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RESEARCH PAPER

On the Ex Ante Valuation of IT Service Investments

A Decision Theoretical Perspective

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Abstract The paradigm of service orientation and its incarnation in the form of service-oriented architecture (SOA) and information technology (IT) services play a crucial role in enabling companies to achieve considerable competitive advantages. However, to be able to leverage the opportunities of SOA and IT services, companies need to gain a thorough understanding of the business value of IT service investments. Nevertheless, research on IT services has focused mainly on technical questions so far; the economic perspective largely has been neglected. Therefore, the authors aim to contribute to the ex ante valuation of IT service investments from a decision theoretical point of view. Using decision theory as a theoretical base, the main aim is to identify and discuss specific challenges regarding the financial ex ante valuation of IT service investments, which arise from the inherent flexibility of IT services and the various interdependencies within a company's IT service portfolio. The authors thereby emphasize that the application of common methods from financial theory for valuating IT service investments has to be treated with caution, as these methods are often tied to rather restrictive assumptions based on the specifics of capital markets. By analyzing different clusters of IT service investment decision problems using decision theory, the authors identify and discuss pitfalls that might occur when applying financial valuation methods to capture the flexibility and interdependencies of IT service investments. The decision theoretical considerations are intended to help build a solid basis for future multi-criteria valuation approaches, of which an essential component is a theoretically well-founded financial valuation.

Keywords Decision theory · Dynamic decision structure · Intratemporal interdependencies · Intertemporal interdependencies · IT service investments

1 Introduction

In an increasingly dynamic and competitive market environment, companies are forced to improve agility, collaborate with various business partners, and continuously innovate products and business models to compete successfully for customers and market share (Kohlborn et al. 2009, p. 51; Rai and Sambamurthy 2006, p. 327). The reasonable and business-driven use of new developments in information technology (IT) plays a crucial role in addressing these challenges. In particular, the paradigm of service orientation and its incarnation in the form of service-oriented architecture (SOA) and IT services are intended to offer considerable competitive advantages for companies that succeed in exploiting their full economic potential (Kohlborn et al. 2009, p. 51). Based on the

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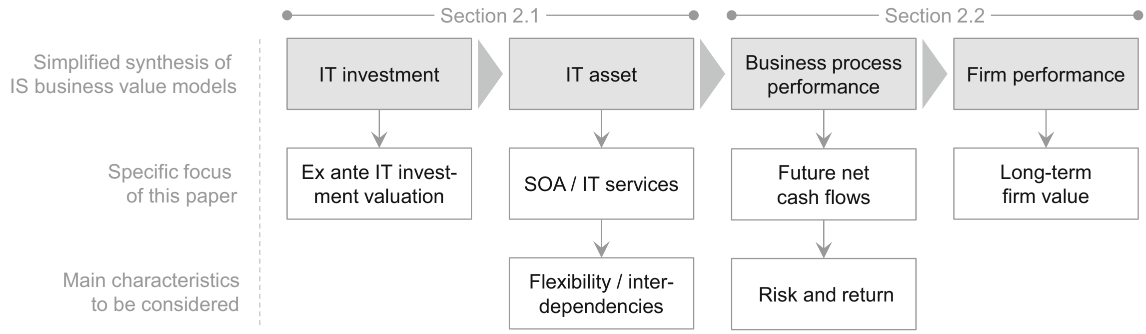

Fig. 1 This study in the context of IS business value models proposed in IS research

concept of loosely coupled and reusable IT services that provide encapsulated business functionalities via standardized interfaces (Becker et al. 2011, p. 199; Beimborn et al. 2008, p. 1), SOA is aimed at enabling straightforward and fast integration of business partners, increased business process integration and flexibility, cost advantages by standardization, as well as improved agility and responsiveness to customer needs (cf. e.g., Choi et al. 2010; Grefen et al. 2006; Moitra and Ganesh 2005). For instance, retailers and financial institutions can easily incorporate a creditworthiness assessment of their potential customers by integrating the SCHUFA web-based IT service into their processes (SCHUFA 2015). Besides these opportunities, however, implementing SOA and investing in IT services is accompanied by manifold challenges, both at the IT and strategic levels (Becker et al. 2011, p. 197). Whereas performance or security issues are commonly cited obstacles from a technological viewpoint (Becker et al. 2011, p. 194), the considerable latency between high investment spending and unclear long-term economic benefits hampers broad institutionalization of SOA from a strategic angle (Becker et al. 2011, p. 197). These challenges are underpinned by the results of a Forrester Research study, which finds that only 20 % of the surveyed organizations manage to achieve expected SOA benefits fully (Heffner et al. 2009; Joachim et al. 2013, p. 86).

Against this backdrop, companies' need to take economically well-founded investment decisions regarding their IT service portfolios (ITSP) becomes evident. An essential precondition is that companies gain a thorough understanding of the business value of IT service investments and its determinants. However, the economic perspective on IT service investments largely has been ignored in the literature so far (vom Brocke et al. 2009, p. 226). Instead, the vast majority of research on SOA and IT services addresses solely IT-related issues, such as the conceptual implementation and realization of SOA in companies (cf. e.g., literature reviews by Kaczmarek and Wecel 2008, p. 52ff.; Viering et al. 2009, p. 52f.). Qualitative work dominates the sparse literature focusing explicitly on the business value of SOA and IT services. According to the comprehensive literature review of Becker et al. (2011), this stream of research can be divided into studies that provide qualitative models and those that conduct qualitative empirical research. The former primarily aim for a structured categorization of the potential benefits of SOA and its determinants along different dimensions (cf. e.g., Abelein et al. 2009; Müller et al. 2007; vom Brocke et al. 2008). By contrast, the latter focus on the identification of economic benefits of SOA in the context of specific real-world application scenarios based on expert interviews and case studies (cf. e.g., Baskerville et al. 2005; Klischewski and Abubakr 2010; Luthria and Rabhi 2009; Tewary et al. 2009). Besides these few qualitative studies, there are hardly any quantitative approaches regarding the business value of SOA and IT services, from either an ex post or ex ante perspective. Quantitative empirical studies of Becker et al. (2011), Kumar et al. (2007), and Oh et al. (2007) investigate the benefits of SOA in different dimensions (e.g., supply chain performance, process integration and flexibility, and agility) from an ex post perspective based on large-scale surveys. From an ex ante perspective, a few studies can be found that address specific problems. For instance, Braunwarth and Heinrich (2008) focus on the optimization of a company's ITSP considering dependency structures, Braunwarth and Friedl (2010) develop an optimization approach to determine the optimal functional scope of IT services from a financial perspective, and Probst and Buhl (2012) investigate the optimal budget allocation of investments in various possible IT service and supplier combinations. While these studies apply financial valuation methods (e.g., Markowitz portfolio theory) to selected real-world problems, there is no general theory-based and structured discussion of challenges and pitfalls that might occur when financial valuation methods are applied to capture the specific characteristics of IT service investments.

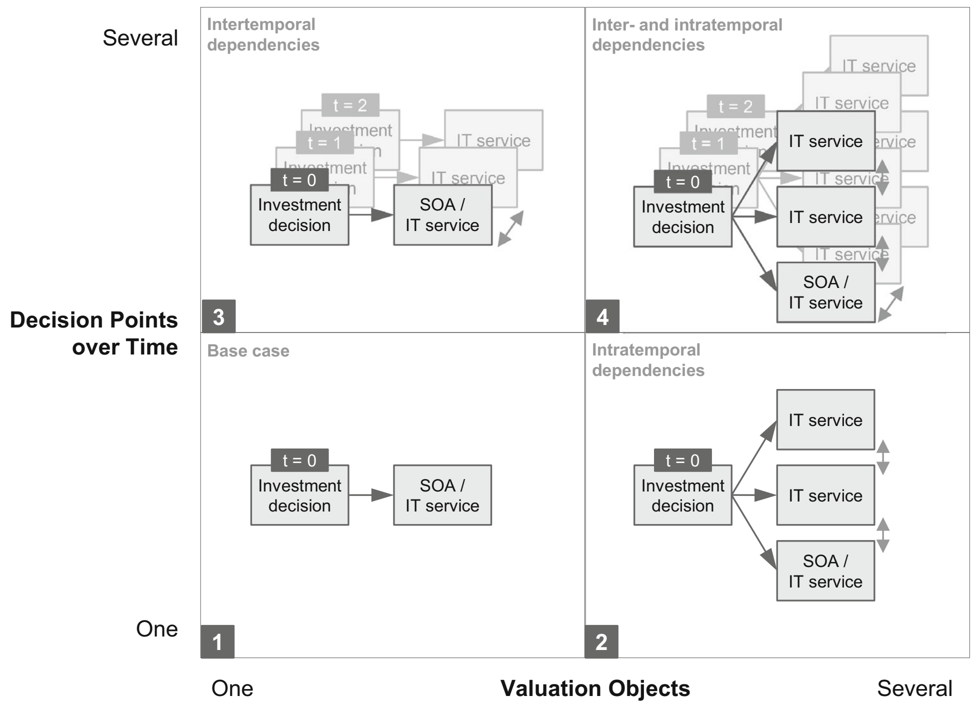

Fig. 2 Different SOA/IT service investment decision problems

Given, on one hand, the high relevance of taking economically well-founded IT service investment decisions in business practice and, on the other, the sparse consideration of theoretically sound approaches for the quantitative ex ante valuation of IT service investments in the literature, we aim to contribute to closing this research gap. As a first step, we focus on the financial ex ante valuation of IT service investments based on cash flows from a decision theoretical viewpoint. A solid assessment of the "bottom-line" financial impact of IT service investments is of particular importance, as it allows for comparing and ranking different investment alternatives using a consistent base, and thereby, helps to ensure mindful allocation of scarce financial resources (e.g., Irani 2010; Irani and Love 2002). Moreover, financial figures are commonly accepted, well understood, and allow for reporting processes with high information density, as a result of which they are the dominating decision criteria in the budgeting processes of companies.

A major challenge in assessing the business value of IT service investments is to appropriately consider their specific characteristics that distinguish them from other IT investments. Due to the granularity of single IT services (cf. e.g., Krammer et al. 2011), IT service investments can be more flexible, considerably less capital intense, and more reversible than, for instance, IT infrastructure investments. At the same time, the interplay of a usually high number of IT services within a company's ITSP that support certain business processes leads to various interdependencies that might considerably influence the value of IT service investments (e.g., intratemporal dependencies during the run-time of IT services, such as the availability of IT services, as in Braunwarth and Heinrich 2008 and Probst and Buhl 2012; or intertemporal dependencies from an investment point of view, as in Diepold et al. 2011). From a financial ex ante view, it is a common and straightforward approach to capture the flexibility and interdependencies of IT (service) investments by means of well-known methods from financial theory, such as real option theory (cf. e.g., Ullrich 2013) or Markowitz portfolio theory (cf. e.g., Probst and Buhl 2012). However, their application to evaluate IT service investments has to be treated with caution. This is particularly due to the fact that these methods were initially developed to deal with financial assets and thus, are often based on rather restrictive assumptions that are tied to the specifics of financial commodities and capital markets (cf. e.g., Asundi and Kazman 2001; Copeland et al. 2008; Ullrich 2013; Verhoef 2002). In other words, some of the basic assumptions of methods from financial theory might be violated in their application to evaluate IT service investments. Common examples are the usually missing existence of a duplication portfolio for IT service investments when applying approaches based on real option theory, or the missing divisibility and liquidity of IT service investments when applying Markowitz portfolio theory. Therefore, we take the perspective of decision theory and aim to identify and discuss specific challenges and potential pitfalls that might occur when financial valuation methods are applied to capture the flexibility and interdependencies of IT service investments.

To structure our decision theoretical discussion regarding the challenges of a financial ex ante valuation of IT service investments, we apply a two-step approach. Although both steps are embedded in an extensive discussion of relevant literature streams regarding IT business value in general and IT service investments in particular, we do not aim to provide a descriptive structured literature review (cf. e.g., King and He 2005; Webster and Watson 2002). Instead, we focus on the specifics of IT service investments to create a literature- and theory-driven framework that enables structured analysis of IT service investment decision problems. Considering that in decision theory, "valuation" ultimately means solving a certain decision problem, in the first step, we derive different clusters of IT service investment decision problems from the plentiful literature concerned with IT services. These clusters reflect the specific characteristics of IT service investments and structure our decision theoretical discussion of existing valuation approaches in the second step.

In the second step, we apply the general decision theoretical framework to identify and discuss selected challenges of a financial valuation of IT service investments along the previously identified clusters. From a decision theoretical viewpoint, the specific structure of a decision problem has a determining influence on the question of which valuation method, or combination of different valuation methods, should be applied (Hirshleifer 1965, p. 516). Hence, we analyze the suitability of certain financial valuation methods given a specific IT service investment decision problem, represented by the previously identified clusters. Consequently, this study also entails substantial normative aspects. This is particularly the case as we apply the decision theoretical framework to derive normative propositions and recommendations regarding the applicability and suitability of certain financial valuation methods for the identified IT service investment decision problems. In addition, we identify critical knowledge gaps (cf. e.g., Rowe 2014; Webster and Watson 2002). Besides discussing challenges regarding the financial ex ante valuation of IT service investments, we provide suggestions for coping with the identified problems and emphasize directions for further research.

In essence, we aim to answer the following research questions by means of the outlined two-step approach.

1. Considering the specific characteristics of IT service investments discussed in the literature, which different clusters of IT service investment decision problems can be distinguished?
2. From the perspective of decision theory, which challenges regarding a financial ex ante valuation of IT service investments arise within the different clusters?

By providing new insights into the financial ex ante valuation of IT service investments, we build a solid base for the development of future multi-criteria valuation approaches that, in addition, enable capturing the non-financial value components of IT service investments. There is wide agreement in the literature that the business value of an IT service investment is a multidimensional construct comprising both tangible and intangible value components (cf. e.g., Alshawi et al. 2003; Kohli and Grover 2008; Melville et al. 2004). Although multi-criteria decision theory may represent an alternative to capture these multi-faceted value components, we abstain from the complexity and theoretical problems arising with such approaches at this point. Instead, given the virtual absence of well-founded ex ante valuation approaches for IT service investments, we aim to facilitate and assure the development of theoretically sound financial ex ante valuation approaches in the first step.

The remainder of the paper is organized as follows. In the following Sect. 2, we briefly position our study within the existing literature on business value of IT investments. Moreover, we discuss specific characteristics of IT service investments and derive clusters of characteristic decision problems that guide the subsequent discussion (Sect. 2.1). In addition, we reflect the impact of IT service investments on business process and firm performance as well as various affected dimensions of business value (Sect. 2.2). In Sect. 3, we apply the general framework of decision theory to the ex ante valuation of IT service investments and discuss selected challenges regarding the financial valuation of IT services along the derived clusters. Finally, we summarize our findings in Sect. 4 and point out directions for future research to improve the ex ante valuation of IT service investments.

2 Ex Ante IT Service Investment Valuation

The business value of IT investments has been discussed intensively in information systems (IS) literature throughout the last decades. Whereas a few early studies doubt the economic benefits of IT investments (e.g., Dos Santos et al. 1993; Hitt and Brynjolfsson 1996; Rai et al. 1997), there is agreement in the broad IS business value literature that IT can generate significant business value for the firm (e.g., Han et al. 2011; Kohli and Grover 2008; Lee et al. 2011).

To model the relationship between IT investments and firm performance, several business value models have been proposed (e.g., Dedrick et al. 2003; Dehning and

Richardson 2002; Melville et al. 2004). We apply a simplified synthesis of these well-established models based on the work of Schryen (2013, p. 144) in order to position our study within this field of research, structured in the following two Sects. 2.1 and 2.2 (cf., Fig. 1).

2.1 Ex Ante Valuation of IT Investments and Characteristics of IT Service Investment Decision Problems

Regarding the business value of IT investments in general, existing research can be divided into studies that investigate the value of IT investments from an ex ante perspective and those that take an ex post perspective (Kohli and Grover 2008, p. 25). In the IS literature, the ex post perspective prevails (Schryen 2013, p. 142), and is mainly concerned with the extent to which IT investments have created value for firms. By contrast, the ex ante perspective is related to which available IT investment alternatives best contributes to a firm's business goals or preferences (Schryen 2013, p. 141) and thereby aims to support decision-making processes. As the ex ante perspective is rather underrepresented in the existing literature, we focus on the ex ante valuation of IT investments (cf., Fig. 1).

IT investments usually result in IT assets, such as IT infrastructure or IT services (cf. e.g., Ross and Beath 2002; Zimmermann 2008b), or human resource or management capabilities (cf. e.g., Schryen 2013). Schryen (2013, p. 154) points out that the IS literature mainly draws on straightforward classifications of IT assets (e.g., hardware, software, telecommunications, and services of IT personnel) and criticizes the literature for not considering properly the purpose of the IT asset or the business goals of the firm. Therefore, we specify our understanding of the IT assets under consideration, that is, of SOA, IT services, and related business goals.

As outlined in Sect. 1, the goal of many companies is to overcome structural barriers to improve agility, collaborate with various business partners in order to focus on core competencies, and continuously innovate products and business models to retain customers (Kohlborn et al. 2009, p. 51; Rai and Sambamurthy 2006, p. 327). To achieve these goals, the concept of SOA has been introduced, and can be defined as a "[…] computing paradigm that utilizes services as the basic constructs to support the development of rapid, low-cost and easy composition of distributed applications even in heterogeneous environments" (Papazoglou 2008, p. 223). Many business benefits, such as agility and cost reduction through SOA and the embedded IT services providing encapsulated business functionalities via standardized interfaces (Becker et al. 2011, p. 199; Beimborn et al. 2008, p. 1), have been confirmed in the literature (for an overview, see, e.g., Joachim 2011). However, there are also critical voices who claim that "[i]n practice, […SOA] often results in a company left with thousands of services, a couple of expensive software tools, and few business benefits" (Bradley 2008, as cited in Trkman et al. 2011, p. 211). Against this background, Viering et al. (2009, p. 52) state "[…] researchers need to further investigate how SOA investments improve a firm's capabilities and thereby create business value." A review of the few studies focusing on the value of SOA is found in Becker et al. (2011, p. 200f.). Given, on one hand, the high relevance of determining the business value of SOAs and IT services in business practice and, on the other, the sparse consideration in the existing literature, we aim to contribute to the quantitative ex ante valuation of IT service investments from a decision theoretical viewpoint.

SOA and IT service investments show several specific characteristics that distinguish them from other IT investments and that require special attention within investment valuation (vom Brocke et al. 2009, p. 226). First, IT service investments are characterized by considerable interdependencies (Braunwarth and Heinrich 2008, p. 103; Diepold et al. 2011, p. 806; Probst and Buhl 2012, p. 73; Zimmermann 2008b, p. 462). In particular, two types of dependencies can be distinguished, that is, intertemporal and intratemporal dependencies (Häckel et al. 2011, p. 415; Wehrmann et al. 2006, p. 235; Zimmermann 2008a, p. 360). Intertemporal dependencies can occur between different points of time and may exist for a single IT service, between different IT services, or between IT services and the SOA infrastructure. For instance, whether investment in SOA infrastructure provides returns depends considerably on the IT services running on the platform. However, the future concrete IT service setup might be unknown at the point of time when the investment decision for the SOA platform has to be made. Thus, intertemporal dependencies exist between today's decision and future decisions on IT service investments. Moreover, at the IT service level, today's decision about granularity and thus, the functional scope of a certain IT service directly affects its ability to be reused and recomposited to react to future changes in a company's business environment (cf. e.g., Krammer et al. 2011). For instance, the financial service consultation and sales process at a financial service provider could either be implemented as one large IT service or it could be implemented as fine-grained single services that cover each process step on their own (cf. e.g., Braunwarth and Friedl 2010). In the latter case, single IT services for specific tasks, such as typing in customer data, could be reused in further processes, for instance, the process of opening a bank account. Consequently, in the case of intertemporal dependencies, investment decisions could depend on all previous decisions and may in turn affect subsequent possible alternatives (Kundisch and

Meier 2011, p. 480). Besides intertemporal dependencies, intratemporal dependencies have been discussed intensively in the IS business value literature (e.g., Aral and Weill 2007; Bharadwaj et al. 1999; Cho and Shaw 2009; Melville et al. 2004; Orlikowski and Iacono 2001; Rai et al. 1997; Sircar et al. 2000). In the context of IT service investments, intratemporal dependencies can occur between different IT services or between IT services and the SOA infrastructure at a certain point of time, such as due to their necessary interplay via defined interfaces (e.g., Millard et al. 2009). Thus, the correct execution of an IT service could depend on the availability of another IT service or a certain type of infrastructure (Probst and Buhl 2012, p. 77). For instance, the availability of the SCHUFA creditworthiness service from our example in Sect. 1 could depend on the availability of the underlying infrastructure, for example, a web server. The availability of the SCHUFA service itself could affect a second IT service that supports the process of opening a bank account. If the credit score of a potential customer cannot be calculated, the service might not be authorized to open the account. Taken together, SOA and IT service investment decision problems are often characterized by several valuation objects that are particularly interdependent over time.

Second, with existing SOA infrastructure, IT service investments are more flexible, considerably less capital intense, and more reversible than other IT investments (e.g., monolithic systems). For instance, supporting a business process with multiple IT services with restricted functional scope (the degree of functional scope of one service is usually referred to as granularity) can lead to reduced development and maintenance efforts as well as increased likelihood of reusability in other business processes (see, e.g., Krammer et al. 2011 for an overview on the granularity of IT services). Thus, in some cases, the sheer recomposition of IT services might be sufficient to adapt to environmental changes and developments (Schelp and Winter 2007). For instance, regulatory changes, such as know your customer (KYC) policies, can be implemented in a new IT service that allows verification of the identities of clients. Subsequently, the new service can be integrated in the process of opening a bank account by recompositing the process with a new activity between typing in customer data and further process steps that activate the bank account. Hence, it is not necessary to change and newly implement the whole process. Overall, the granularity of IT services makes it possible to (re)-combine them in multiple ways to provide certain business services or support different business processes, allowing for a high degree of flexibility. Since realizing or adapting business solutions for the first time often requires the combination of granular IT services, a steady realignment of a company's ITSP and continuous selection decisions between different IT services, which could potentially be considered, are required (Schelp and Winter 2007, p. 1; vom Brocke and Sonnenberg 2007, p. 188; vom Brocke et al. 2009, p. 227). Therefore, IT service investment decision problems are often characterized by dynamic decision structures with frequent decision points over time (Brandl et al. 2007, p. 92; Kontogiannis et al. 2007).

Based on the specific characteristics of SOA and IT service investments, Fig. 2 classifies SOA and IT service investment decision problems into four separate clusters. We structure decision problems along the dimensions of "number of decision points over time" and "number of valuation objects". Cluster (1), as the most straightforward case, describes decisions regarding a single SOA or IT service investments with only one decision point in time (static decision structure). However, evaluating SOA infrastructure without incorporating the business value of potential IT services to be run on the infrastructure might make little sense. In addition, in the case of a single IT service, an absence of all dependencies on the SOA infrastructure or other IT services that should be considered when evaluating the IT service investment is unlikely. Cluster (2) comprises static portfolio selection decisions, which take into account several SOA/IT service investment opportunities showing intratemporal dependencies. This situation would occur if SOA infrastructure were already in place and intertemporal interdependencies between the IT services and the SOA infrastructure could be neglected. Furthermore, this could be the case if an investment decision about SOA infrastructure and a portfolio of future IT services were made at the same point in time. However, in both cases, any options on future investment decisions would be neglected. Taken together, clusters (1) and (2) are theoretical in nature but show little relevance for investment decisions in SOA/IT services, as the underlying assumptions hardly hold in business practice. Thus, we particularly focus on the more relevant but more complex clusters (3) and (4).

Cluster (3) considers single SOA/IT service investments that offer options for future action and thus, are characterized by several decision points in time and intertemporal dependencies (dynamic decision structure). For example, this would be the case if an investment in SOA infrastructure enabled future investments in single IT services that run on this infrastructure. However, as discussed earlier in this section, in reality, several IT services might interact and depend on each other at each point in time. This case is addressed by cluster (4). This cluster contains dynamic portfolio selection decisions and thus, comprises both inter- and intratemporal dependencies between several SOA/IT service investments. In summary, cluster (3) and in particular cluster (4) reflect the specific characteristics of SOA/IT service investments, that is, a dynamic decision structure as well as inter- and intratemporal dependencies. In Sect. 3, we discuss common challenges regarding these different IT service investment decision problems against the backdrop of decision theory.

2.2 Impact of IT Service Investments on Business Process and Firm Performance

To describe the relationship between IT investments and performance as well as capabilities, the literature has drawn on various theoretical paradigms, such as microeconomic theory (cf. e.g., Brynjolfsson and Hitt 1995; Dewan and Min 1997) and the resource-based view (cf. e.g., Mata et al. 1995). We follow the synthesis of the well-established IS business value models of Schryen (2013, p. 144) and take a process-oriented view to model the relationship between IT investments, business processes, and finally, firm performance (cf. e.g., Soh and Markus 1995).

There is general agreement in the literature that the impact of IT investments on business process performance and firm performance is a multidimensional construct (cf. e.g., Melville et al. 2004) and can be tangible or intangible. To quantify the tangible impact, numerous studies emphasize that financial appraisal techniques should play an important role within decision-making processes. For example, Alshawi et al. (2003, p. 416) argue that such techniques "[…] are specifically designed to assess the 'bottom-line' financial impact of investments, by often setting direct IT-related costs against quantifiable benefits achievable." Many researchers emphasize the need to justify investments by carefully weighing costs and benefits and by comparing and ranking different investments to ensure a mindful allocation of financial resources (e.g., Dehning and Richardson 2002; Irani 2010; Irani and Love 2002). Next to ex ante decision support, financial appraisal techniques also enable comprehensive benchmarking within ongoing projects, that is, the performance of IT investments can be compared with planned deliverables or targets (Angell and Smithson 1991). Thus, financial appraisal techniques may act as control mechanisms over expenditure, benefits, and the development and implementation of IT projects (e.g., Ayal and Seidmann 2009; Irani and Love 2002).

Within the stream of research focusing on financial appraisal techniques, future net cash flows as a specific financial measure are often considered as a suitable approach to evaluate IT investments on a financial basis (e.g., Irani 2010; Irani and Love 2002; Renkema and Berghout 1997). In the case of IT services, future net cash flows can, for instance, be estimated by comparing the costs of manual versus automated process executions (Probst and Buhl 2012). Further possibilities to quantify cash inflows and outflows as well as related prediction uncertainties are discussed, for instance, in Brandl et al. (2007), Diao and Bhattacharya (2008), and Thomas and vom Brocke (2010, p. 76ff.). A central argument for the use of future net cash flows often cited in the literature is their direct relationship to the concept of value-based management, which aims to maximize the net present value (NPV) of all future cash flows (Buhl et al. 2011, p. 164f.; Coenenberg and Salfeld 2003, p. 3). This means that an IT investment offering a positive NPV directly contributes to the company's value maximization. Another advantage of using future net cash flows as a financial measure is the fact that, in contrast to periodical accounting measures, they take into account the time value of money and thus, in general support decision making oriented to the long term (e.g., Renkema and Berghout 1997, p. 3). Furthermore, the NPV approach enables comparatively easy integration of risk, for example, by adjusting the discount rate according to the IT investment's specific risk (e.g., Verhoef 2005, p. 318).

Despite the widespread use of financial appraisal techniques and net cash flow approaches in particular, several studies emphasize that in addition to a purely financial valuation, further appraisal techniques should be applied to consider also the non-financial and intangible benefits and costs of IT investments (Alshawi et al. 2003; Ayal and Seidmann 2009; Irani 2010; Irani and Love 2002). Kohli and Grover (2008, p. 33), for instance, argue that beyond direct economic benefits, intangible value components, such as organizational capabilities or agility, should be taken into account. Other studies emphasize the importance of further intangible benefits, such as higher customer and staff satisfaction (Ayal and Seidmann 2009, p. 47) and an improved strategic position of the firm in its competitive environment (Irani and Love 2002, p. 78). A key challenge regarding intangible assets is the fact that, contrary to tangible assets, they can hardly be assessed by means of quantitative performance measures. Therefore, the literature proposes alternative approaches, such as the application of perceptual measures (Chau et al. 2007, p. 197) or the use of ordinal metrics that allow a ranking based on a comparison with competitors or between current states and former states (Schryen 2013, p. 152). Considering the complexity arising from the multi-faceted nature of IT business value, Irani and Love (2002, p. 76) conclude that "[…] the development of an all-embracing generic appraisal technique that takes account of the wide variety of IT/IS-related implications may be considered too rigid and complex for use by decision-makers".

Therefore, we focus on the financial valuation of the tangible value components of IT service investments and aim to enrich the literature by discussing selected challenges in IT service investment decision problems against the backdrop of decision theory. A central challenge is that the inherent flexibility and various intra- and intertemporal dependencies of IT service investments lead to cash flow interrelations, which have to be taken into account appropriately when evaluating such investments on a financial basis. The literature concerned with the financial valuation of IT investments usually addresses such aspects with the help of methods from financial theory. Thus, flexibility and the associated dynamic decision structure are regarded in numerous approaches based on real option theory (e.g., Benaroch and Kauffman 1999; Benaroch et al. 2007; Fichman 2004; Ghosh and Li 2013; Kauffman and Li 2005). Stochastic interdependencies between the cash flows of different IT investments are commonly considered by means of approaches based on financial portfolio selection theory (e.g., Cho and Shaw 2013; Fridgen and Moser 2013; Zimmermann et al. 2012). However, such monetary valuation of IT investments based on methods from financial theory needs to be critically discussed for each specific case (Asundi and Kazman 2001; Verhoef 2002), as these methods are often based on rather restrictive assumptions (cf. e.g., Asundi and Kazman 2001; Copeland et al. 2008; Verhoef 2002). Therefore, we take the perspective of decision theory to identify challenges and pitfalls that might arise from an overly careless application of methods from financial theory to evaluate IT service investments. In addition, we discuss potential approaches to overcome the identified problems.

3 The Perspective of Decision Theory

In accordance with Schryen and Bodenstein (2010), we choose decision theory as the theoretical basis for our analysis. The general framework consists of the following elements. A *set of alternatives* (*acts/options*) is available, which can be finite or even infinite. We can distinguish *states of nature* caused by unknown exogenous factors. Concerning these states, information is available regarding their likeliness (e.g., probabilities). As a combined effect of a chosen alternative and the state of nature, a specific *outcome* is realized. A central concept in decision theory is the distinction between outcome and its *utility*, that is, the value of the respective outcome for the decision maker.

Related to the ex ante valuation of IT service investments based on cash flows, we specify the general framework as follows. The set of alternatives includes combinations of one or more IT services and potential SOA infrastructure investments as well as capital market instruments. States of nature describe realizations of the market, the firm, and technological uncertainty. As far as multi-periodic problems are considered, we differentiate time-state combinations. Net cash flows from operative and capital market activities are the relevant outcome. They can be used for consumption. Likewise, utility reflects this explicit monetary perspective: cash flows are valued according to the decision maker's intertemporal consumption preferences.

The inclusion of capital market instruments might be surprising; yet, as financial markets allow for the transfer of money between time-state combinations, cash flow consequences of operative, IT service-related decisions can be adapted according to the decision maker's needs. Hence, operative and financial decisions essentially are to be treated simultaneously (cf. e.g., Häckel et al. 2011). In addition, the simultaneous consideration of operative and capital market activities is important for our decision theoretical discussion regarding the suitability of certain methods from financial theory to evaluate IT service investments. Since many methods from financial theory are based on rather restrictive assumptions, especially with respect to the interconnection between operative and capital market activities, their simultaneous consideration is essential for identifying problem areas from a decision theoretical point of view. For example, approaches based on real option theory rest on the assumption that option payments from an operative investment are duplicable by an underlying traded instrument or another market instrument (see Sect. 3.2 for more details).

According to our understanding, an intertemporal problem is a special case of multi-criteria decision making, in which different criteria (attributes) are substantiated by consumption possibilities in multiple periods (i.e., the decision is based on different consumption possibilities over time). Multi-criteria decision making in general deals with multidimensional outcomes, which are valued corresponding to multiple criteria. These outcomes may be influenced by one or multiple (static or dynamic) actions taken by the decision maker. In summary, in the spirit of classical theory, we treat "analysis of investment as a redistribution of consumption opportunities over time" (Hirshleifer 1965, p. 510f.).

In decision theoretic thinking, "valuation" ultimately means solving a decision problem. It can be represented formally as follows:

$$\max_{\bar{v},\bar{y}} \phi_0(C_0, C_1, \ldots, C_T),$$

$$\text{subject to } C_t = X_t(\bar{v}) + Z_t(\bar{y}) + h_t,$$

$$\bar{v} = (v_0, \ldots, v_T)^T \in D_{\bar{v}}, \text{ and}$$

$$\bar{y} = (y_0, \ldots, y_T)^T \in D_{\bar{y}}.$$

The notation is defined as:

$\phi_0(\cdot)$ preference value, depending on current and future consumption possibilities

C_t state-contingent consumption in period t

$X_t(\cdot)$ state-contingent cash flow from operations (IT services) in period t
$Z_t(\cdot)$ state-contingent cash flow from capital market instruments in period t
t time index, $t \in \{0, 1, \ldots, T\}$
$\bar{v}$ state-contingent operative strategy (decision variable)
$\bar{y}$ state-contingent capital market strategy (decision variable)
$D_{\bar{v}}$ set of admissible operative strategies (represents project-specific restrictions)
$D_{\bar{y}}$ set of admissible capital market strategies (represents institutional and/or individual restrictions)
h_t state-contingent cash flow from initial endowment (non-marketable income) in period t

The problem could also be formulated in continuous time, as commonly practiced in the context of real options, but this would not provide further economic insight. The decision maker attempts to maximize his/her preference value within his/her opportunity set (Hirshleifer 1965, p. 510). Frequently, the preference value is assumed to equal the expected utility of the consumption stream in the sense of von Neumann and Morgenstern (1947).

$$\phi_0 = E_0[U(C_0, C_1, \ldots, C_T)].$$

Negative cash flows from operations ($X_t(\cdot) < 0$) are understood as net investments. Positive cash flows ($X_t(\cdot) > 0$) imply net cash inflows. In practice, investment valuation is associated with certain quantitative tools for decision making (e.g., NPV, portfolio analysis, and real options valuation). From a decision theoretic viewpoint, these different (well-known) valuation methods and combinations thereof are the *result* of certain assumptions concerning the general problem. Hirshleifer (1965, p. 516) states that "[…] [t]he competing approaches to investment decision […] diverge in their specification of the basic objects of choice." That means, in the case of application, all elements of the general framework must be specified. The sets of admissible operative and capital market strategies translate into concrete side conditions to be included. Together with specifications regarding the decision maker's preferences and the distribution of random variables, a viable representation of the decision problem can be derived. For the latter, consider the famous hybrid model in which normally distributed random variables and constant absolute risk aversion, in the sense of Arrow (1965) and Pratt (1964), lead to a mean-variance criterion (Bamberg and Spremann 1981), which is also widely applied in the literature on the quantitative ex ante valuation of IT investments (e.g., Fridgen and Moser 2013; Häckel and Hänsch 2014; Zimmermann et al. 2012). Thus, depending on the concrete structure of the resulting model, certain procedures for solution or optimization (e.g., dynamic programming) are implied.

Financial transactions deserve particular attention, since the capital market's potential to allocate risks is a crucial factor. Notably, the concepts of "spanning" and "complete markets" have to be mentioned. Spanning means that future cash flows arising from a particular operative strategy $\bar{v}$ can be duplicated by market instruments, that is, by using the capital market strategy $\hat{y}$:

$$Z_t(\hat{y}) = X_t(\bar{v}) \quad \forall t \in \{1, \ldots, T\}.$$

If every conceivable operative strategy can be duplicated, the capital market is considered complete. Therefore, future cash flows of the object(s) to be valued are attainable without implementing it (them). As a result, the value of the operative strategy to the decision maker equals – regardless of his/her preferences – the initial investment of the duplicating capital market strategy, as follows.

$$V_0(X_1(\bar{v}), \ldots, X_T(\bar{v})) = -Z_0(\hat{y}).$$

As individual attitudes are irrelevant, spanning provides for preference-free valuation results. Regarding investment decisions, the following rule holds. An investment is advantageous, if the initial investment of the operative strategy $X_0(\bar{v})$ is smaller than that of the duplicating capital market strategy $Z_0(\hat{y})$. Then, in the case of multiple shareholders, projects are unanimously supported by all decision makers irrespective of their possibly conflicting consumption preferences (DeAngelo 1981; Wilhelm 1989). In this way, "shareholder value" is a meaningful objective of the firm. Hence, with complete markets, decision theory reconciles individual and market perspectives and enables the combination of different levels of examination.

As far as IT services and their cash flows are concerned, firm and technological uncertainties play a major role. These investment-specific risks can at best be partially hedged by trading securities. Therefore, it is implausible to assume spanning (cf. e.g., Diepold et al. 2011; Kauffman and Li 2005; Schwartz and Zozaya-Gorostiza 2003). As a result, we have to account for both preferences and – owing to fragmentary hedging – cash flow interrelations.

In the following Sect. 3.1, we build on the decision theoretical framework outlined in this section and discuss the four clusters representing characteristic decision problems derived in Sect. 2.1 (cf., Fig. 2). To grasp the specific characteristics of the different clusters from a financial perspective, the literature usually draws on straightforward approaches from financial theory that, at first sight, seem adequate to address the relevant decision problem. For instance, approaches based on real option theory are widely applied to consider the dynamic decision structure and the intertemporal interdependencies that are characteristic for decision problems of cluster 3. However, as common methods from financial theory are often based on rather restrictive assumptions, their application to IT service investments needs to be critically reflected for each case. Therefore, for each cluster, we use the general decision theoretical framework to identify and discuss potential challenges that might arise from the application of common financial valuation methods in a structured way. We refer to the basic elements of the general framework, such as the sets of admissible operative strategies and capital market strategies, the decision maker's preferences, or the distribution of cash flows to guide our discussion on fundamental problem areas within the single clusters. Thus, the following discussion aims to sharpen awareness of the underlying assumptions of financial valuation methods and the resulting challenges and limitations when it comes to evaluating IT service investments. In addition to discussing challenges, we provide suggestions for coping with the identified problems. The results of the discussion may lead to a more conscious application of methods from financial theory and may give rise to further research in the field of financial ex ante valuation of IT service investments.

At this point, we want to emphasize that our approach is neither intended nor suitable for developing concrete decision models for the single clusters. As we choose a rather coarse-grained clustering of decision problems along the two dimensions, that is, "number of decision points over time" and "number of valuation objects", a large variety of manifestations of the concrete decision problem are possible even within a single cluster. However, the clustering fits very well with our goal to identify structural problems and challenges within the single clusters that might arise when methods from financial theory are applied to capture the flexibility and interdependencies of IT service investments. These structural challenges are mostly independent from the concrete manifestation of the decision problem (i.e., within our discussion, we can, for instance, abstract from the concrete set of available investment opportunities or the concrete risk preference of the decision maker). However, the coarse-grained clustering hampers the development of a single, all-embracing decision model for a certain cluster. Due to the large number of concrete manifestations of decision problems contained in one cluster, such a decision model would be too generic to be applicable to decision support in a meaningful way.

3.1 Clusters 1 and 2: Static Decision Structure and Intratemporal Dependencies

As outlined in Sect. 2.1, cluster (1) describes decisions about single IT service investments with only one decision point in time (static decision structure). Cluster (2) comprises static portfolio selection decisions, which take into account several IT service investment opportunities showing intratemporal dependencies.

The standard approach for valuing single static IT service investments as contained in cluster (1) is the NPV method, which takes as inputs future net cash flows and a discount rate. Usually, risk is accounted for as a part of the discount rate, the so-called risk premium. Alternatively, future net cash flows could be reduced. In general, the amount of risk adjustment is mostly justified on grounds of capital market data. Consider the well-known capital asset pricing model (CAPM; Lintner 1965; Sharpe 1964), which is often used in the context of traditional firm or project valuation. Here, the risk adjustment depends on the correlation of the market portfolio with the asset to be valued. However, as capital market data are only sparsely available for IT service investments, the discount rate in this case particularly mirrors individual preferences and alternative choices of action. Therefore, the direction of risk-adjustment depends on the concrete IT service investment to be valued and its position within the whole opportunity set of the decision maker. That is, both risk premiums and risk discounts are possible (Cochrane 2005).

Static portfolio selection considering intratemporal dependencies as given in decision problems contained in cluster (2) is usually based on the framework of Markowitz (1959). However, as the Markowitz model is intended to optimize the selection of financial instruments, its application to IT service investment problems needs to be handled with care. Here, we want to mention only two aspects. First, standard portfolio theory assumes that assets are infinitely divisible, a requirement rarely met by IT services. Of course, as the granularity of IT services can differ considerably, it might be possible to split up a rather coarse-grained IT service into a set of more fine-grained IT services that are characterized by a more narrow functional scope (e.g., financial service consultation and sales process, as outlined in Sect. 2.1). Thus, compared to other IT investments (e.g., infrastructure investments) IT services have a tendency to show higher divisibility, but of course, they are not infinitely divisible in the sense of liquid financial assets. Second, only linear cash flow interdependencies, that is, covariances, are included in the Markowitz model. By contrast, investments in IT services can be subject to sub-additive cost and super-additive value structures, as recently explicated by Cho and Shaw (2013). Even though their work is an important first step, their model merely allows for two-way synergies and thus, the challenge cannot be regarded as completely solved. Therefore, the structure of the interdependencies between IT services needs to be carefully considered when applying the Markowitz model to valuate IT service investments with intratemporal dependencies.

3.2 Cluster 3: Single Investment with Options for Future Action (Real Options)

Cluster (3) considers single IT service investments that offer options for future action and thus, are characterized by several decision points in time (dynamic decision structure). IT investments and particularly IT service investments are often affiliated with options for future action. The literature refers to different options providing managerial flexibility (Ullrich 2013, p. 322), such as the option to abandon, contract, expand, stage, defer, grow, or switch. As a common feature of all these options, a decision made at an earlier point in time influences subsequent investment decisions, as it creates preconditions or constraints imposed for making these decisions. Therefore, the set of admissible operative actions at every point of time t depends on project-specific restrictions as well as previous actions:

$$\bar{v}_t = v_t \in D_{v_t}(v_0, \ldots v_{t-1}).$$

Consider an option to delay (defer) an investment in an innovative, first-of-a-kind IT service, in a scenario in which the level of customer acceptance for this service is very uncertain due to missing experiences from comparable IT services. There may be costs for the delay – foregone cash flows or the risk of entry by competitors – but these costs must be balanced against the benefits of waiting for new information. If the IT service increases in value (e.g., due to rising customer acceptance), payoffs from investing arise. If its value declines, the decision maker need not invest, and will at most lose the amount spent to obtain the investment opportunity. Mapping these cash flow effects into the decision model has to take into account that an investment is possible at every point of time unless the investment has already been undertaken. Another example is the (variety of) growth option(s) that arise from investing in SOA infrastructure. The usually high initial investment costs can be justified only by firmly considering the option to invest in a broad variety of future IT services that run on this infrastructure. Of course, a major challenge when valuating these option values arises from the circumstance in which the complete set of future IT service investment opportunities might be unknown at the decision point. Due to this uncertainty, the exact value of the initial SOA infrastructure investment usually is not known ex ante. Nevertheless, companies are well advised to consider at least the option values stemming from the set of future IT service investment opportunities that are already known at the decision point. In most cases, such an approach promises a considerably more solid assessment of the business value of the SOA infrastructure than simply ignoring any options for future action.

Traditional valuation methods, such as the NPV, cannot account for such managerial flexibility. Hence, the literature suggests the application of real options theory, which applies option pricing models from financial theory to the valuation of IT investments (cf., Ullrich 2013 for an overview). Unfortunately, real option models rest on the assumption of complete markets and therefore, in particular assume that option payments are duplicable by an underlying traded instrument or another market instrument. However, insofar as IT service investments are considered, project-specific risks are of paramount importance and thus, often impede the duplicability of cash flow effects. Therefore, in terms of our general decision problem, the set of admissible capital market strategies has to be restricted adequately. Moreover, as valuation is no longer preference-free, the decision maker's utility function needs to be selected carefully. With regard to real options embedded in IT investments, several ways to cope with the resulting problem of incomplete markets have been proposed. Hereafter, these approaches are introduced and critically analyzed.

Frequently, if the underlying instrument is not traded, it is substituted by the present value of future cash flows from the project and thereby, usually a constant discount rate is applied (e.g., Benaroch and Kauffman 1999; Harmantzis and Tanguturi 2007; Schwartz and Zozaya-Gorostiza 2003). In addition, the recent analysis of the migration to SOA by Ghosh and Li (2013) applies a constant discount rate. One essential feature of classical option pricing theory, however, is that it does not rely on a single discount rate (e.g., Black and Scholes 1973). Hence, this advantage is not yet taken into account in many IT valuation approaches suggested in the literature. Moreover, if the volatility of the underlying instrument is to be changed, for example, in the course of comparative static analysis, the discount rate applied should change as well (cf. Davis 2002). Thus, existing sensitivity analyses, like those in Harmantzis and Tanguturi (2007) or Ghosh and Li (2013), need to be critically reflected from a decision theoretical viewpoint.

Another way to address the problem of incomplete markets is to distinguish between market risk and project-specific risk (private risk). In Balasubramanian et al. (2000), market risk is accounted for by risk-neutral probabilities, as is usual in derivative pricing. Project-specific risk is provided for by subjective probability estimates. Diepold et al. (2011) capture market risk with the help of the Black-Scholes model. Project-specific risk is valued by an expected utility function, which leads to an expected shortfall-preference function. However, these approaches to overcome the problem of incomplete markets have to be discussed in light of earlier findings of Smith and Nau (1995). Smith and Nau (1995) show for so-called partially complete markets and under certain preferential conditions that market risks and not duplicable investment-specific risks can be valued separately. The latter is accounted for according to the preferences of the decision maker. Unfortunately, to this day, separation is only proven possible for additively separable exponential utility functions. Whether further preference functions can be used in the sense of Smith and Nau (1995) – as suggested by Balasubramanian et al. (2000) and Diepold et al. (2011) – needs further investigation in future research. Therefore, further research regarding a preference-based valuation of real options is required, especially in the context of IT service investments.

Finally, some authors circumvent the problem of valuating risky cash flows by assuming risk-neutral decision makers. Examples are Kauffman and Li (2005) and Li (2009). However, as experimental and empirical evidence suggests, decision makers are typically risk averse. Consequently, assuming risk neutrality can be a reasonable first step but should be avoided in future ex ante valuation models for IT service investments.

Taken together, several challenges remain for future research to enable sound valuation of IT service investments offering options for future action from a decision theoretical perspective. Up to now, the issue of market incompleteness due to project-specific risks of IT service investments has not been solved satisfactorily in the existing literature. As a result, IS research should adopt existing approaches toward a preference-based valuation of real options (e.g., Smith and Nau 1995) and refine them adequately. While recent literature proposes to combine "[…] partial extensions [of option pricing models] […] so that several critical assumptions can be considered at the same time" (Ullrich 2013, p. 338), one has to be very careful, as consistent valuation models can be deduced only by adequately specifying the individual decision problem, as shown in Sect. 3.

3.3 Cluster 4: Dynamic Portfolio Selection

Cluster (4) addresses dynamic portfolio selection decisions and thus, comprises both inter- and intratemporal dependencies between several IT services investments. In dynamic portfolio selection, the setting is intertemporal and uncertainty is resolved in each future period. It is assumed that at each date $t \in \{0, 1, \ldots, T\}$, the decision maker has a preference ordering defined over present and future state-contingent consumption:

$$\phi_t(C_t, C_{t+1}, \ldots, C_T).$$

In that context, time-consistent planning means the following. If, at each point in time, the decision maker could plan for every future eventuality, plans that were optimal with respect to preferences ϕ_t would remain optimal in all later periods τ given the way uncertainty has evolved in the meantime:

$$(\bar{v}*, \bar{y}*) = \arg\max_{\bar{v},\bar{y}} \phi_\tau(C_\tau, C_{\tau+1}, \ldots, C_T) \in \arg\max_{\bar{v},\bar{y}} \phi_t(C_t, C_{t+1}, \ldots, C_T) \quad \text{and} \quad t < \tau.$$

Concerning decision problems over time, such as IT service portfolio investments over multiple periods, time consistency appears indispensable. In its absence, service portfolios would be rebalanced, not caused by external events or new information, but merely because of conflicting successional preference orderings of the decision maker.

In existing approaches, time consistency is usually neglected or in heuristic approaches, inconsistency is accepted. An example is Probst and Buhl (2012). As a starting point, an existing IT service portfolio is assumed. Against this backdrop, investment decisions in further IT services for the support of different process actions provided by multiple internal or external suppliers should be valued. Concerning the decision structure, it has been argued that companies face frequent investment decisions for several reasons, as outlined in Sect. 2. To account for these dynamics, multiple decision points, at which decisions about investments in IT services can be made, are assumed. As Probst and Buhl (2012) consider stochastic, normally distributed cash flows depending on the IT services' availability, so-called money market-invariant preferences (cf. Bamberg et al. 2006), and constant absolute risk aversion in the sense of Arrow (1965) and Pratt (1964), the following preference function is implied

$$\phi(\mu, \sigma) = \mu - \frac{b}{2} \cdot \sigma^2,$$

where μ and σ^2 denote mean and variance of the stochastic NPV of the IT service portfolio (Bamberg et al. 2006; Bamberg and Spremann 1981) and b indicates the degree of absolute risk aversion of the decision maker.

According to Probst and Buhl (2012), IT services should be chosen from the present viewpoint. However, if time is interpreted in a relative way, future decisions are made with regard to future preferences – by means of discounting cash flows to the respective points in future time. Hence, preferences form a temporal sequence of orderings. In this case, would future actions indeed adhere to past preferences? At every decision point, the optimal action depends on the reference point, that is, the chosen preference ordering. If decisions relate to current preferences (as in Probst and Buhl 2012), actions are planned that might not be realized in the future. Thus, IT services previously classified as advantageous could be rejected eventually. According to the pioneering work of Strotz (1955), there are two methods for dealing with time-inconsistent decisions. On the one hand, future actions could be determined at present ("precommitment"). Thus, applied to the model of Probst and Buhl (2012), the decision problem would no longer be dynamic but static. However, the requirement of up-to-date supplier portfolio management could hardly be met in this way. On the other hand, "consistent planning," as suggested by Strotz (1955, p. 173), could be applied: "[…] the man with insight into his future unreliability may adopt a different strategy and reject any plan which he will not follow through. His problem is then to find the best plan among those that he will actually follow." To this end, further consistency constraints have to be added to the optimization problem, as occasionally implemented in commodity and financial portfolio management (cf., Cui et al. 2012; Geman and Ohana 2008). That is, the set of admissible operative and capital market strategies has to account for this. As a dynamic decision structure is of utmost importance in selecting IT services, future research in this area should emphasize time-consistent solutions in order to allow for a theoretically sound handling of dynamic portfolio selection problems comprising both inter- and intratemporal dependencies between several IT services investments. In this context, future research should consider the results of the recent paper of Bamberg and Krapp (2016), who provide clear-cut conditions that ensure time consistency in an expected utility framework.

4 Conclusions, Limitations, and Directions for Further Research

The literature on IT services and SOA so far has focused mainly on technical questions, for instance, the design of IT services or the conceptualization and implementation of SOA. Consequently, the economic perspective has been widely neglected. While there are at least a few quantitative empirical studies that analyze the benefits of IT services from an ex post perspective, research from an ex ante perspective is rare. Therefore, in the present study, we aimed to contribute to closing this research gap by focusing on the financial ex ante valuation of IT service investments. By taking a decision theoretical perspective, our major aim was to identify and discuss specific challenges regarding the financial ex ante valuation of IT service investment, which arise from the inherent flexibility of IT services and the various interdependencies within a company's ITSP. For structuring our discussion, we distinguished four clusters of IT service investment decision problems and for each cluster, we discussed the challenges and pitfalls that might arise from a poorly founded application of methods from financial theory to evaluate IT service investments. In doing so, we analyzed in depth the following two IT service investment clusters: single investment with options for future action and dynamic portfolio selection. These two clusters reflect flexibility and interdependencies as specific characteristics of IT service investments. The decision theoretical analysis of these two clusters revealed the following crucial challenges and starting points for possible solutions.

- The case of single IT service investments with options for future action, that is, so-called real options, has been discussed intensively in the IS literature. As real options and financial options show comparable characteristics, pricing techniques developed for financial options are frequently mapped to IT investment options. Traditional option pricing models require that the payoff of the option can be duplicated by a portfolio of the (traded) underlying and a riskless asset. However, as long as the payments associated with real options concerning IT service investments are highly project specific, duplication by market instruments is not – or only partly – possible. Unfortunately, the existing literature deals with the issue of market incompleteness insufficiently. As a result, IS research should adopt existing approaches toward a preference-based valuation of real options (e.g., Smith and Nau 1995) and refine them adequately.
- Dynamic portfolio selection is characterized by several decision points over time and multiple valuation objects. Usually, due to external events or resolution of uncertainty, portfolios are rebalanced at any point of time in order to re-establish a proper relationship among the single investments. However, insofar as preferences are time dependent, portfolio management has to account for time consistency, which prevents unnecessary portfolio shifting solely caused by the advancement of time. Typically, the selection of ITSP is based on mean-variance analysis borrowed from financial portfolio management. Unfortunately, this kind of objective function provokes time-inconsistent solutions. The literature suggests two methods to cope with time-inconsistent decisions, namely, precommitment and consistent planning. Whereas the former does not account for the dynamic nature of the problem, the latter still awaits implementation in IS research.

We structured the study using a classification of different decision problems that typically arise, leading to four clusters of decision problems. Even though "[…] there is not a single, uniform approach to developing a […] review article" (Schwarz et al. 2007, p. 44), this approach bears the risk of ignoring relevant content. On the other hand, descriptive, systematic literature reviews (cf. e.g., Levy and Elli 2006; Webster and Watson 2002) put much emphasis on completeness and reproducible research results, however, this technique has also been critically discussed in academia (for an overview, see Boell and Cecez-Kecmanovic 2014, p. 258f.). Therefore, we believe that a structured and theory-driven discussion is a reasonable first step to identify and discuss specific challenges regarding the financial ex ante valuation of IT service investments. However, we encourage future systematic literature reviews that comprehensively investigate single questions derived from our findings. Considering the highly complex, multi-faceted nature of IT business value, we focused on the financial ex ante valuation of IT service investments based on net cash flows from a decision theoretical perspective. Therefore, our study is subject to limitations, which offer several starting points for future research from both a theoretical and a practical perspective, as follows.

- We did not explicitly account for the specific characteristics of intangible value components, which can hardly be measured by means of quantitative, financial performance measures. Thus, a possible next step for future research is in-depth investigation of different types of IT service investments and their specific, intangible value components. For this purpose, classification schemes that cluster intangible benefits along certain criteria and allow for a structured analysis of the broad range of varying intangible benefits could be a helpful starting point for future work. Hares and Royle (1994) arrange intangible benefits according to their difficulty of measurement. To consider the often-delayed impact of intangible benefits, they distinguish between ongoing intangible benefits (e.g., internal improvements on process level or improved customer service) and future intangible benefits (e.g., aspects of foresight and adaptability to changing market environment). Future work could analyze different types of IT service investments and their specific intangible value components along such a classification scheme and discuss suitable approaches to measure the impact of the various intangible benefits. Given the high relevance of financial justification techniques in the budgeting processes of companies and considering ever-increasing economic and competitive pressure, we believe that further research is needed to deepen our understanding on how specific intangible benefits are related to the financial bottom-line of companies. While it is obvious that many intangible benefits elude a direct monetary valuation by their very nature, some approaches in the literature show that in certain cases, an indirect financial ex ante valuation of intangible benefits could be achieved (e.g., Dutta 2004; Murphy and Simon 2001; Peacock and Tanniru 2005). By means of a structured and comprehensive analysis of the underlying causal chains, these approaches aim to quantify the ability of an intangible benefit to affect the financial bottom-line indirectly (e.g., the intangible benefit of "improved customer satisfaction" could be related to a quantifiable increase of a company's sales). Future research could build on such approaches and apply them to the case of different IT service investments.
- Taking into account the multi-faceted business value of IT service investments, further research is required on the possibilities of decision theory to capture the multidimensional value components of IT service investments in an integrated way. Decision theory in general provides a sound theoretical framework to address this issue for several reasons. First, decision theory allows for capturing the different performance types of IT service investments by means of different scale levels (e.g., Schryen 2013, p. 152; Schryen and Bodenstein 2010, p. 9). In this way, intangibles that usually cannot be measured on a cardinal level could be considered by applying an ordinal scale (e.g., by comparison with competitors). Second, decision theory provides the possibility to valuate these different types of performance by means of utility functions that reflect the subjective preferences of the respective decision maker. Third, decision theory allows for the simultaneous consideration of different and possibly conflicting performance types by means of approaches for multi-criteria decision making (e.g., Sylla and Wen 2002). Thus, based on multi-criteria decision making, multiple evaluation criteria can be aggregated into a single value, that is, various tangible and intangible performance types can be considered in an integrated way to assess the multi-faceted business value of IT service investments. In summary, further research should investigate the question of how well-known methods from multi-criteria decision making have to be modified to enable an integrated, multidimensional ex ante valuation of IT service investments as a next step. Our decision theoretical considerations regarding the financial valuation of IT service investments might build a solid base for future research, since assessing the financial bottomline in a theoretically well-founded way provides an essential component within multi-criteria valuation approaches.
- Due to the theoretical nature of our study, we did not address the practical challenges that come with implementing a financial ex ante valuation of IT service investments in business practice. In particular, problems regularly occur regarding the collection and estimation of input data necessary for a financial ex

ante valuation. For instance, estimating the benefits of innovative, first-of-a-kind IT service investments is challenging, as their market impact is often unclear and experiences from comparable projects conducted in the past are largely missing. Thus, estimating the potential cash flow effects of such investments is often based on the gut feeling of area experts. Consequently, the inherent uncertainty of estimations has to be taken into account by an adequate risk discount or by performing scenario analyses. Furthermore, cooperative knowledge sharing with business partners that have already gained experience with comparable IT service investments might help enhance the validity of benefit estimations. Another challenge is that a comprehensive evaluation of IT service investments requires the involvement and collaboration of experts from both business and IT sides. This often results in complex communication and coordination processes that generate considerable overhead costs, lead to time delays, and might distort the quality of valuation. Thus, further research with a stronger emphasis on the challenges of implementing financial valuation approaches in business practice is needed. In particular, the provision of methods and processes that support companies in determining the necessary input data for financial valuation approaches is a worthwhile research area.

Despite these open topics for future research, our decision theoretical considerations shed light on the suitability of common financial valuation approaches to capture the specific characteristics of IT service investments. Considering the manifold challenges and limited consideration of ex ante valuation approaches for IT service investments in the literature, we believe that our decision theoretical discussion represents a valuable first step toward the future development of theoretically sound financial ex ante valuation approaches.

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