3-5-2015

Interactions in IS Project Portfolio Selection - Status Quo and Perspectives

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Status Quo and Perspectives

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Abstract. One central and important requirement for IS project portfolio selection is the adequate consideration of project interactions. However, the IS discipline notably lacks a common understanding of the nature of project interactions and their impact on IS project portfolio selection. To remedy this we conduct a systematic and interdisciplinary literature review thereby providing a starting point for a cumulative research tradition. The main contribution of this paper is the development of a taxonomy to summarize the current state-of-the-art. Thereby, we provide a basis enabling researchers to develop integrated approaches. Based on the identified research gaps we formulate a research agenda for the field of IS project portfolio selection considering interactions.

Keywords: IS Investment Portfolio Management, Intertemporal Interactions, Intratemporal Interactions, IS Project Portfolio Selection, Literature Review

1 Introduction

The selection of the most appropriate projects for a project portfolio has become an increasingly important and recurring activity in many organizations [3]. Its importance has been recognized by researchers, as well as IS executives [58]. Since there are usually more project proposals available than can actually be undertaken within the financial and organizational constraints of a firm [66], crucial choices have to be made in the selection of the most suitable projects for inclusion in a viable project portfolio [3]. There is ample evidence that the implementation of a consistent portfolio management process has a positive impact on portfolio performance [17]. The identification and consideration of project interactions in the planning of a project portfolio is a “crucial success factor” [11], albeit one that is often neglected in business practice [70]. For comprehensibility, and in line with [25] and [46], we use the term ‘interaction’ instead and treat it synonymously to the term ‘interdependency’ for the remainder of this article. The inadequate consideration of project interactions, such as synergistic or cannibalizing effects due to IS resource sharing, has been iden-

12th International Conference on Wirtschaftsinformatik,
March 4-6 2015, Osnabrück, Germany

Müller, M. P.; Meier, C.; Kundisch, D.; Zimmermann, S. (2015): Interactions in IS Project Portfolio Selection - Status Quo and Perspectives, in: Thomas. O.; Teuteberg, F. (Hrsg.): Proceedings der 12. Internationalen Tagung Wirtschaftsinformatik (WI 2015), Osnabrück, S. 737-751

tified as one of the main reasons for project failure [12]. Additionally, "valuable cost savings and greater benefits" can be made by considering these interactions [58]. In the context of, on the one hand, project failure rates of above 25% [52], representing a global value destruction of approximately 900 billion USD [30] and, on the other, ever increasing investments in IS [31], it seems all the more indispensable to account for these interactions if unfavorable project portfolio selection (PPS) decisions are to be avoided (e.g., [47, 70]). Over the past decades an extensive body of literature contributing to the understanding of interactions in the PPS process has emerged in fields as diverse as capital budgeting, research and development (R&D), operations research (OR), information systems (IS), and project management. The different contributions often apply methods and models from very different methodological camps. Up to now, these contributions typically focus on the development of approaches for very specific problem domains and usually comprise only subsets of all possible types of interactions, while most IS projects in practice are potentially subject to multiple (different) types of interactions. As a result, an integrated, comprehensive consideration of different types of interactions in a comprehensive approach for a more general problem class does not exist. Consequently, it is a challenging task to transfer learnings from these rather specific approaches to facilitate a better understanding of different types of interactions and their impact on PPS decisions and portfolio performance. The fragmentation of the various insights from across the often widely disconnected literature strands may explain why it is difficult to establish a cumulative research tradition, which enables a more comprehensive and fruitful understanding of interactions employed within various approaches and disciplines. In order to fill this void the main contribution of this paper is the development of a taxonomy to summarize the current state-of-the-art. Thereby, we provide a basis enabling researchers to develop integrated approaches and identify a lack of descriptive knowledge. Based on the identified research gaps we formulate a research agenda for the field of IS PPS considering interactions.

2 Taxonomy Development

Taxonomies can provide a structure for a better understanding of knowledge in complex domains and constitute the input that is necessary for building theory and identifying new research directions [55]. A taxonomy for a structured analysis of the literature may likewise help to clearly present the valuable knowledge that has already been created by researchers in the field of interactions in IS PPS. We apply the empirical-to-conceptual approach [55]. In this approach, first relevant meta-characteristics from the literature for categorizing a subset of objects are identified. Subsequently, specific characteristics of these objects that follow from the meta-characteristics are deduced. Hereafter, these characteristics are grouped and form the initial dimensions of our taxonomy (cf., [55]). For our literature review, the derived meta-characteristics are then used as a guiding framework to categorize the literature. For the development of our taxonomy and the following classification of the literature, we conducted a literature review according to [68]. As PPS is a multi-facetted discipline we take into account literature from IS, capital budgeting, R&D, project management, finance and economics, and OR. We conducted a keyword search using the Google Scholar service, the Scopus database, and the Thomson Reuters Web of Science. As a starting point, we searched for "Project Interdependency" and "Project Interaction" as well as the corresponding plural forms. These rather general keywords cover a wide range of articles that are concerned with, for example, project management and project selection in conjunction with the term interaction or interdependency. As we specifically focus on articles concerned with the construction of project portfolios, we also included the keywords "Project Portfolio Selection", "Project Portfolio Management", and "IS Portfolio", as well as their plural forms into our search. To narrow the scope of our search, we also included the more specific keywords "IS Investment", "Real Option" on their own and for the corresponding plural forms. Additionally, we included the articles reviewed by [46, 65] and the articles concerning interactions reviewed by [15]. After conducting a title and abstract analysis we excluded contributions which either considered interactions as a marginal note or which do not contribute substantially to the discussion of interactions in PPS. After eliminating duplicates, we reviewed the references contained in the articles to determine the contributions on which their work is built. Finally, we used Google Scholar to identify contributions citing the previously found articles. 36 peer-reviewed articles remained in our literature pool to build the taxonomy and for the subsequent classification (see Table 1).

In a first step, we define the meta-characteristics that are used to discriminate the articles. Our first meta-characteristic of interest is *Types of interactions*. Different approaches support different types of project interactions to be incorporated into the PPS decision. Various 'ad hoc' definitions of project interactions can be found in the literature, each operationalizing a particular understanding of project interactions (e.g., [1, 7, 20, 32]). First steps towards a consolidation of the manifold definitions found in the literature have been provided by [15] for R&D and [46] for IS projects. Based on [20, 46], we derive the following characteristics for this meta-characteristic: 1) Intertemporal: Output interactions, output-resource interactions; 2) Intratemporal: Resource interactions, output interactions, output-resource interactions.

Interactions that occur if multiple IT projects are conducted consecutively within consecutive portfolios are referred to as intertemporal interactions. Additionally, we use the term intratemporal to designate interactions that occur if multiple IT projects are conducted simultaneously within the same portfolio. Resource interactions occur if two or more projects require the same resource and, therefore, the amount of resource required for their joint implementation is larger or smaller than the sum of the projects. Resource interactions are solely intratemporal. Output interactions occur if there is a non-proportional decrease or increase in the benefits achieved when two or more projects are conducted together rather than individually. Output interactions can either be intratemporal (occurring among projects within the same portfolio) or intertemporal (occurring among projects in consecutive portfolios). Output-resource interactions occur if a project cannot stand alone and requires outputs of other projects conducted as mandatory resources. While Output-resource interactions are typically intertemporal they may also occur among projects within the same portfolio. Output-resource interactions can therefore be either intra- or intertemporal.

A substantial part of the literature on interactions stems from the R&D literature. R&D models often consider interactions between only two projects at a time (i.e., pairwise interactions), while approaches for IS PPS have been proposed that are able to consider interactions among three or more projects. To capture the ability to incorporate such higher-order interactions we introduce the meta-characteristic *Order of Interactions* into our taxonomy. From this we derive the following two concrete characteristics: pairwise interactions, and higher order interactions.

The third meta-characteristic we define is *Methodological Origin*. The methodological origin of the proposed approaches strongly influences the types of interactions that an approach is able to consider, as well as the required inputs and expected outputs of an approach. We follow a conceptual-to-empirical approach [55] and use and build on the methodical classification framework of [35] who subdivide approaches for project selection into: Mathematical programming, cognitive emulation models, benefit measurement methods (including financial investment models such as real option approaches, cf. [35]), and ad hoc methods.

Some approaches aggregate project outputs into a single (often a financial benefit) measure, while other approaches provide the opportunity to define and consider multiple goals (e.g., benefits, degree of resource utilization, and risks) within the PPS decision. Single- and multi criteria approaches each bring unique strengths and limitations to particular decision environments. To consider these differences we include the *Objective Function* meta-characteristic and distinguish between single-criteria (Single) and multi-criteria (Multi) approaches within our taxonomy.

Most articles of the domain suggest some sort of artifact. Different evaluation types for these artifacts have been applied in the literature. Each evaluation type has its merits and limits. To identify future research directions it is important to consider the scope and extent to which different approaches have been evaluated. Consequently, our fifth meta-characteristic concerns the *Type of Evaluation* of the artifacts presented in the literature. We identified the following evaluation types: proof of concept, performance evaluation, artifact comparison, sensitivity analysis, scenario analysis, and lessons learned. The scope of evaluation and the conclusions that can be drawn from it are related to the type of data used. Thus, we introduce the meta-characteristic *Data*. We identified different types of data used to visualize the application of approaches for IS PPS, namely, artificial examples, randomly generated data sets, real world examples, and numerical examples.

Another meta-characteristic defines the *main paradigmatic focus*, which determines what type of knowledge the article aims to produce. In accordance with [34] we identified two types of main paradigmatic focus. Namely, articles either mainly generate descriptive knowledge or prescriptive knowledge. Descriptive knowledge represents knowledge that informs the research problem ("what-knowledge"; cf., [34]). Specifically, in the context of our work, descriptive knowledge aims at understanding the nature and the origins of interactions, their effect on PPS, or the development of a theoretical foundation and sets of assumptions necessary to understand and solve the problem of IS PPS. Prescriptive knowledge represents the development of artifacts that are used to solve the same or similar research problems ("how-knowledge"; cf., [34]). In the context of IS PPS, the development or use of approaches to select IS projects considering interactions constitute examples for prescriptive knowledge. The resulting taxonomy is depicted in Table 1.

3 Literature Review

We structure and discuss the results of our literature review according to the meta-characteristic Types of Interactions, which almost perfectly separates the articles into two distinct streams of literature.

3.1 Intertemporal Interactions

In the IS literature approaches have been suggested to incorporate intertemporal interactions, either intertemporal output interactions (e.g., [7, 57]) or intertemporal output-resource interactions (e.g., [24, 45, 56, 62, 63,]), in PPS decisions. Specifically, output-resource interactions can be found in most articles whereas only a few articles consider output interactions (cf., results of the literature review depicted in Table 1).
The majority of articles integrating intertemporal interactions in PPS decisions only consider pairwise interactions (e.g., [5, 6, 21, 24, 37, 45, 53, 56, 62, 63]) while higher order interactions are by now only considered in a few articles (e.g., [7, 57]). The IS literature acknowledges that to consider intertemporal interactions in the evaluation of IS investments by basing PPS decisions on benefit measurements, like net present value (NPV) analysis, leads to an undervaluation of IS investments as this approach neglects managerial flexibilities in terms of options to, for example, defer, abandon, extend, reduce an IS investment (e.g., [10, 60, 62]). In this context, real option analysis (ROA) to value managerial flexibilities, specifically output-resource interactions that are embedded in IS investments such as the introduction of standard software (e.g., [4, 63]), individual software (e.g., [7]), or new technologies (e.g., [9, 41]) has increasingly caught the attention of researchers in recent years ([10]; the classification of IS investments is taken from [65]). To value such real options considering output-resource interactions, many approaches in the IS literature use standard financial option pricing models that incorporate different future states of the world, particularly the Black-Scholes model (BSM) (e.g., [10, 37, 62]), its discrete counterpart the Binomial model (e.g., [42]), or the Margrabe model (e.g., [7, 24]), an extension of the BSM. As most articles apply approaches developed in other disciplines (e.g., Finance and Economics) evaluations of the applicability of these approaches to value IS investments are conducted. Some articles rely on sensitivity analysis to show that their results are stable even in a changing business environment (e.g., [23, 36, 53]), while other articles apply an artifact comparison to highlight the superiority (or differences in the results) of one, two or more approaches (e.g., [6, 10, 24, 45, 62]). Specifically, most articles illustrate that the BSM is superior to NPV analysis (e.g., [36, 37, 53, 56, 60, 63]). Other articles highlight the differences between the results of the BSM and the Margrabe Model (e.g., [45, 62]) or the superiority of a modified approach to a standard ROA approach (e.g., [6, 10, 20, 21, 26]). As a next step it would be interesting to conduct an ex-post evaluation where approaches are validated in terms of a comparison of the model results and the actual results from the real world examples

by, for example, interviewing IS executives ex-post. The ex-post evaluation of approaches and their accuracy would be interesting and supportive to advance existing approaches and estimation techniques for input parameters and to evaluate the applicability of these approaches for practice.

Another commonality among the articles on intertemporal interactions is their exemplification of their approaches through real-world business cases (e.g., [5, 7, 24, 26, 32, 53, 56, 60, 62, 63]), ranging from software platform decisions for a company manufacturing auto parts [62, 63] to the decision between moving a financial function to several regional shared services centers or to a global shared services center [60].

The main paradigmatic focus of the literature on intertemporal interactions lies on designing approaches for the valuation of real options embedded in uncertain IT projects (e.g., [4, 5, 6, 7, 10, 20, 21, 23, 24, 26, 32, 37, 45, 53, 56, 57, 60, 62, 63,]). Hence, they focus on the further development of prescriptive knowledge (cf., [34]). Descriptive knowledge is not discussed extensively or further developed (cf., Table 2), but is usually mentioned to discuss single assumptions and ground the developed approaches (e.g., [4, 8, 9, 21, 41, 62]). Even though these articles are well grounded in the literature they exhibit a strong focus on prescriptive knowledge and do not exclusively focus on theory building.

The majority of articles to date aim to visualize how the consideration of intertemporal interactions changes the IS investment decision in comparison to traditional approaches like DCF analysis (e.g., [24, 60, 62]), or how ROA approaches have to be extended to fit the underlying IS investments (e.g., [6, 10, 21]). Numerous other articles communicate and visualize how to apply ROA approaches in the field of IS investments (e.g., [4, 5, 21, 26, 53, 62]). At the same time, critics raise concerns about the assumptions underpinning ROA approaches developed in Finance. Several authors question assumptions such as, for example, discounted cash inflows following a geometric Brownian motion (e.g., [38, 62, 63]), the existence of a complete market (e.g., [21, 42]) or certainty and knowledge concerning discounted cash outflows (e.g., [4, 7, 41]). Thus, researchers should not only increase the understanding of "option thinking" [63], but also develop more accurate approaches for valuing real options that are embedded in uncertain IS investments [61]. This suggests that a worthwhile next step would be to develop models that are more aligned with characteristics of IS investments. The issue of applicability also reflects a potential gap between theory and practice. For example, [44] observed that one of the most frustrating challenges for an upper level executive of a high technology company is to get the approval for a new investment project because of a lack of analytical support for such an investment, even though it is clear to the decision makers that its real value may not stem from direct cash-flows but from future opportunities it creates. The body of literature on intertemporal interactions has certainly increased the understanding of "option thinking" and illustrates the application of ROA approaches in the field of IS investments using real world examples. Nevertheless, as [66] point out, ROA approaches are not yet applied by managers who feel that ROA approaches overvalue the real value of investments and that, since they were developed for financial options and not for complex business investments, there is an obvious hiatus in the underlying assumptions. At the same time managers know that DCF analysis underestimate the value of business investments [66]. [70] concludes that the gap between practical knowledge, practical applications, and theoretical real option models to value IS investments considering intertemporal interactions exists. He also points out that ROA seems to be some kind of "terra incognita" for most companies, as they use qualitative analysis or fundamental quantitative analysis, for example, cost utility analysis. Likewise [18] argue that companies try to use ROA approaches to value investment projects but give it up due to difficulties in applying these approaches or they are not satisfied with the results as investment projects are far more complex than financial options, and it would be careless to reduce its complexity by trying to make the investment project fit into the financial option pricing approach. Future research should try to develop approaches that value IS investments by considering intertemporal interactions, the characteristics of IS investments, and that managers can apply these approaches.

3.2 Intratemporal Interactions

Due to the complexity resulting from the consideration of intratemporal interactions, techniques from the mathematical programming domain have been employed to calculate optimal project portfolios. In the R&D, capital budgeting, and OR literature a variety of approaches have been suggested to incorporate the different types of intratemporal interactions. In particular, resource interactions seem to be well recognized in the literature, judging by the number of articles (e.g., [1, 14, 29, 32, 47, 49, 50, 58, 59]). There is a relatively clear understanding of what causes resource interactions in IT projects, with numerous examples featuring in the literature, but always related to a specific resource level (e.g., sharing of hard- or software [33, 58]). In contrast, the understanding of output interactions seems to be fuzzy. Only unspecific examples for output interactions can be found, measured only in monetary units.

Some approaches consider pairwise interactions (e.g., [14, 16, 25, 54]) while more sophisticated ones are able to handle interactions among three or more projects (e.g., [1, 13, 19, 22, 29, 32, 43, 47, 48, 58, 59, 69]). Considering only pairwise interactions seems to restrict the real world applicability of approaches in the IS domain severely due to the comparably high degree of interdependency among IS projects [33]. By contrast, the identification and assessment of interactions becomes more and more difficult with an increasing order of interactions needing to be considered [69].

Single criteria optimization approaches (e.g., [1, 14, 29, 32, 54, 58, 69]) as well as multi criteria approaches (e.g., [13, 22, 43, 47, 49]) exist. While single criteria approaches guide the decision making, the focus of multi-criteria approaches lies more on supporting the decision making process by providing alternatives to the decision maker. We identified a notable trend in the literature of the last decade favoring multi-criteria over single-criteria approaches. Despite their differences, all the identified approaches provide the methodical and analytical rigor to produce high quality portfolio solutions under consideration of complex restrictions, while comprehensively considering intratemporal interactions. Some approaches support the consideration of multiple planning periods and, thereby, simple forms of intertemporal output-resource interactions (successor-predecessor relationships) as well (e.g., [13, 22, 48, 59]).

Numerous articles concerning intratemporal interactions are aiming at integrating these interactions into the portfolio planning process. A large part of these articles stem from problem solving domains like OR. Consequently, the contributions of the articles found in our review generally are methods, models, or algorithms that aim at solving specific problems while considering intratemporal interactions ([1, 13, 14, 16, 19, 22, 25, 29, 32, 43, 47, 48, 49, 54, 58, 59, 69]). The *main paradigmatic focus* of these articles can therefore be classified as creating prescriptive knowledge. While prescriptive knowledge constitutes the main focus, descriptive knowledge usually can be found in these articles in forms of motivating the assumptions under which the presented approaches work. Very few articles can be highlighted ([29, 32]), which exhibit an above-average degree of this descriptive knowledge, while maintaining their prescriptive focus. As a conclusion, while the articles found within our review are well grounded in the literature, this research strand exhibits a strong focus on prescriptive knowledge. We could identify virtually no research in this area that exclusively focuses on theory building and understanding the phenomenon of intratemporal interactions and their effect on PPS decisions. While IS PPS itself represents a topic of high practical relevance [51] the functioning of the identified approaches has been demonstrated almost entirely by using simplified, artificial examples (e.g., [1, 43, 47, 69]) or randomly generated data (e.g., [13, 14, 49]). Only few approaches use simplified real world data sets to evaluate their artifacts (e.g., [25, 58]). Artificial, small scale examples are primarily used to proof the concepts of individual artifacts (e.g., [1, 16, 19, 25, 29, 32, 47, 54, 69]). Randomly generated data sets (e.g., [14, 49]) or small, simplified real world examples are used to provide performance evaluations [39] of the proposed artifact – typically in comparison to other competing artifacts or state of the art problem solving approaches (e.g., [25, 58]). While this constitutes a valuable first step for the evaluation of the soundness of the proposed artifacts the literature in this area widely lacks real world applications to demonstrate the relevance for business practice of considering intratemporal interactions.

We identify two major issues that contribute to the absence of real word applications in the literature: First, the comprehensive consideration of the different types of intratemporal interactions typically requires a high methodical complexity within the applied approaches, which potentially leads to a lack of transparency of the solution finding process. While PPS is a "[…] multi-person decision making process involving a group of decision makers […]" [64], this arguably restricts its application in business practice. Second, with increasing capability to consider interactions a substantial and increasing amount of input data are required [69]. [29] identify the difficulty "to assess the interactions directly" as a major reason for the lack of use of those techniques in practice. Our findings suggest that, while from a methodical point of view, the problem of considering intratemporal interactions is more or less solved in the literature, the problem of data gathering to fill these models has not been adequately addressed. Thus, we identify a research gap in the identification and assessment of intratemporal interactions as input parameters for the suggested approaches. If practitioners are adequately supported in the identification of intratemporal interactions in the future, research in this field will be rewarded with an increasing number of real world applications of these approaches. These real world applications are urgently required to not only answer the question of how one can consider intratemporal interactions adequately, but rather identify and quantify the potential economic impact of their consideration. Few articles already provide empirical evidence for the economic effects of output interactions. For example, [2] investigate a data set of 623 U.S. firms and find that the combined implementation of Enterprise Resource Planning, Customer Relationship Management, and Supply Chain Management Systems can lead to over-proportional performance gains. Similar results are provided by [27], who observes positive effects among three enterprise software systems when they are used together. While first empirical evidence can be found for output interactions, particularly for resource interactions, we identify a gap between their prevalence in the models from the literature, and the absence of empirical evidence for the benefits of their consideration during portfolio planning. We therefore identify the need for future research concerning resource interactions in order to provide empirical evidence for the claim made on the importance of resource interactions for PPS.

Table 1. Classification of Research Articles

Intra			Inter		OoI	Methodological Origin	Obj-Func	Evaluation	Data	MPF	Articles
R	O	O-R	O	O-R							
X	X	X		X	HO	MP	Single	PoC	AE	PK	[69]
X	X	X		X	HO	MP	Multi	PoC PE	AE	PK	[59]
X	X	X		X	HO	MP	Multi	PE	RWE	PK	[22]
X	X	X		X	HO	MP	Multi	PE	AE	PK	[48]
X	X	X		X	HO	MP	Multi	PE	RGDS	PK	[13]
X	X	X			HO	MP	Single	PoC	AE	PK	[1]
X	X	X			HO	MP/CEM	Single	PoC	AE	PK (DK)	[29]
X	X	X			PW	BM	Single	PoC	AE	PK	[54]
X	X	X			HO	MP	Single	PE by AC	RWE	PK	[58]
X	X	X			HO	MP	Multi	PoC	*(None)*	PK	[19]
X	X	X			HO	MP/BM	Multi	PoC	AE	PK	[47]
X	X	X			HO	MP	Multi	PE	AE	PK	[43]
X	X	X			PW	BM	Multi	PoC	AE	PK	[16]
X	X	X			PW	MP	Multi	PE	RGDS	PK	[49]
X	X			X	HO	MP/CEM	Single	PoC	*(None)*	PK (DK)	[32]
X	X				PW	MP	Single	PE	RGDS	PK	[14]
X	X				PW	MP	Multi	PoC	RWE	PK	[25]
				X	PW	BM (ROA)	Single	AC	RWE	PK	[20, 21, 24, 26, 37, 60]
				X	PW	BM (ROA)	Single	AC, ScA	NE	PK	[45, 10]
				X	PW	BM (ROA)	Single	AC, ScA	RWE	PK	[56, 62, 63]
				X	PW	BM (ROA)	Single	LL	RWE	PK	[5]
				X	PW	BM (ROA)	Single	AC, SeA	RWE	PK	[53, 32]

				X	PW	BM (ROA)	Single	AC, SeA	NE	PK	[6]
				X	PW	BM (ROA)	Single	SeA	RWE	PK	[23]
			X	X	HO	BM (ROA)	Single	AC, SeA	RWE	PK	[7]
		X		X	HO	BM (ROA)/MP	Single	SeA	RWE	PK	[4]
	X		X	X	PW	BM (ROA)/MP	Single	PE	RWE	PK	[57]

Legend Table 1		
Table Captions	**Cell Entries**	
Intra – Intratemporal Interactions Inter – Intertemporal Interactions OoI – Order of Interactions Obj-Func – Objective Function MPF – Main Paradigmatic Focus R – Resource Interaction O – Output Interaction O-R – Output Resource Interaction	BM – Benefit Measurement Methods CEM – Cognitive Emulation Models MP – Mathematical Programming RGDS – Randomly Generated Data Sets ROA – Real Option Analysis	AE – Artificial Example DK – Descriptive Knowledge HO – Higher Order Interactions NE – Numerical Example PW – Pairwise Interactions PK – Prescriptive Knowledge RWE – Real World Example

4 Research Agenda and Conclusion

"A major challenge for IS research lies in making models and theories that were developed in other academic disciplines usable in IS research and practice" [8]. First steps towards advancing the knowledge in the field of IS PPS considering project interactions are conducted in this literature review by the development of a taxonomy for the aggregation of a knowledge base. To enable a cumulative development of knowledge, we summarize our major findings and suggest the following research questions as starting points for future research in Table 2.

The literature on intratemporal interactions focuses on the question how the different types of interactions can be systematically incorporated into the decision making process. As one major finding, we suggest that future research should investigate different types of project interactions, and thus, answer questions concerning the value of considering interactions during IS PPS. First approaches that aim at exploring the different types of these interactions can be found in the literature. For instance, [67] apply case study research to facilitate an understanding of project team members' prioritizations and their relationship to performance among R&D projects even though they do not focus on the effects of PPS. Further, it is necessary to investigate the trade-off between search costs associated with the identification and assessment of interactions for PPS and the benefits of considering them. In this context [50] provide a first approach for the identification of resource interactions.

The literature considering intertemporal interactions is usually concerned with the provision of better, more reliable cost and benefit estimation techniques for interrelated IS investments, taking into account managerial flexibilities of IS investments. Further, it has been worked out why certain approaches, like DCF analysis, are not applicable in the context of IS investments considering intertemporal interactions. It would appear, then, that an interesting next step would consist in considering the characteristics of IS investments in more detail to develop more accurate approaches that consider intertemporal interactions embedded in uncertain IS investments [61]. This could involve investigating the applicability of ROA from other disciplines to value IS investments considering intertemporal interactions, but would require approaches from finance, economics, and OR (e.g., [28, 40]) to be adapted and extended in order to comply with the characteristics of IS investments and intertemporal interactions.

Table 2. Findings and Future Research

Topic	Findings	Future Research Questions
Real world applications for intratemporal approaches	• Lack of real world applications of intratemporal approaches • High amount of input data required, which is often unavailable	• How can the identification and assessment of different types of intratemporal interactions be adequately supported?
Effect of intratemporal resource interactions on PPS decisions	• Comparably clear understanding of the nature of resource interactions • Anecdotal evidence for the importance of intratemporal resource interactions on PPS decisions • High costs associated with data gathering for resource interactions	• Is it worth considering resource interactions when selecting an IS project portfolio?
Effect of intratemporal output interactions on PPS decisions	• Fuzzy understanding of output interactions • First empirical evidence for the economic relevance of intratemporal output interactions on portfolio selection	• Is it worth considering output interactions when selecting an IS project portfolio? • How can output interactions be made more tangible to portfolio planners?
Effect of intertemporal interactions on PPS decisions	• Anecdotal and analytical evidence for the importance of considering intertemporal interactions • ROA approaches from finance and economics are superior to traditional DCF analysis • Characteristics of IS investments are not considered adequately • For IS managers ROA is still a kind of "terra incognita"	• How can characteristics of IS investments be better integrated into ROA approaches? • How can researchers support the use of ROA approaches in companies? • How can approaches from other disciplines be adapted?
Integration of inter- and intratemporal interactions	• Intertemporal approaches focus on valuing of IS investments • Intratemporal approaches focus on PPS • No approach available that comprehensively incorporates inter- AND intratemporal interactions	• Is it economically justified to comprehensively incorporate inter- and intratemporal interactions into a holistic approach? • How can inter- and intratemporal interactions be adequately incorporated into a common research framework?

Despite the fact that research on inter- and intratemporal interactions addresses very similar issues, the literature lacks approaches that are able to incorporate the benefits of considering inter- as well as intratemporal interactions into a common framework. This is noteworthy as IS investments often comprise both inter- and intratemporal interactions as highlighted by [7] or [57]. Many models discussed in this article are already able to incorporate successor-predecessor relationships and multiple periods. These models could make good use of the estimates for interdependent projects derived by ROA to include them into PPS. First valuable efforts to bring these two streams together have been provided by [7] and [57]. While the literature on intra- and intertemporal interactions provides insights on how to incorporate different types of interactions into PPS decisions, our analysis highlighted a lack of articles specifically focusing on a further development of descriptive knowledge. Descriptive knowledge is required to better understand the phenomenon of interactions, their causes, and to develop well-founded approaches. Our work provides a first step towards developing descriptive knowledge and a better understanding of interactions in PPS. Further, we encourage researchers to engage in facilitating the development of a well-founded understanding of interactions. We also argue that a trade-off exists between the effort that has to be invested to identify and quantify relevant intra- and intertemporal interactions and the potential benefits of considering those interactions. We encourage researchers to investigate this trade-off in the future to provide qualitative as well as quantitative answers to the question whether it is economically justified to consider intra- and intertemporal interactions when planning project portfolios.

Concluding, our findings indicate that while the methodical toolbox differs widely between approaches that specialize on considering either inter- or intratemporal interactions, the approaches used within the corresponding research streams often utilize similar approaches and assumptions. Practitioners can draw from a number of valuable approaches to consider interactions during IS PPS. Admittedly, practitioners have to select carefully, because different approaches require different amounts of input data, provide varying degrees of flexibility, based on differing assumptions, with varying levels of transparency to the portfolio planner. Our work offers a useful source of information to practitioners on the capabilities and limitations of the state of the art in IS PPS and, thereby, reduces potential barriers to introducing these approaches into business practice. Researchers can use our taxonomy to position their own research more precisely and to address the identified research gaps.

Acknowledgments
We thank the Austrian Science Fund (FWF): P 23567-G11 for funding this research.

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