + b \cdot vol_b)$ can serve the difference between the defined workload peak q_α and the total on-premise resource capacity $(Cap_a + a \cdot vol_a)$. The number of bandwidth building blocks b must be selected accordingly. Thus, the cost function is subject to the following condition. Concerning the objective of cost minimization, b is the next larger integer that fulfills the condition.

$$Cap_b + b \cdot vol_b \geq q_\alpha - (Cap_a + a \cdot vol_a) \qquad (1)$$

$$\Rightarrow b = \left\lceil \frac{q_\alpha - Cap_a - a \cdot vol_a - Cap_b}{vol_b} \right\rceil$$

Since b only accepts non-negative values, we needed to make a case distinction. Thus, we got the term *FPC* in Table II.4-3.

The *variable costs (per time) for public cloud resources* (*VPC*) comprise usage-proportional service fees as well as data transfer costs for bandwidth usage. We integrated both into the cost rate $c_{ex} \in \mathbb{R}_0^+$ for a deployed resource unit from the public cloud per period. To determine the expected deployment of public cloud resources, we considered the integral of the expected workload from the point that workload exceeds internal capacity $(Cap_a + a \cdot vol_a)$ up to the maximum workload (q_α). Thus, we got the term for *VPC* in Table II.4-3.

The overall resource provision costs can be calculated by the sum of the four costs components.

$$Costs(a) = FOP(a) + VOP(a) + FPC(a) + VPC(a) \qquad (2)$$

Table II.4-3 provides an overview of the cost components.

Costs	Calculation	
$FOP(a)$	$c_a \cdot a^\gamma$	
$VOP(a)$	$c_{in} \cdot \Big[\int_{Cap_a}^{Cap_a + a \cdot vol_a} x \cdot f(x)dx$ $+(Cap_a + a \cdot vol_a) \cdot \big(1 - F(Cap_a + a \cdot vol_a)\big) \cdot$ $-Cap_a \cdot \big(1 - F(Cap_a)\big)\Big]$	
$FPC(a)$	$c_b \cdot \left\lceil \frac{q_\alpha - Cap_a - a \cdot vol_a - Cap_b}{vol_b} \right\rceil^\delta$	if $q_\alpha > Cap_a + a \cdot vol_a + Cap_b$
	0	else
$VPC(a)$	$c_{ex} \cdot \int_{Cap_a + a \cdot vol_a}^{q_\alpha} \big(x - (Cap_a + a \cdot vol_a)\big) \cdot f(x)dx$	

Table II.4-3 Cost Components

For optimization, we minimized the objective function. The solution set for a is limited, owing to the characteristics of a. First, the investment in on-premise resources is limited to the maximum capacity q_α. Thus, we determined the maximum number of building blocks a by the amount at which the maximum workload can be processed with on-premise resources with the dedicated probability α. Second, owing to the indivisibility of building blocks and the inadmissibility of capacity disposals, a is a non-negative integer. Thus, we must solve the following integer non-linear programming problem.

min $\quad Costs(a)$

s.t. $\quad a \leq \left\lceil \frac{q_\alpha - Cap_a}{vol_a} \right\rceil$

and $\quad a \in \mathbb{N}^0$

The objective function contains at least two non-linear terms ($FOP(a)$ and $FPC(a)$) if γ and δ are different from 1. Depending on the specific density function $f(x)$, the terms $VOP(a)$ and $VPC(a)$ are likewise usually non-linear functions. Since the sum of these terms requires an integral solution, in contrast to Lilienthal (2013), we lack a computable analytical solution. This follows from the more realistic assumption of non-continuous scalability (A4). However, to provide a generally feasible method, we propose a complete enumeration with computerized support. Since the company only needs to compute the complete enumeration once per budget period, we consider this an acceptable method.

II.4.5.2. Explanation Phase

In the explanation phase, we analyzed the parameters and their effects on the model (Meredith et al. 1989). To contribute to existing knowledge, we illustrate the model's inherent mechanics by analyzing the model's sensitivity. We first describe the explanation setting and then conduct a sensitivity analysis so as to better understand how distinct parameters influence the model results. Based on the sensitivity analysis, we derive hypotheses grounded in the model behavior.

II.4.5.2.1. Explanation Setting

The computation of many calculations based on large datasets usually is distributed across multiple processing units (e.g., MapReduce and Hadoop frameworks). Thus, we consider this service to be suitable for cloud bursting. A company processing the computation of calculation services must make an ex ante decision on the available resources required to provide the service for the next budget period. Since the calculation of large datasets is a CPU-intensive service, we consider CPU as the most critical resource. Depending on the company's size and its specific IT policy, the on-premise resource capacity can be upgraded on the level of racks. For our evaluation, we examined the allocation of additional workload to on-premise and public cloud resources.

II.4.5.2.2. Sensitivity Analysis

Based on this setting, we conducted a ceteris paribus sensitivity analysis for all parameters. Lacking real-world data on the range of our parameters, we needed to create scenarios, assuming realistic distributions for our input parameters. Thus, we followed a two-step approach. On the one hand, we searched for reliable sources that underpin the data ranges. On the other hand, we double checked the data ranges with industry expert I1, who gave us valuable insights into the realities of a service provider.

In a first step, we applied a Monte Carlo Simulation for a basic scenario with 10,000 randomly generated decision scenarios for resource provision. Based on the basic scenarios, we conducted our ceteris paribus sensitivity analysis. The simulation results indicate that the average results for 500 and 10,000 simulations barely differ. Thus, for our further analysis, we considered 500 iterations to represent a legitimate procedure. To conduct the sensitivity analysis, we generated comparative scenarios by varying the input parameters ceteris paribus by +25%, +10%, -10%, and -25%.

We set the range for the expected workload and the expected deviation of the workload to a wide interval. Considering bandwidth, Integra Telecom (2015) offers bandwidth options from 1.5 Mbit/s to 10 Gbit/s. The volume of data that can be transmitted per deployed cloud instance and per period varies from case to case. Thus, we assumed a broad range for the capacity of an extra bandwidth building block. For the variable costs of public cloud computing, we referred to current price quotes of comparable Amazon (2015) and Microsoft (2015) instances. As depicted in previous sections, one-time costs for construction works and fixed network charges per period vary. Thus, we set a broad range for the hourly costs based on I1's cost estimates. The same applied to the economies of scale of bandwidth upgrades, where the company can achieve significant cost benefits with increasing number of building blocks – even at a greater scale than for on-premise IT capacity. Finally, the probability that the maximum workload suffices ranges from 99.671% to 99.995%.

Considering the usage case illustrated above, we used the input data depicted in Table II.4-4.

Workload distribution: $\tilde{X} \sim \text{lognorm}(\mu, \sigma^2)$			
Parameter	**Range** (equally distributed)	**Parameter**	**Range** (equally distributed)
μ	1 to 100,000	Cap_a	0% to 100% of q_α
σ	0% to 50% of $E(\tilde{X})$	vol_a	10 to 100
c_a	10 to 100	vol_b	100 to 10,000
c_b	10 to 500	α	0.99671 to 0.99995
c_{ex}	0.01 to 5	γ	0.75 to 1
c_{in}	0.01 to 0.1	δ	0.5 to 1
Cap_b	0% to 100% of $(q_\alpha - Cap_a)$		

Table II.4-4 Simulation Parameters

II.4.5.2.3. Findings and Hypotheses

To derive the following hypothesizes, we analyzed the sensitivity analysis results. We calculated the average share of public cloud resources measured against the overall additional workload for each basic and comparative scenario. We used a paired-samples t-test to determine whether there is a statistically significant mean difference between the adjoining scenarios (we tested each scenario against the basic scenario). Appendix I contains a table with the aggregated results. The simulation indicates which circumstances may lead to which bursting decision.

Later, we derived nine hypotheses grounded in our observations of the model's behavior. Notably, the hypotheses' formulations were critically discussed in the post-testing interviews, in line with Meredith et al. (1989). Since we only made minor changes to formulations, we present the final hypotheses here.

1. With a higher expected workload per period μ, we observed a growing workload quota that is burst to the public cloud. The coherence is almost linear, but quite low. Owing to this coherence, we concluded that companies with a high expected workload should have relatively more external resources available than companies with a low expected workload.

Hypothesis 1: Companies with a high expected workload tend to burst more workload to the public cloud.

2. σ describes the workload fluctuation. Since the model assumes that workload is not static but changes during the period under consideration, we expected a significant influence of the standard deviation of workload on the model. Observing the data, a higher standard deviation increases the workload quota that is burst to the public cloud.

   Hypothesis 2: The more volatile the workload is, the more a company bursts to the public cloud.

3. Both fixed-cost variables have a significant influence on the model's behavior. While the fixed costs for on-premise resources c_a have a positive relationship with bursting to the cloud, the fixed costs for public cloud resources c_b act in the opposite way. However, the fixed costs for on-premise resources have a stronger impact on the workload quota that is burst to the cloud. Thus, if fixed costs for on-premise resources rise, it is more attractive to burst workload to the public cloud. If the fixed costs for public cloud resources (mainly bandwidth costs) rise, it is less attractive to burst workload to the public cloud. However, the fixed costs for public cloud resources act over-proportionally. Thus, very high fixed costs for public cloud resources have a stronger impact on the decision than relatively low fixed costs for public cloud resources.

   Hypothesis 3: Fixed costs for public cloud resources and for on-premise resources strongly influence the bursting decision.

   Hypothesis 3a: The influence of required bandwidth expansions is stronger than the influence of fixed costs for on-premise resources.

   Hypothesis 3b: The higher the fixed costs for public cloud resources are, the lower the quota of workload is that is burst to the public cloud.

4. While variable costs for on-premise resources c_{in} hardly influence the decision, the simulation indicates that variable costs for public cloud resources c_{ex} negatively impact the workload quota that is burst to the public cloud. The higher the variable costs for public cloud resources are, the more on-premise resources are required.

   Hypothesis 4a: The higher the variable costs for public cloud resources are, the lower the quota of workload is that is burst to the public cloud.

   Hypothesis 4b: The influence of variable costs is weaker than the influence of fixed costs.

5. The model's behavior was also influenced by the minimum size of upgrades. While the minimum bandwidth upgrade size vol_b is not significant, the minimum upgrade size for on-premise resources vol_a significantly influences the model. Thus, the larger the building

blocks for on-premise resources are, the lower the workload quota is that is burst to the public cloud. At first glance, this seems to be counter-intuitive. However, as large capacities are bought, there is a higher probability, that the bought capacity can address small fluctuations in workload.

Hypothesis 5: The larger the building blocks for on-premise resources are, the lower the workload quota is that is burst to the public cloud.

6. If a company decides to increase the probability that the maximum workload is sufficient α (management decision), the workload quota that is burst to the public cloud also rises. In the model, we used public cloud resources to address unexpected workload increases. Thus, the influence of a small increase in α is smaller than the influence of a large increase.

   Hypothesis 6: The higher the probability that the maximum workload is sufficient, the higher the workload quota is that is burst to the public cloud.

7. If high economies of scale for on-premise resource capacity γ can be realized (low γ), the on-premise resources can be provided for a low price. Thus, fewer public cloud resources are required. The economies of scale for bandwidth δ create an effect that acts reversely. However, the economies of scale for on-premise resource capacity have a stronger influence than the economies of scale for bandwidth.

   Hypothesis 7: The higher the economies of scale for on-premise resource capacity are, the lower the workload quota that is burst to the public cloud.

8. Existing bandwidth capacity Cap_b has a strong impact on the bursting decision. Sufficient existing bandwidth strongly indicates more consumption of public cloud resources, while low existing bandwidth hinders its provision. This is favored by high costs for expanding the bandwidth over a certain amount.

   Hypothesis 8: The lower the existing bandwidth capacity is, the lower the workload quota is that is burst to the public cloud.

9. The extent of existing on-premise resource capacity Cap_a is the variable with the strongest impact on the decision, based on the t-tests. This is clear, since in the case of sufficient on-premise resources, companies have no need to buy further resources. However, if on-premise resources are limited, there is a high probability (depending on bandwidth capacity) that companies will buy cheap public cloud resources.

   Hypothesis 9: The higher the extent of existing on-premise capacity is, the lower the workload quota is that is burst to the public cloud.

II.4.5.3. Post-testing

After deriving the hypotheses from the key findings of the simulation, we discussed them with five of the six industry experts (I2 to I6). To enhance our findings' quality, we followed Myers and Newman's (2007) interview guidelines. Table II.4-5 summarizes our results.

Hypotheses	Industry expert feedback
1	All interviewees confirmed H1. Especially I4 emphasized that, for CPU-intensive operations, the workload has a significant impact on the bursting decision.
2	All interviewees confirmed H2. Since companies face the challenge to lower their costs, they must find solutions for high volatility. I5 underlined the importance of volatility for the bursting decision.
3	All interviewees confirmed the general hypothesis H3.
3a	All interviewees confirmed H3a. I3 reported that his company is currently switching to fiber-optic networks, which is causing very high expenses.
3b	All interviewees generally confirmed H3b. I4 added intensity of use for consideration. Thus, bursting decisions must be reached based on the single use case. Public cloud computing can usually be provided at a lower price. Thus, rising fixed costs for public cloud computing strongly influence the decision. I4 stated: *"The costs for different alternatives always influence the final decision. I think that public cloud computing really is an alternative that needs to be considered."*
4a	All interviewees confirmed H4a. I4 thought the hypothesis especially valid for high load peaks.
4b	All interviewees confirmed H4b.
5	All interviewees confirmed H5. I2 stated: *"This definitely is an important topic for us. We have quite large building blocks for on-premise resources that we need to invest in if we want to enlarge our data center. If we only need a little more capacity, we wouldn't build a new data center."*
6	All interviewees confirmed H6.

7	I2 to I6 confirmed H7. I4 added that economies of scale play a key role. If internal economies of scale are high, the price difference decreases. However, especially hidden champions are challenged by the security and safety requirements. *"To compete with large data centers, millions of euros need to be invested to reach the same security and safety requirements."*
8	All interviewees confirmed H8. I6 emphasized that the costs for bandwidth expansion strongly depend on location.
9	All interviewees generally confirmed H9. I2 experienced that his colleagues tend to hold on to established concepts they already know. However, the decision strongly depends on investment cycles (I3 to I5). Since resources need to be regularly renewed, this hypothesis only holds true for the resources that don't need to be replaced within the investment period. If large parts of the existing resources must be renewed, companies should be open to discuss the bursting alternative. However, I2, I4, and I5 stated that the transformation processes from on-premise to public cloud must be ensured.

Table II.4-5 Discussion of Hypotheses

II.4.6. Conclusion, Limitations, and Outlook

Many companies are at a crossroads and face the decision about whether to expand on-premise resources or move certain workloads to the public cloud. Thus, many IT departments are developing strategies to shift workload to the public cloud. Hybrid clouds enable for instance load balancing for workloads that can technically be smoothly shifted between two sites in terms of cloud bursting. Lilienthal (2013) developed a model that enables the determination of a cost-optimal resource allocation. We discussed Lilienthal's (2013) model in a pre-testing phase with six industry experts focusing on the special requirements of hidden champions in rural regions. Our interviews indicated that hidden champions face an additional challenge of insufficient bandwidth capacity. Thus, we identified the need for a second research cycle, according to Meredith et al. (1989).

The second research cycle incorporated the special requirements of hidden champions in the existing model and explained the model behavior for that context. In the description phase, we adjusted the setting, assumptions, and the model in line with the pre-testing results. In the explanation phase, our sensitivity analysis indicated that bandwidth availability plays a key role in the investment decision. Further, economies of scale and discrete decision variables regarding building blocks impact on the decision. Finally, the incorporation of existing on-premise resources also impact on the bursting decision. In our model, the demand may never surpass the on-premise resource capacity; thus, no need for bursting exists. If hidden champions used Lilienthal (2013)'s model, they may take wrong decisions, since Lilienthal (2013) did not consider all these aspects. According to our interviewees, depending on the availability of bandwidth, high additional costs can occur. For example, if a company with low available bandwidth used Lilienthal (2013)'s model for decision making, it would not consider additional costs up to several thousands of euro for bandwidth extensions. If this money has to be invested additionally, the total costs of the bursting decision substantially rise.

In the interviews of the testing phase, I6 brought up another interesting point: On-premise IT vendors have realized the threat of public cloud's pay-per-use model. Thus, some providers have also begun to improve the flexibility of their provision model. Nowadays, companies can rent servers for their on-premise infrastructure for a short timespan, for instance, one or two weeks. This development enables companies with existing data centers to improve their medium-term on-premise provision.

To improve general applicability, future research may turn to interviews with large, global players and may identify new aspects. Further, the practical applicability could be tested by applying the model in real-world settings (e.g., by conducting case studies). This may provide a deeper understanding of the model behavior and may further validate our hypotheses. In addition, in line with Weintraub and Cohen (2017), future research may distinguish between specialized providers.

Overall, we contribute to the research on the economic perspective of load-shifting in data centers. We have increased the general applicability of an existing research model. The hypotheses contribute to a deeper understanding of sourcing decisions and load-shifting in rural regions. Researchers can build on those results to transform and develop their models accordingly. Practitioners can use our results to improve their basic understanding of bursting decisions and may use the insights to develop guidelines for advanced decision support systems.

II.4.7. Appendix

Appendix I: Sensitivity Analysis

Table II.4-6 illustrates the various input parameters (column 1) that are varied to generate the comparative scenarios (column 2). Column 3 lists the average share of public cloud resources measured against the overall additional workload $\overline{s_{ex}}$ for each basic and comparative scenario. The average share of additional on-premise IT capacity measured against the overall additional workload $\overline{s_{in}}$ can be calculated on this basis ($\overline{s_{in}} = (1 - \overline{s_{ex}})$). We used a paired-samples t-test to determine whether there is a statistically significant mean difference between the $\overline{s_{ex}}$ of adjoining scenarios (we tested each scenario against the basis scenario).

	Variation	$\overline{s_{ex}}$	Significance		Variation	$\overline{s_{ex}}$	Significance
	+25%	32.98%	* (p=0.0433)		+25%	43.17%	*** (p=0.0001)
	+10%	32.47%	– (p=0.1506)		+10%	35.02%	*** (p=0.0001)
$E(\tilde{X})$	Basis	32.08%		Cap_a in % of q_α	Basis	30.90%	
	-10%	31.82%	– (p=0.3572)		-10%	27.67%	*** (p=0.0001)
	-25%	30.94%	** (p=0.0081)		-25%	22.48%	*** (p=0.0001)
	+25%	35.38%	*** (p=0.0001		+25%	28.98%	*** (p=0.0001)
	+10%	33.31%	*** (p=0.0001)		+10%	31.04%	*** (p=0.0007)
$SD(\tilde{X})$ in % of $E(\tilde{X})$	Basis	32.08%		vol_a	Basis	32.08%	
	-10%	30.71%	*** (p=0.0001)		-10%	33.90%	*** (p=0.0001)
	-25%	27.73%	*** (p=0.0001)		-25%	37.08%	*** (p=0.0001)
	+25%	36.36%	*** (p=0.0001)		+25%	32.86%	– (p=0.0624)
	+10%	33.99%	*** (p=0.0001)		+10%	32.35%	– (p=0.3606)
c_a	Basis	32.08%		vol_b	Basis	32.08%	
	-10%	30.30%	*** (p=0.0001)		-10%	31.54%	– (p=0.0616)
	-25%	27.47%	*** (p=0.0001)		-25%	30.63%	*** (p=0.0003)
	+25%	30.69%	*** (p=0.0006		+0.0813%	33.15%	*** (p=0.0001)
	+10%	31.45%	* (p=0.0232)		+0.0325%	32.16%	* (p=0.0300)
c_b	Basis	32.08%		α	Basis	31.55%	
	-10%	33.26%	** (p=0.0031)		-0.0325%	31.12%	– (p=0.0967)
	-25%	34.88%	*** (p=0.0001)		-0.0813%	30.58%	** (p=0.0035)
c_{ex}	+25%	30.23%	*** (p=0.0001)	γ	+6.25%	35.90%	*** (p=0.0001)
	+10%	31.39%	*** (p=0.0006)		+2.5%	32.15%	*** (p=0.0001)

	Basis	32.08%			Basis	30.27%	
	-10%	33.10%	*** (p=0.0005)		-2.5%	28.22%	*** (p=0.0001)
	-25%	34.61%	*** (p=0.0001)		-6.25%	24.73%	*** (p=0.0001)
	+25%	32.10%	*** (p=0.0011)		+12.5%	30.99%	*** (p=0.0005)
	+10%	32.09%	** (p=0.0032)		+5%	31.58%	*** (p=0.0005)
c_{in}	Basis	32.08%		δ	Basis	31.94%	
	-10%	32.08%	** (p=0.0035)		-5%	32.31%	– (p=0.0604)
	-25%	32.06%	*** (p=0.0003)		-12.5%	32.78%	** (p=0.0036)
	+25%	22.72%	*** (p=0.0001)				
	+10%	21.13%	*** (p=0.0001)				
Cap_b in % of q_α	Basis	19.89%		-: $\overline{s_{ex}}$ is not significantly different *: $\overline{s_{ex}}$ is different with a significance at the 0.05 level (two-tailed) **: $\overline{s_{ex}}$ is different with a significance at the 0.01 level (two-tailed) ***: $\overline{s_{ex}}$ is different with a significance at the 0.0005 level (two-tailed)			
	-10%	18.70%	*** (p=0.0001)				
	-25%	17.98%	*** (p=0.0001)				

Table II.4-6 Overview of the Sensitivity Analysis

Appendix II: Detailed Formula for VOP

(1)

$$c_{in} \cdot \int_0^{Cap_a + a \cdot vol_a} x \cdot f(x) dx$$
$$+ c_{in} \cdot (Cap_a + a \cdot vol_a) \cdot \left(1 - F(Cap_a + a \cdot vol_a)\right)$$

(2)

$$c_{in} \cdot \int_0^{Cap_a} x \cdot f(x) dx + c_{in} \cdot Cap_a \cdot \left(1 - F(Cap_a)\right)$$

(1) – (2) = (3)

(3)

$$VOP = c_{in} \cdot \left[\int_{Cap_a}^{Cap_a + a \cdot vol_a} x \cdot f(x) dx + (Cap_a + a \cdot vol_a) \cdot \left(1 - F(Cap_a + a \cdot vol_a)\right) - Cap_a \cdot \left(1 - F(Cap_a)\right)\right]$$

III. Ex Nunc Steering of a Project: Manage your Blind Flight – The Optimal Timing for IT Project Re-Evaluation [1]

This chapter gives an outlook on the ex nunc project steering of a project. It includes only one paper: P5 "*Manage your Blind Flight – The Optimal Timing for IT Project Re-Evaluation*", as described below.

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Abstract: As the value of an IT project can change over time, management is in blind flight about the state of the project until the project has been re-evaluated. As each evaluation causes costs, continuous evaluation is economically unreasonable. Nevertheless, the blind flight should not take too long, because the project value can considerably deviate from its initial estimation and high losses can occur. To trade off costs of re-evaluation and potential loss of project value, this paper will elaborate upon an economic model that is able to determine the optimal time until re-evaluation considering the risky cash flows of a project. Based on a simulation, we find that it makes good economic sense to optimize the interval of re-evaluation. Therefore, companies are able to avoid financial loss caused by evaluating too early as well as hazarding project value caused by evaluating too late.

Keywords: IT project evaluation, risky cash flows, re-evaluation interval.

[1] The doctoral thesis includes a slightly improved version of the research paper published in the Proceedings of the 12th Internationale Tagung Wirtschaftsinformatik (WI) in 2015. However, there were no major adjustments that change the aim and findings of the research paper.

III.1. Introduction

According to a study from the University of Oxford, one out of six IT projects turns out to exceed the planned cost by 200%, and the planned time by 70% (Flyvbjerg and Budzier 2011). The failure of IT projects with high initial investment and huge cost overrun usually do not only force top managers to resign, but can also cause devastating problems or even business failure to a company (Flyvbjerg and Budzier 2011). Management should therefore aim at avoiding project failure by devising capable project management means.

In today's management processes, usually IT projects are only evaluated monetarily before the project start in an effort to decide about investment alternatives. Possible changes affecting the project's cash flows are often not considered. As the project's cash flows are influenced by a dynamic environment, the cash flows are risky and the project value can change over time. If no re-evaluation is conducted later on, the initial evaluation is followed by a blind flight, during which management does not know about the current state of the project (Buhl 2012). During this blind flight, possible changes within a project or in the project's environment can cause major problems without being recognized. Therefore, a high deviation of the project value from its planned value can occur, resulting in high losses. If the blind flight continues, the possible deviation of the initially estimated value increases, as does the potential loss. To consider the changing circumstances and requirements that influence the risky cash flows of a project, and thus to recognize changes and problems earlier, management should re-evaluate an IT project during its runtime from a risky cash flow-based point of view (Remenyi and Sherwood-Smith 1999).

From this perspective, one might conclude that management should continuously evaluate an IT project without accepting any blind flight. But as each re-evaluation consumes time and money, it is economically unreasonable to continuously evaluate a project. Management should accept a certain blind flight phase to conserve the financial resources of a company. But the blind flight phase should be limited. If it is not, the project value can deviate significantly from its initial estimation and the project's value gets out of control. Thus, management faces a trade-off between financial loss caused by evaluating too early and hazarded project value caused by evaluating too late.

Existing frameworks usually do not take into account the risky cash flow-based project value in order to determine the point in time for re-evaluation. Therefore, the monetary development of the project is not considered by these procedures, and the project cannot be evaluated according to value-oriented principles. Therefore, the optimal time until re-evaluation from an economic point of view should be determined. In this point in time, there is a balance between financial loss caused by evaluating too early and hazarded project value caused by evaluating too late.

To generate further insights, the aim of this contribution is to develop a formal-deductive economic model to provide an understanding of the importance of determining the optimal time until re-evaluation in IT project management. Therefore, we extend existing IT project management methods by considering risky cash flows for the optimization of the re-evaluation interval. To the best of our knowledge, there are no scientific papers addressing this question, yet.

Following a brief review of the essential literature, we develop an economic model that allows for a quantitative determination of the optimal time until re-evaluation subject to simplifying assumptions. Furthermore, we show that a better decision regarding the point in time of re-evaluation can be achieved by using the model. To conclude we summarize our results and address practical implications, and limitations, as well as possible areas of future research.

III.2. Literature Overview

An IT project should be managed as efficiently as possible (Project Management Institute 2008). For this purpose, it is monitored and controlled, and the value of the IT project is determined (Walter and Spitta 2004). Willcocks (1994) defines project evaluation as "establishing, by quantitative and/or qualitative means, the worth of IS to the organization". Generally, there are several main objectives of evaluation. First, if projects are evaluated before the project start, multiple projects can be compared, and the organization can choose the most beneficial one (Gunasekaran et al. 2006). Second, evaluation enables controlling and management of an IT project. Performance and the deviation from the planned project value can be regularly observed, allowing management to consider corrective actions early on in the project (Project Management Institute 2008). Thus, the effective utilization of the organization's financial resources can be ensured, and good returns can be achieved. Third, by comparing ex post achieved results to ex ante planned values, the company is able to analyze mistakes as well as achievements, and can thus apply this information to future projects (Buhl 2012; Farbey et al. 1992, 1999; Remenyi and Sherwood-Smith 1999).

To implement these objectives, literature offers a wide range of evaluation methods. According to Beer et al. (2013) an integrated method for evaluation that considers costs, benefits, risks and interdependencies should be used. In order to consider those factors monetarily, Beer et al.

(2013) developed a practically applicable, integrated approach which focuses exclusively on point in time evaluation. However, Beer et al. (2013) state that an integrated method for evaluation should comprise the entire lifecycle of an IT project. Thus, an IT project should be evaluated before it starts (ex ante), during its runtime (ex nunc) and after it ends (ex post) (Irani 2010).

Ex ante and ex post evaluation alone might not be sufficient for successful IT project management because they do not consider possible changes during the course of a project (Remenyi and Sherwood-Smith 1999). As changes in a project's environment can unfavorably affect its successful completion (Ewusi-Mensah and Przasnyski 1991), they should be managed (Kappelman et al. 2006). Without proper controlling and management of those changes, an IT project can be subject to failure, or may have to be abandoned (Ewusi-Mensah and Przasnyski 1991). Since each re-evaluation provides additional information, re-evaluation during the course of a project is increasingly considered an opportunity to reduce causes of failure and might thus improve decision-making (Eveleens and Verhoef 2009; Remenyi and Sherwood-Smith 1999). Being aware of the current state of a project, a project manager has a chance to successfully turn around, or sensibly abandon an IT project (Montealegre and Keil 2000). Furthermore, early warning signs that indicate problems can be identified long before project failure. Thus, the deviation of the project value can be detected early, and management can then decide more quickly whether and which corrective actions they want to take (Ewusi-Mensah and Przasnyski 1991; Kappelman et al. 2006). In contrast, if the project is not monitored over time, management is oblivious to the project's state. To prevent this, IT project evaluation over time is required (Beynon-Davies et al. 2004; Irani 2010; Lanzinner et al. 2008; Remenyi and Sherwood-Smith 1999).

In practice, evaluation is usually conducted by a detailed cost valuation while risks, interdependencies and benefits are oftentimes neglected (Buhl 2012). Furthermore, formal evaluation methods are rarely used by practitioners. One of the major reasons is that the practical application of formal methods is difficult. The identification and quantification of relevant costs and benefits of an IT project are especially challenging tasks (Alshawi et al. 2003; Beer et al. 2013; Seddon et al. 2002). Thus, organizations may consider such evaluations to be difficult and costly, and may thus refrain from implementation (Lin and Pervan 2001). Another reason may be that managers do not understand the importance and economic potential of the evaluation (Remenyi et al. 2007). Furthermore, lack of time, management support and organizational structure can hinder formal evaluation (Ballantine et al. 1996). Another problem might be that formal evaluation methods oftentimes focus solely on ex ante situations and do not make a statement about at what point in time management should re-evaluate an IT project. A missing understanding about when to evaluate an IT project appears to be a central issue for managers (Irani 2010; Remenyi and Sherwood-Smith 1999). In literature few statements about the point in time of re-evaluation can be found. If addressed at all, predetermined review intervals are suggested (Ewusi-Mensah and Przasnyski 1991; Keil 1995).

Most procedures like for example PRINCE2 do not regard the cash flow-based value of an IT project. Thus, the risk that the initial project value changes over time and that losses due to too early or too late re-evaluation may occur is not addressed. The longer a project is not re-evaluated the higher the probability that the project value will deviate substantially from its initial value. This deviation influences the project performance as costs and low returns might occur. To take these consequences into account, risky cash flows should be considered.

The procedures of literature and practice mentioned above might not be in line with value-oriented principles, because they do not monitor the value contribution of a project. They deliver a point in time for re-evaluation that does not regard the development and the risk exposure of the project during its runtime. Thus, the project might either be re-evaluated too early, when the project value did not essentially deviate from its initial value, or too late, when the project value already strongly deviated from the initial estimation. On the one hand, the project might be re-evaluated at a point in time where the probability that the project value considerably changed is low. Thus, re-evaluation might not have been necessary from a cash flow-based perspective. Since re-evaluation utilizes money and time, each re-evaluation consumes value. If the project is re-evaluated too early, the company’s resources are unnecessarily spent. Thus, it is economically reasonable to accept a certain blind flight phase to hold down the costs of re-evaluation. On the other hand, if the IT project is re-evaluated too late, the blind flight phase may continue too long and major issues that might appear during the blind flight may be discovered too late. Thus, the project value can considerably deviate from its initial estimation without being recognized, and management cannot take corrective actions. In this case, management hazards project value and high losses may occur. Since both too early and too late re-evaluation could potentially consume value, we admit that the establishment of a predetermined review interval that does not regard the risky cash flows of an IT project might not be a reasonable approach. Therefore, we want to extend project evaluation by considering the risky cash flows that picture the deviation of the project value from its initial estimation. Thus, we determine the optimal time until re-evaluation that ensures that the project is neither re-evaluated too early nor too late. For this purpose the following research question is discussed in this article:

Research Question: *What is the optimal time until re-evaluation for an IT project based on risky cash flows?*

III.3. Determination of the Optimal Time until Re-Evaluation

As a first step to answer this research question, we provide an economic model that is able to determine the optimal time until re-evaluation of an IT project for one period, considering risky cash flows. It enables the determination of how long the blind flight is acceptable until the next re-evaluation is necessary.

III.3.1. Setting

IT projects are executed in a dynamic environment. Thus, their value can change over time. On the one hand, anticipated changes of an IT project's circumstances occur during its runtime. Thus, the company knows that the project value can deviate from its initial estimation. However, the company does neither know how circumstances vary, nor which impact the changing circumstances might have on the IT project. On the other hand, highly unlikely and completely unexpected events with a possible impact on the IT project can arise, such as natural or economic disasters. The company is not able to anticipate these kinds of events. As completely unexpected events require different treatment than anticipated changes, we only consider anticipated changes, while very unlikely and completely unexpected events are excluded from contemplation. If an unforeseen event occurs, a non-scheduled re-evaluation becomes necessary.

In the following section, we focus on a situation in which a company wishes to determine the optimal time until re-evaluation for a given IT project, considering anticipated changes. Therefore, we determine the time interval during which the project value is unlikely to undercut a threshold that is defined by management.

To determine the monetary project value, different approaches like Earned Value Management Method (Anbari 2004), Net Present Value (NPV) (Fridgen and Müller 2009; Zimmermann et al. 2008) or the Real Options Theory (Ullrich 2013) can be taken into account. As the NPV is oftentimes used in practice and literature, in the following we use the expected NPV.

By considering cash flows, the project's NPV discounted to project start can be calculated. They contain estimated payouts and incomes that can occur during the entire course of the IT project. As all past and future cash flows are taken into account, the NPV refers to the entire project progression, and the deviation of the actual project value from the planned value can be observed. By using the NPV, the project value stays comparable during its entire runtime, and thus performance can be measured monetarily. As the project value especially of very long and complicated projects is influenced by a variety of different factors, the cash flows are uncertain. Figure III.3-1 illustrates four possible sample paths of the project's NPV that changes over time (NPV(t)). Starting from the NPV at a certain point in time, the value can follow any of the given, or any other sample path.

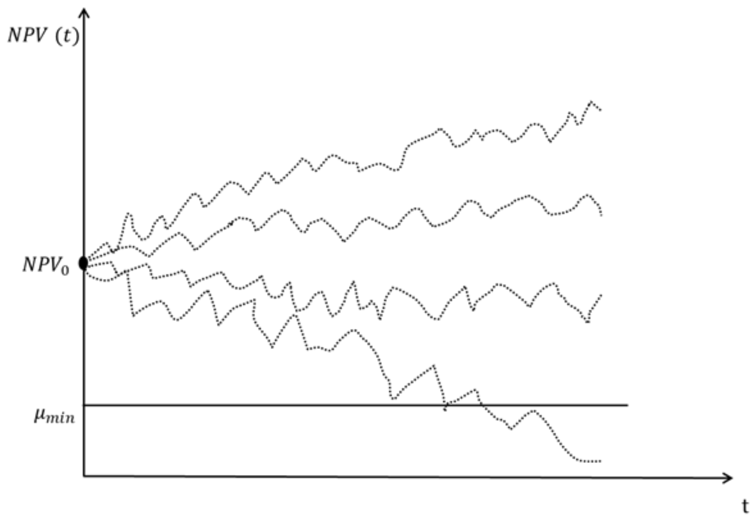

Figure III.3-1 Development of the Project Value over Time

The project inherent risk is depicted by the standard deviation. As positive and negative deviations do not meet the expected project value this two-sided risk measure is able to reflect reality. The negative deviation obviously results in less project value for the company. A positive deviation might reflect suboptimal resource allocation, since freed up resources can be allocated to other projects and improve the efficiency of the overall project portfolio.

However, we assume that a company usually examines the risk to lose money and hence focuses on the negative deviation. Even though one-sided risk measures like the expected shortfall or the Value at Risk might better reflect this behavior, for reasons of simplification, we stick to the standard deviation. In Figure III.3-1, we set the threshold for the project μ_{min}. In order to manage the project in a good way, a threshold that is not supposed to be undercut should be defined before the project starts. Thus, management claims that the project value has to exceed a pre-defined project value. If this value is undercut, the project can be regarded as failed. Since management, only considers the negative deviation an undesirable event, we do not set an upper limit.

In this model, the threshold is represented by a certain NPV μ_{min}. On the basis of investment theory, the smallest acceptable NPV for an investment is zero. A project with a NPV that is greater than zero can cause a positive value contribution, and thus it is aspired by the company. In contrast to that, μ_{min} here represents the expectations of the management towards the IT project, and thus can attain any value.

μ_{min} can also be used for damage control. If the project has to be implemented for example for regulatory reasons, the project might be accepted even though it has a negative NPV. In this case, μ_{min} represents the bottom line above which damage caused by the IT project is tolerated. Thus, μ_{min} can also be negative. Generally, management wants to be informed if μ_{min} is undercut so that corrective actions can be taken in an effort to avoid higher losses.

III.3.2. Assumptions

Since the NPV of an IT project is comprised of uncertain cash flows, the NPV is uncertain. Because circumstances and requirements of the project change with time, the project's NPV might change as demonstrated in Figure III.3-1. Thus, the changing project value can be depicted by a stochastic process.

Assumption 1: *The IT project's NPV follows an arithmetic Brownian motion.*

An arithmetic Brownian motion is a special kind of stochastic process. Especially long term projects with a large and complicated scope can be depicted this way as they are influenced by many different factors that might behave like they change randomly. This behavior is depicted by an arithmetic Brownian motion. To assume an arithmetic Brownian motion, however, three requirements have to be fulfilled (Dixit and Pindyck 1994).

First, the probability distribution of the future values of the stochastic process only depends on its current value, and is not influenced by the past, or by any other information. As all available information about the state of the IT project is considered when determining the actual project value, no other factors influence this value. Thus, the probability distribution for the future value of the IT project can be determined, if the current project value is known.

Second, independent increments exist in the arithmetic Brownian motion. "This means that the probability distribution for the change in the process over any time interval is independent of any other (nonoverlapping) time interval" (Dixit and Pindyck 1994). Due to the variety of factors influencing the development of an IT project, for reasons of simplification, we assume that the probability for the changes in the project value is independent of past and future changes.

Third, changes in the stochastic process are (a) normally distributed and (b) the variance increases linearly over time.

(a) requires the change of an IT project's NPV to be normally distributed. As project cash flows are influenced by normally distributed market risks as well as other factors, we assume that the cash flows and therewith the NPV of the project is normally distributed. As the change in the NPV is depicted by the respective cash flow that occurs between the two points in time, the change of an IT project's NPV can be considered normally distributed. The NPV can be represented by a normally distributed random variable $NPV_n \sim N(\mu, \sigma)$ (Fridgen and Müller 2009; Zimmermann et al. 2008). The expected value at the point in time of the n-th re-evaluation $(n = 0, 1, 2, \ldots, N)$ is given by $E(NPV_n) = \mu_n$. The project inherent risk is conceived as symmetric positive or negative deviation from the given expected value per day, and is quantified by the standard deviation $\sigma(NPV_n) = \sigma_n$.

(b) implies that the variance of the project value is multiplied by the duration of the blind flight. To model a linear increase, the project inherent risk exposure of the project value should stay constant over time. Since varying cash flows during and after the end of the project occur (Buhl 2012), we state the simplifying assumption that the possible deviation for each time interval of the same length remains constant between the points in time of evaluation and re-evaluation. The resulting deviation of the project value from its initial estimation increases with the length of the blind flight, and is therefore multiplied by the duration thereof.

As the model exclusively enables one-at-a-time evaluation, the requirements for an arithmetic Brownian motion only have to remain valid until the end of an evaluation interval. Since an iterative determination of the optimal time until re-evaluation might be enabled in a re-evaluation cycle, a re-assessment of the project parameters enables an approximately realistic depiction of the real world. Thus, all requirements for an arithmetic Brownian motion are met by a one-at-a-time re-evaluation of an IT project.

To specify the project value, the project's expected NPV μ_n and the associated project inherent risk σ_n have to be determined. As this is very difficult in reality, (Beer et al. 2013) tried to develop a pragmatic method to determine μ_n and σ_n for an IT project. Those parameters can be determined at any time in the project. Nevertheless, as previously mentioned, the changing environment and circumstances continuously modify the project's requirements, and thus influence the project parameters. Since evaluation takes time, the input parameters for the model are usually outdated. Furthermore, the process of deciding which corrective actions should be taken also requires time. Thus, a time lag occurs. However, for reasons of simplification, we state the following assumption.

Assumption 2: *Re-evaluation can be conducted at any time during the project. After each re-evaluation, subsequent actions can be taken. Neither re-evaluations nor subsequent actions require time for accomplishment.*

As the subsequent actions are individual and can differ significantly for each project we do not focus on this topic in the following.

III.3.3. Model

After having determined the initial project value, its development during the course of the IT project is uncertain and the blind flight begins. Since the NPV follows an arithmetic Brownian motion, a cone that illustrates the deviation of the project value over time can be determined. By determining the cone, management knows the value range within which the NPV probably deviates during the project and can thus get an initial appraisement of its development.

For each single point in time, a $(1-p)$-confidence interval for the NPV that indicates in which range the NPV lies with a probability of $(1-p)$ can be compiled. $p \in]0;1[$ represents the probability that the project's NPV at a certain point in time does not lie within the confidence interval. Thus $(1-p)$ is the probability that the NPV lies within the confidence interval. The complementary probability of the confidence level p, is defined by management.

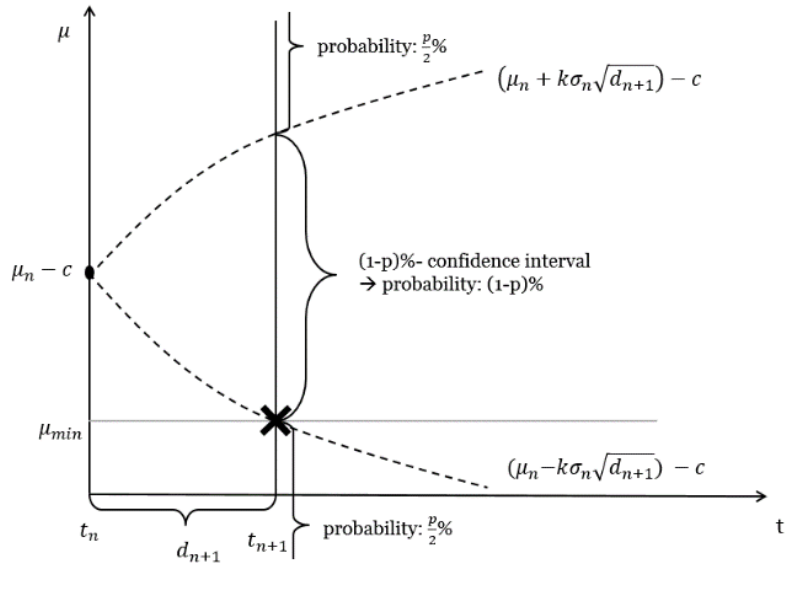

Figure III.3-2 Determination of the Optimal Time until Re-Evaluation $\boldsymbol{d^*_{n+1}}$

Figure III.3-2 illustrates the $(1-p)$-confidence interval at the point in time of the $n+1$- st re- evaluation t_{n+1}. The part within the interval limits reveals where the expected NPV of the IT project lies with a probability of $(1-p)$. Consequently, the IT project's expected NPV is smaller than the lower limit of the confidence interval with a probability of $\frac{p}{2}$. By determining the lower limit of the confidence interval, management knows that in t_{n+1} the NPV does lie above this value with a probability of $\left(1-\frac{p}{2}\right)$. If management chooses that μ_{min} is not supposed to be undercut with a probability of 10% ($\frac{p}{2}=10\%$), the project value lies within the confidence interval with a probability of 80%. Furthermore, the value lies above the upper limit and below the lower limit of the confidence interval with a probability of 10% each ($p=20\%$).

The value of the interval limits depends on two parameters. On the one hand, the interval limits are influenced by the value that management chooses for the probability p. On the other hand, the limits diverge over time, because the standard deviation changes with time. Since the variance ${\sigma_n}^2$ grows in proportion to time, the standard deviation σ_n increases in proportion to the square root of time $\sqrt{d_{n+1}}$ (Dixit and Pindyck 1994). d_{n+1} is the duration of the blind flight, and therefore the time interval from the n-th until the $n+1$-st re-evaluation. Thus, the standard deviation in t_{n+1} is $\sigma_n\sqrt{d_{n+1}}$, for example the standard deviation of a project increases by the factor 3 in 9 days.

Because the value of the interval limits also depends on the probability p, a typical measure to determine the value for one point in time is the $k\sigma$-range of the normally distributed NPV. k measures the deviation from the expected NPV in multiples of σ_n. Thus, the lower (upper) limit of the confidence interval corresponds to the negative (positive) deviation of the expected NPV. The wider the confidence interval, the smaller is the probability that the expected NPV falls short of the lower limit. The value of k can be deduced from the distribution function for the standard-normal distribution. With $\Phi(x)$ denoting the standardized normal distribution function, we know for the distribution of NPV_{n+1} that

$$P\left(\mu_n - k\sigma_n\sqrt{d_{n+1}} \le E(NPV_{n+1}) \le \mu_n + k\sigma_n\sqrt{d_{n+1}}\right) \quad (1)$$

$$= 2\,\Phi(k) - 1 = (1-p)$$

Thus, we can deduce, for example, that for a 66%-confidence interval k=1 and for an 80%-confidence interval k=1.28. By choosing different confidence intervals, management can decide with which probability the project value can fall short of or exceed its limits. To retain generality, we consider the variable k.

Furthermore, the costs of each re-evaluation c should be considered for the determination of the interval limits, as each evaluation utilizes the company's resources and thus decreases the project value. Therefore, we define the costs of re-evaluation of an IT project to be greater than zero ($c > 0$). To depict the development of the interval limits over time, Figure III.3-2 illustrates the resulting cone. The limits of the cone can be calculated (Dixit and Pindyck 1994). The lower limit of the cone is defined as

$$LL(d) = \left(\mu_n - k\sigma_n\sqrt{d_{n+1}}\right) - c \quad (2)$$

As previously outlined, management does not want the IT project's NPV to fall short of μ_{min}. Therefore, the point of intersection between the lower limit of the cone and μ_{min} is calculated. At this point in time the IT project's expected NPV does not fall short of μ_{min} with a probability of $(1 - \frac{p}{2})$.

$$\left(\mu_n - k\sigma_n\sqrt{d_{n+1}}\right) - c = \mu_{min} \quad (3)$$

By solving equation (3), we receive a possible solution.

$$\widehat{d}_{n+1} = \left(\frac{\mu_n - \mu_{min} - c}{k\sigma_n}\right)^2 \quad (4)$$

This possible solution should be checked for validity by verifying whether or not $\hat{d}_{n+1}$ is smaller than the remaining project term. If $\hat{d}_{n+1}$ is smaller than the remaining project term, $d^*_{n+1} = \hat{d}_{n+1}$ becomes the permitted solution and the answer to the research question. If $\hat{d}_{n+1}$ is larger than the remaining project term, the project is completed without further re-evaluation. If the calculated point in time of re-evaluation cannot be realized, management should find the next possible point in time of re-evaluation before and after. Those two points should be evaluated, compared and the economically preferred point in time should be used. The project should be re-evaluated when the optimal time until re-evaluation d^*_{n+1} according to the risk exposure of a project's cash flows has passed, and corrective actions have potentially become necessary. By adhering to this process, management can recognize problems early enough to avoid large losses due to project failure without spending too much money on unnecessarily frequent re-evaluation.

So far the model enables the determination of the time until re-evaluation of an IT project for one-at-a-time re-evaluation. To enable the application to multiple periods the model should be integrated into a re-evaluation cycle. Thus, management can apply corrective actions after each evaluation period. As corrective actions differ for each project we refrain from specific recommendations to project managers. The application of a re-evaluation cycle for evaluating an IT project over time enables project management according to value oriented principles.

III.3.4. Model Evaluation

In the following chapter, we want to illustrate that project re-evaluation after the optimal time until re-evaluation that regards the risky cash flows of an IT project is economically more reasonable than re-evaluating a project after a predetermined evaluation interval. Therefore, the following chapter outlines the range in which the financial loss or the hazarded project value occur. Overall, we illustrate that significant losses can occur, if management does not consider the decision at hand. Therefore, we apply the model presented above to a simulated data set.

Since a sufficient amount of IT project data for a formal evaluation is hard to acquire, we conduct a Monte Carlo simulation to create real world settings by varying the input parameters. To illustrate the advantages that can be utilized by applying the developed model, we compare the optimal time until re-evaluation ($d^*{}_{n+1}$) to non-optimized re-evaluation intervals (d_{reg}).

In the following, we distinguish how and why the optimal time until re-evaluation delivers superior results for two settings. On the one hand, if the optimal time until re-evaluation is undercut, financial loss caused by evaluating too early can occur. On the other hand, the company does additionally hazard project value caused by evaluating too late.

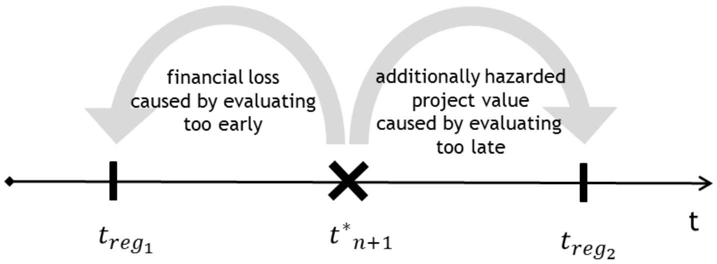

Figure III.3-3 Consequences of Non-Optimized Re-Evaluation

As Figure III.3-3 shows, if the point in time for the regular re-evaluation t_{reg_1} lies before the point in time for the optimal re-evaluation $t^*{}_{n+1}$, the IT project is re-evaluated too early. Thus, the company's resources are unnecessarily spent. The project is re-evaluated even though the blind flight did not take long and it is not likely that the project value significantly deviates from its initial expectation. The money spent for this early evaluation can be described as financial loss. It can be calculated by considering the difference between the optimal time until re-evaluation $d^*{}_{n+1}$, and the regular evaluation interval d_{reg} in proportion to d_{reg}. As a result of these calculations, the proportional premature evaluation can be identified. To capture the premature evaluation in monetary units, we multiply it by the costs of one re-evaluation. Thus, we calculate the financial loss caused by evaluating too early with the formula $\left(c\,\frac{d^{*}{}_{n+1}-d_{reg}}{d_{reg}}\right)$. To enable a comparison, the financial loss is related to the initial project value.

If the point in time for the regular re-evaluation t_{reg_2} lies after the point in time for the optimal re-evaluation $t^{*}{}_{n+1}$, the IT project is re-evaluated too late (see Figure III.3-3) as problems that cause a deviation of the project value from its initial expectation might be discovered too late. If management does not recognize the deviation, they hazard losing project value, and high losses due to project failure can occur.

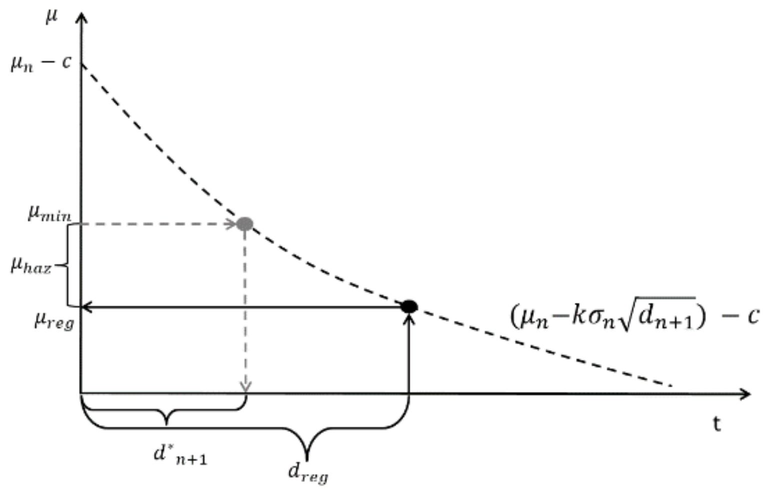

Figure III.3-4 Additionally Hazarded Project Value caused by Evaluating too Late

If μ_{min} is used as a threshold for the project, the model delivers $d^{*}{}_{n+1}$ as the optimal time until re-evaluation. If a regular re-evaluation interval d_{reg} that is longer than $d^{*}{}_{n+1}$ is used, the introduced model delivers μ_{reg} as the lower limit of the confidence interval in t_{reg}, which is not undercut with a probability of 10%. Since μ_{reg} is smaller than μ_{min}, the threshold set by the company is undercut (see Figure III.3-4). The difference between μ_{min} and μ_{reg} determines the monetary project value that is additionally hazarded μ_{haz}. This value is not definitely lost, but the risk that μ_{min} is undercut increases. To enable a comparison of several IT projects with a different project value, the additionally hazarded project value also is related to the initial project value.

To derive conclusions we examine the consequences of non-optimized evaluation by means of a Monte Carlo simulation. Thus, we outline two exemplary scenarios (re-evaluation after 30 and 180 days (Remenyi and Sherwood-Smith 1999)) that represent regular re-evaluation. During our evaluation we used more scenarios which lead to the same conclusion.

Following the simulation approach of IT projects in Fridgen and Müller (2011), we simulate 10.000 IT projects with an expected net present value and the associated project inherent risk (μ_n, σ_n). The model parameters can be found in Table III.3-1.

For each simulated IT project, the optimal time until re-evaluation $d^*{}_{n+1}$ is calculated. We then calculate the financial loss caused by evaluating too early, and the additionally hazarded project value caused by evaluating too late for each scenario.

Input parameter	*Value*	*Distribution*
μ_n	[10; 10,000] (in thousand €)	equal
σ_n	[0.05%; 5%] of μ_n	equal

Table III.3-1 Input Parameters

We set μ_{min} to 75% of μ_n. $\frac{p}{2}$ is supposed to be 10%. c is assumed to be 1% of μ_n.

Table III.3-2 shows, the fraction of the simulated projects that are evaluated too early, as well as the average and the highest financial loss caused by evaluating too early as a fraction of the initial project value. In general, it can be stated that the shorter the regular re-evaluation interval is, the higher the financial loss caused by evaluating too early will be. Additionally, Table III.3-2 illustrates, as expected, that the shorter the evaluation interval, the more simulated projects are evaluated too early.

Regular interval	*Fraction of projects evaluated too early*	*Average financial loss*	*Highest financial loss*
30 days	62%	6.6%	45.9%
180 days	19%	2.2%	6.8%

Table III.3-2 Financial Loss caused by Evaluating too Early

Table III.3-3 shows the fraction of the simulated projects that are evaluated too late, as well as the average and the highest additionally hazarded project value caused by evaluating too late as a fraction of the initial project value. It can thus be stated that the greater the regular re-evaluation interval is, the more project value is hazarded. Furthermore, as expected, the greater the evaluation interval is, the more likely it is that the simulated IT projects will be evaluated too late.

Regular interval	*Fraction of projects evaluated too late*	*Average ad. hazarded project value*	*Highest ad. hazarded project value*
30 days	35%	5.8%	11.1%
180 days	80%	31.2%	61.9%

Table III.3-3 Additionally Hazarded Project Value caused by Evaluating too Late

As we can see from the model, an optimal point in time for project re-evaluation can be identified according to the risk exposure of a project's cash flows. At this point, corrective actions have potentially become necessary. By conducting this procedure, management can recognize problems early enough to avoid large losses due to project failure without spending too much money on unnecessarily frequent re-evaluation. Therefore, the model determines the optimal time until re-evaluation, and thus enhances existing evaluation methods by a risky cash flow-oriented view. As we illustrated in the model's evaluation, a company hazards more project value or spends more money than necessary, if a regular evaluation interval is applied. The simulated data shows that significant losses can occur, if the project is evaluated too late or too early. Thus, we can conclude that the determination of the optimal time until re-evaluation considering risky cash flows is an economically relevant decision that can improve IT project management and preserves financial resources.

III.4. Practical Implications, Limitations and Outlook

When an IT project fails, high losses can occur. Through the progressional evaluation of a project, transparency regarding risky cash flows could help to avoid high losses, given that appropriate corrective actions are taken. Best practices already provide methods to solve some of the application problems, but do not regard the risky cash flows, and therewith also disregard the potential change in project value. This paper provides a guideline for management regarding at what point in time an IT project should be re-evaluated. By integrating risky cash flows to determine the optimal time until re-evaluation, existing project management approaches can be enhanced by an economic aspect.

The introduced model shows that the development of the project value over time should be assessed, and thus issues influencing the project value can be recognized early. The evaluation of the introduced model illustrates that the implementation of the decision model within a company can prevent significant losses for the company. If the pre-determined evaluation interval is shorter than the optimal result of the model, the company loses financial resources because a re-evaluation is executed even though the risk of high losses for the company is low. In this case, the company might lose 7% of the initial project value on average for the sole reason that the IT project was re-evaluated too early. If the regular evaluation interval is longer than the calculated optimum, the deviation of the project value might not be discovered in time, because the blind flight takes too long. As a result the company additionally hazards project value. If a project is re-evaluated after 180 days instead of the optimal time until re-evaluation on average more than 31% of the project value is additionally hazarded. By determining the optimal time until re-evaluation, both effects can be avoided and management can significantly save project value. Thus, an economically reasonable model for IT project re-evaluation is provided.

With regard to the limitations of our findings, we have to mention that the IT project's NPV in the model is regarded as a normally distributed random variable, and therefore we use an arithmetic Brownian motion to picture the project progression. Nevertheless, an arithmetic Brownian motion might not be able to depict every kind of IT project. Other stochastic processes might better be able to depict project progression. Moreover, it might be hard to determine the input variables in practice. Since the model only enables one-at-a-time determination of the time until re-evaluation, the influence of the model on multiple periods cannot be considered.

As this is a first approach in the direction to determine an optimal time until re-evaluation future research should extend the model to other stochastic processes in an effort to represent e. g. skewed distributions, fat tails, and trends. Furthermore, a Bayesian formulation that considers the foreground knowledge of a manager and newly arriving information might be used to depict the expectations towards the development of the project in future research. As the developed model has not yet been exhaustively tested with empirical data a computation of the coherences and relationships within the model based on real world data should be provided. Furthermore, a sensitivity analysis to measure the effect of estimation errors on the model parameters is subject to further research. Since the model only enables one-at-a-time determination of the time until re-evaluation, the influence of the model on multiple periods cannot be considered. A re-evaluation cycle that enables the repetitive utilization of the introduced model might state a first step for the application of the model to multiple periods. Furthermore, future research should provide a categorization for the project value and consider corrective actions and their consequences.

Although the model pictures reality in a constrained way, it provides a basis for firms to improve their re-evaluation strategies in IT projects by economically considering the risky cash flows of an IT project. The model evaluation shows that companies should not stick to fixed evaluation intervals but consider individual ones for their projects. Thus, companies might be able to re-evaluate their IT projects more efficiently and project management can be improved. Even though it is still difficult to determine the relevant input parameter in practice, the model can be used as a guidance for project management. The paper furthermore contributes to the scientific knowledge base by creating awareness for a practically relevant topic that has not yet been deeply discussed in project management literature. Moreover, the model is a theoretically sound economical approach, which allows for further development, and delivers insights to IT project re-evaluation. Thus, IS researchers should further be concerned with the examination of model intrinsic correlations and derive further hypotheses for empirical testing.

IV. Results, Future Research, and Conclusion

This chapter contains the thesis' key findings in chapter IV.1 and an outlook on future research areas in chapter IV.2. It also provides a short conclusion in chapter IV.3.

IV.1. Results

This thesis' main objective was to contribute to modern project management by developing and improving project management approaches. After motivating project management's relevance to achieve successful project results, this thesis presented new approaches and tools in the area of ex ante evaluation and ex nunc steering.

Chapter IV.1.1 and chapter IV.1.2 conclude on the key findings of the research papers presented in this thesis.

IV.1.1. Results in the Area of Ex Ante Evaluation

Chapter II focused on approaches to improve the ex ante evaluation. This thesis has examined approaches that address projects on different levels. Overall, it has developed four approaches that can help companies to achieve better decisions in ex ante evaluation. The thesis' main focus was the evaluation of the overall value of digitalization (P1), the evaluation of a single IT project concerning the value contribution of a digitalization project (P2) and the identification of complexity in an IT project (P3), as well as the evaluation of a specific IT infrastructure project concerning cost-efficient IT resource provision to hidden champions (P4).

While digitalization is becoming increasingly important, companies still don't know the real value they can gain for their businesses. In P1, we conducted a structured literature review of the scientific and management literature to identify digitalization's benefits. We identified 38 different benefit types of digitalization and categorized them in line with an established model for information and communication systems by Buhl and Kaiser (2008). We interrelated the benefits by using logic trees on each of the information and communication system layers. Based on this categorization, we identified potential value drivers of digitalization that should be considered when measuring the impacts of digitalization initiatives. Since digitalization influences a company's whole ecosystem, including customers, we identified value drivers that enable the measurement at the interface of the intra-organizational and extra-organizational perspectives. P1's results contribute to scientific research by providing a detailed basis for the development of measurement approaches for digital value drivers. Further, P1 can help companies to identify their main benefits and value drivers in digitalization. With this approach, companies can gain a better understanding of their digital potentials.

Based on P1, in P2 I developed an assessment scheme for digitalization projects. Since in P1 we identified *customer experience* and *efficiency* as a potential starting point for value drivers of digitalization, the assessment scheme is based on these two factors. A company can assess every potential digitalization project based on these factors. Only digitalization projects that contribute to at least one of the factors should be started, from a digitalization perspective. I also developed a four-step procedure that enables the advantageous selection of digitalization projects. For this purpose, in a first step, a company needs to determine the status quo in both dimensions. In a second step, it needs to define a target state for both dimensions. Based on the first two steps, it can choose a combination of projects that lead to the target state. After a first evaluation, the target state and the project portfolio should be regularly re-evaluated. Overall, P2 delivers a valuable contribution for companies, since they can assess their digitalization projects and can select the projects that contribute to their digitalization goals best based on P2. Thus, a reasonable steering of the digitalization progress is possible.

Besides evaluating the project value as in P2, P3 focused on the evaluation of complexity in IT projects. Since IT project complexity seems to strongly impact on IT project failure, and IT projects are especially prone to fail, in P3 we examined the characteristics of IT project complexity. We developed a two-dimensional framework based on the literature to seek conceptual clarity regarding IT project complexity. According to the literature, complexity usually depends on the area of occurrence and the observation context (Lee and Xia 2002). We considered project areas as our framework's first dimension. Further, we determined antecedents of complexity as the second dimension, to display how complexity develops in different project areas. We evaluated the framework concerning validity and applicability in five semi-structured interviews with industry experts. Overall, the framework is beneficial for both research and practice, since it clarifies the concealed aspects of IT project complexity. We analyzed and structured the literature and derived hypotheses about the causes of complexity. The framework can also help practitioners to better understand the complexity in their IT projects. They can use the framework as an ax ante evaluation tool and can identify problems prior to an IT project's implementation. Based on the identification of problems, practitioners can take various mitigation actions and can therefore improve their IT project even before it starts.

IT departments face high cost pressures and a demand for high flexibility. Thus, they need to accomplish IT projects that enable cost-effective IT service provision. A new opportunity for IT service provision delivered by digitalization is cloud computing. However, especially hidden champions in rural region often still refrain from extensive use of cloud services. A key reason for this restraint is a lack of available bandwidth. In P4, we developed an ex ante decision model that helps companies to decide whether and how cloud computing can be considered in their service model. In P4, we especially focused on cloud bursting as a special form of hybrid cloud computing. Lilienthal (2013) developed a model for cost-efficient cloud bursting. Thus, in a first step, we examined whether Lilienthal‘s (2013) model can be used for decision-making by hidden champions in rural regions. For this purpose, we conducted six semistructured interviews with industry experts (pre-testing). Lilienthal (2013) did not consider bandwidth restrictions and several other factors, which our interviewees considered relevant. If hidden champions in rural regions have used Lilienthal‘s (2013) model for decision-making, they may take the wrong decisions, which would lead to higher costs (e.g., for additional bandwidth expansion). Thus, we identified the need for a second research cycle. In line with Meredith et al. (1989), the second research cycle consisted of three phases: description, explanation, and post-testing. In the description phase, we adjusted the setting, assumptions, and the model in line with the insights from the interviews in the pre-testing. In the explanation phase, we conducted a sensitivity analysis and derived hypotheses on the model behavior. We found that bandwidth availability plays a key role in the decision whether or not to use cloud resources. Further, companies should consider economies of scale in the internal data center in their decision. Existing on-premise resources should also be considered for the decision. In the post-testing phase, we discussed the derived hypotheses in interviews with five industry experts. They confirmed our hypotheses based on their experience. Researchers can build on our insights and can adapt their models accordingly. Further, practitioners can use our results by considering the key influencing factors in their decisions.

IV.1.2. Results in the Area of Ex Nunc Steering

Chapter III provided an outlook on project management in the ex nunc steering phase. This thesis focused on the optimal time for re-evaluating an IT project during its run-time.

The ex nunc steering phase seeks to ensure that IT projects are successfully implemented and that fewer project failures occur. Since IT projects are conducted in a dynamic environment and digitalization has even raised the speed of change (Gimpel and Röglinger 2015), IT projects should be re-evaluated during their run-time so as to avoid failures (Fridgen et al. 2015b).

However, since every project is different, it is hard for a company to decide when an IT project should be re-evaluated. On the one hand, if a company waits too long before re-evaluating the project, it is in a blind flight in which it does not know the project status. Thus, it risks the project value if the project deviates much from the initially planned value. On the other hand, every evaluation implies costs. If a project is re-evaluated too early, money is spent unnecessarily. In P5, we developed an economic decision model about when an IT project should be re-evaluated. The model considers risky cash-flows. In a simulation, we illustrated that a company can lose up to 7% of the initially estimated project value, if it re-evaluates the project too early. Late re-evaluation can have even worse consequences. Overall, although the model is a simplification of reality, it provides a solid basis for companies to reconsider their re-evaluation strategies. The model and the evaluation illustrate that companies should not stick to fixed evaluation intervals. They should consider determining individual evaluation times for different projects based on the project-inherent risk. The developed model also contributes to the scientific knowledge base, since it sheds light on a topic that has barely been discussed in the literature. Further, the model delivers theoretical insights into IT project re-evaluation and can be used as a basis for future research.

IV.2. Future Research

Chapters II and III addressed the two perspectives ex ante evaluation and ex nunc steering in project management. However, the papers in this thesis focused on specific parts of these manifold research areas. To provide a concluding outlook on the research topics in this thesis, I will discuss future research opportunities for both project management phases. On the one hand, I will draw on future research for each phase. On the other hand, I will elaborate on possible extensions for each research paper included in the thesis.

IV.2.1. Future Research in the Area of Ex Ante Evaluation

As described in chapters I and II, the ex ante evaluation phase significantly impacts on a company's selecting an efficient project portfolio. Thus, the underlying assessment models for project selection play a key role in a company's success and should thus be developed further to improve decision-making.

A topic that should be considered in greater detail by researchers is the development of advanced measurement models. On the one hand, decision models should be easy for managers to handle and understand. Thus, project managers can really use the models for decision-making instead of relying on their gut feelings. However, decision support models should also realistically reflect business problems. Since reality is very complex and dynamic, decision models that really reflect reality are often very complicated and hard to understand. Thus, researcher should develop applicable models in the tradeoff between usability and realistic representation.

In P2, I developed a management approach that uses a pragmatic, easy-to-handle assessment scheme to evaluate digitalization projects. The assessment scheme is based on a three-step scale (low, middle, high) and enables an assessment with low effort and easy applicability. However, for a more precise evaluation, a quantitative measurement approach may enhance the explanatory power of the developed assessment scheme. Further, in P3 we developed a framework for the assessment of complexity of IT projects. This is a valuable first step in the identification of IT project complexity. However, for a more detailed analysis and as a basis for complexity mitigation actions, researchers should develop a quantitative approach that measures IT project complexity. Based on a quantification method, researchers could examine which complexity level is most advantageous for which IT project type and can thus provide companies with recommendations for coping with complexity.

The second aspect that should be further examined by researchers is the integration of different evaluation parameters into an integrated approach. Beer et al. (2013) stated that an IT project should be evaluated based on its costs, benefits, risks, and dependencies. However, for an in-depth examination, the research has usually concentrated on one or two characteristics of a project (e.g., P1, P2 – benefits; P4 – costs). However, even if all four aspects are considered, for instance an IT project's complexity is still not fully reflected in the measurement model. P3 claims that complexity incorporates more antecedents than just dependencies. Thus, researchers should further address the integration of different evaluation parameters in an integrated model to reflect projects more realistically.

This thesis has focused on different evaluation parameters. While it considered benefits to be the main object of reflection in digitalization in P1 and P2, researchers should also examine the costs, risk exposures, and dependencies that influence the decision to implement a digitalization project. Further, researchers should consider projects' complexity in evaluation models, which we considered in P3. Overall, this thesis can conclude that, for each examination level, researchers need to conclude about the most relevant evaluation parameters and should therefore develop integrated evaluation approaches on every level.

The third aspect that researchers should consider is the validation of derived hypotheses and developed models. The papers included in this thesis derived hypotheses about complex relationships (P1, P3, P4) and developed two ex ante decision models for project evaluation (P2, P4). The included papers based their investigations on literature and interviews with industry experts. However, the derived hypotheses in P1, P3, and P4 need to be further tested in quantitative empirical studies. Further, the developed models (P2, P4) should be applied in real-world settings. In P4, we adjusted an existing model towards the special characteristics of hidden champions in rural regions and analyzed the theoretical model behavior in a sensitivity analysis. By applying the model to a real-world setting, researchers could gain deeper understanding of the model behavior.

Another aspect that should be considered by researchers is the transfer of developed solutions to different application areas. This thesis has developed two decision models that can be applied in a special context. In P2, I developed a measurement model for digitalization projects for use in service companies. While efficiency as a value driver can easily be transferred to other industries, customer experience cannot be transferred without limitations. Thus, researchers should analyze the characteristics of different industries and how the model can be transferred accordingly. Further, in P4, we adapted an existing model to the requirements of hidden champions in rural regions. However, researchers should examine whether our results can be generalized and which aspects should also be considered by larger companies.

IV.2.2. Future Research in the Area of Ex Nunc Steering

As described in chapters I and III, companies should re-evaluate their projects during a project's run-time to enable ex nunc project steering and to avoid project failure. Based on ex ante evaluation, researchers should provide measures that enable early detection of project deviations and that help companies to identify appropriate actions to lead projects to success.

In P5, we developed a theoretical model that helps companies to identify the optimal IT project re-evaluation times based on a Brownian motion. However, researchers should examine whether other stochastic processes may reflect reality with fewer restrictions. Further, researchers should conduct sensitivity analysis to examine how the model parameters influence the decision. Since many parameters are still hard to estimate, estimation errors may significantly influence the decision. Thus, robust methods are of high value.

Besides further developing the model presented in P5, researchers should address the whole ex nunc steering phase. Having identified appropriate measures for continuous project steering (Fridgen et al. 2015b) as well as the evaluation points (P5), researchers should investigate how project steering can contribute to more successful project completion. In this thesis, we provided only a brief outlook on the ex nunc steering phase; yet many topics promise to improve project management in future.

IV.3. Conclusion

In short, this thesis examined different research questions concerning the management of complex IT projects, which face the challenges of digitalization. The papers included in the thesis have contributed to the scientific knowledge by developing approaches to the ex ante evaluation phase and to the ex nunc steering phase of project management. Although the management of complex IT projects will change further, and will demand adjustments and development in the future, this thesis is a first step towards better managing complex IT projects.

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