IT/IS Project Portfolio Selection in the Presence of Project Interactions – Review and Synthesis of the Literature

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ABSTRACT

Adequately considering interactions among IT/IS projects in the process of constructing an IT/IS project portfolio is an important requirement for value-based IT/IS project portfolio selection. A lot of articles already deal with modeling approaches to incorporate such interactions, but the literature lacks a common terminology and a structured perspective on the manifold types of interactions and their effects. When applied in business practice, this may lead to a systematically wrong project portfolio selection. Based on a comprehensive literature review, our contributions are (1) an identification of relevant classification dimensions of IT/IS project portfolio selection, (2) the development of a framework that provides a structured perspective on deterministic, intratemporal interactions, and – as the main contribution – (3) a unification of the terminology and the semantics of interactions among IT/IS projects. This work shall support decision-makers in the identification of possible interactions among IT/IS project proposals.

Keywords

IT/IS project portfolio selection, IT/IS project, interactions, interdependencies, classification framework

1. INTRODUCTION

The selection of information technology/information systems (IT/IS) projects[1] to construct appropriate IT/IS project portfolios[2] is an important and recurring activity in many organizations [2], [26]. At the time of planning there are usually more projects available for selection than can be undertaken within the financial and organizational constraints of a firm, so "choices must be made in making up a suitable project portfolio" [2].

The selection process of such a project portfolio typically can be decomposed into different phases. As suggested by Archer et al. [2], in a pre-screening phase only project proposals are considered for further evaluation, which fit the strategic focus of the organization. This also includes feasibility analysis of single project proposals as well as the identification of mandatory projects. Then, the remaining proposals have to be evaluated individually and a common set of parameters (e.g. expected benefits, resource consumption) has to be derived to allow comparison among the individual project proposals in a portfolio context. In the subsequent project portfolio selection (PPS) phase, the optimal project portfolio has to be determined based on the parameters derived from the individual evaluation. Within this selection phase, it is a challenging but necessary requirement to account for interactions among IT/IS projects to avoid making unfavorable PPS decisions [28]. Lee et al. even state that "the cost of difficulty in data gathering for modeling is not so critical than the risk in selecting the wrong project without considering the interdependencies" [17].

Following [10], we use the term *interaction* instead of *interdependency* in this article. Generally, we speak of an interaction, if resources consumed or outputs generated by a project influence the use of resources or outputs generated by one or several other projects. If, for example, the same database server is needed in more than one project and each project only temporarily needs this server, it may be shared among the projects and thus has to be procured and installed only once. This example describes a typical interaction among required resources of projects.

In the early capital budgeting literature and especially in the R&D PPS literature, many approaches can be found that consider interactions among projects to some extent ([27], [1], [13], [12]). These two streams of literature already provide very useful fundamentals for the description and modeling of project interactions. But still, too little attention has been payed to the adequate consideration of interactions in the literature [10]. This becomes even more important with the advent of IT/IS projects becoming the

[1]A *project* can generally be defined as "a complex effort, usually less than three years in duration, made up of interrelated tasks, performed by various organizations, with a well-defined objective, schedule, and budget" [3].

[2]A *project portfolio* can be defined as a "group of projects that are carried out under the sponsorship and/or management of a particular organization" [2].

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dominant type of projects conducted in many organizations. One of the major differences between the R&D and IT/IS PPS problems is the increased importance and complexity of interactions among IT/IS projects. For instance Graves et al. emphasize that "[..] R&D interaction modeling is typically pairwise, [whereas] realistic IT modeling requires, that higher-order interdependencies (among three or more projects) be represented" [14].

In contrast to this claimed importance of interactions in IT/IS PPS we find comparably little research in the IT/IS project portfolio management literature that addresses the issue of interactions. Further, our results show that the work that can be found is not based on a unified terminology. In order to have a well-founded starting point for further work in the area of IT/IS PPS, this article makes three contributions. Based on a comprehensive literature review, our contributions are (1) an identification of relevant classification dimensions of IT/IS project portfolio selection, (2) the development of a framework that provides a structured perspective on deterministic, intratemporal interactions, and – as the main contribution based on the classification dimensions and the framework – (3) a unification of the terminology and the semantics of interactions among IT/IS projects. Thereby, we assume that all parameters of interest (e.g. resource consumption of or benefits resulting from projects) are deterministic and known at the time the portfolio is planned. Moreover, we focus on interactions among IT/IS projects that just affect the planning decision of the actual portfolio. The framework shall support decision-makers in the identification of possible interactions among IT/IS project proposals for further valuation and PPS purposes.

The remainder of this article is organized as follows. In section 2, we present the methodology and results of our literature review and identify relevant classification dimensions of IT/IS PPS. In section 3, using the results of our literature review and based on further conceptual considerations, we propose a classification framework for interactions among IT/IS projects and describe possible types of interactions. The results of our research as well as perspectives for future research are discussed in section 4.

2. REVIEW OF THE LITERATURE

Although the importance of considering interactions in the selection process of project portfolios seems to be acknowledged in the literature, the perspective on project interactions and the degree of detail in which they are considered vary greatly. To provide an overview on the extent to which interactions are treated in the literature and to create a basis for further investigation, we conducted an *integrative review* of the literature [11], as described in the following section.

2.1 Methodology

In the first step, we identified journals relevant for our research. Since project management is a multifaceted discipline [16], we employed both the surveys of Lowry et al. [20] covering the *Information Systems* discipline and Barmana et al. [5] covering the *Production and Operations Management* discipline. We included the top 20 journals of each of the surveys' rankings as possible outlets for our review. Additionally, we included two important *Project Management* journals identified by [16] into our review as well. After removing the duplicates of journals (bold entries in table 1), which appeared in more than one of the surveys, we obtained 38 high quality journals as the basis for our review (see table 1).[3]

Within these journals, we conducted a keyword search using the Google Scholar service (http:\\scholar.google.de). We searched for all possible combinations of the terms *project*, *portfolio*, and *selection* in combination with the terms *interaction* or *interdependence* (and their corresponding plural forms). After removing redundant results, we obtained 838 articles from which 766 could be excluded by a title analysis because they did not address our research topic at all. From the remaining 72 articles, we excluded 57 by an abstract analysis, because they considered interactions merely as a marginal note, and they did not contribute substantially to the discussion of project interactions. In table 2, we present an overview of 15 articles, which provide the largest contribution to the problem of considering and modeling interactions in IT/IS PPS. In the following subsection, we discuss the most influential articles on project interactions. Thereby, we focus on the different types of interactions considered.

2.2 Results of the literature review

The article of Weingartner [27], published in 1966, can be considered as a seminal contribution to the discussion of project interactions and their modeling in PPS from a capital budgeting point of view. Using the net present value, Weingartner suggests a single-criteria objective function and linear programming, quadratic integer programming, and dynamic programming as suitable modeling approaches. Particularly, the author discusses the possibility to postpone projects and suggests to model them as a set of *mutual exclusive* projects, from which at most one can be selected at a time. Further, "when acceptance of one proposal is dependent on acceptance of one or more other proposals" [27], Weingartner denotes this as *contingency* and suggests to combine such projects into *compound projects*. In addition, Weingartner denotes "the additional benefits from selecting two projects" [27] as *pair-wise second-order effects*. In the context of R&D projects, Weingartner also discusses interdependent investments with probabilistic returns.

In the 1970s and the 1980s, most approaches that can be found in the literature address the field of R&D PPS and make use of single-criteria objective functions. From these approaches, especially the articles of Aaker et al. [1] and Gear et al. [13] have to be mentioned. In 1978, Aaker et al. [1] present a model for project selection of interdependent R&D projects. In their article, the authors classify three basic types of interactions among R&D projects and incorporate them into an expected value model. They distinguish between *overlap in project resource utilization*, *technical interdependencies*, and *effect interdependence*. Overlap in project resource utilization is described as a positive cost synergy resulting from shared resources. The authors speak of technical interdependencies, if "the success or failure of one project significantly enhances or retards the

[3] The resulting set of journals also covers the top 10 journals of two other rankings of information systems and business computing journals (see [22] and [24]).

Rank	Lowry et al. [20]	Barmana et al. [5]	Kwak et al. [16]
1	Management Information Systems Quarterly	Journal of Operations Management	Project Management Journal
2	Information Systems Research	Production and Operations Management	International Journal of Project Management
3	Journal of Management Information Systems	**Management Science**	
4	**Management Science**	**Decision Sciences**	
5	Communications of the ACM	**Operations Research**	
6	**Decision Sciences**	IIE Transactions	
7	Decision Support Systems	**Harvard Business Review**	
8	IEEE Transactions	International Journal of Production Research	
9	Information and Management	Interfaces	
10	ACM Transactions	International Journal of Operations and Production Management	
11	European Journal of Information Systems	Naval Research Logistics	
12	Journal of the Association for Information Systems	European Journal of Operational Research	
13	Information Systems Journal	Production and Inventory Management	
14	Organization Science	International Journal of Production Economics	
15	**Harvard Business Review**	Omega	
16	Journal on Computing	Journal of Operational Research Society	
17	**Operations Research**	Journal of Purchasing and Materials Management	
18	Journal of Strategic Information Systems	Academy of Management Journal	
19	Journal of Information Systems	Computers and Operations Research	
20	Information and Organization	Academy of Management Review	

Table 1: Journals used in our literature review (duplicates in bold letters)

progress of other projects" [1]. Effect interdependence occurs, if "projects are such that their value contributions or payoffs are non-additive" [1]. Basically, these types of interactions constitute the nucleus for several refinements and extensions by other authors in subsequent articles.

Later in 1980, Gear et al. extend the scope of interactions among R&D projects by dividing the factors that can cause interactions among R&D projects into *internal* and *external* factors. These factors are defined as follows: "internal – or specific – interdependencies arise from factors unique to particular pairs or subsets of the project set, whereas external interdependencies arise over time from overall social and economic changes which have effects that cut across many, if not all, subsets of the project set" [13]. By this, Gear et al. introduced risk factors that have an impact on interactions and subsequent effects on the expected value of the project portfolio. The authors provide a multi-stage resource allocation optimization model focusing solely on the effects of external interdependencies.

Since the 1990s, increasingly multi-criteria approaches for PPS problems are presented in the literature as well as few articles which address the field of IT/IS PPS. From these IT/IS related articles, especially the articles of Santhanam et al. [25] and Bardhan et al. [4] have to be mentioned.

Santhanam et al. emphasize, that – besides many similarities between R&D and IT/IS PPS – the restriction of prior R&D approaches to consider only pairwise interactions is not sufficient for IT/IS PPS. According to the authors, "there exists a great amount of sharing hardware and software resources among various IS applications" [25] and therefore, interactions among more than two projects have to be considered. Similar to [1], Santhanam et al. divide interactions among IT/IS projects into *resource*, *technical* and *benefit interdependencies*. "Resource interdependencies arise because of sharing of hardware and software resources among various IS projects such that the implementation of two or more related projects will require less resources than if they where implemented separately" [25]. "Benefit interdependencies occur when the total benefits [..] derived from implementing two related projects increase due to their synergistic effect" [25]. Further, if "the development of an IS necessitates the development of a related project" this is denoted as *technical interdependency*. Santhanam et al. formulate a nonlinear 0-1 programming problem and present a generalized objective function which accounts for the discussed interactions among more than two projects.

Bardhan et al. [4], in 2004, distinguish between *hard dependencies* and *soft dependencies* as well as *interdependencies* among IT/IS projects. Hard dependencies are present, if "a project cannot be implemented if its predecessor project has not been implemented." [4]. The authors refer to *soft dependencies*, if "a project may be implemented without its predecessor, but its value is reduced." [4]. *Interdependencies* are described as "interactions between capabilities that are shared or leveraged among IT projects in a portfolio" [4]. The authors present a real options model that focuses on the consideration of hard and soft dependencies among IT/IS projects in *current* and *future* project portfolios.

As briefly discussed above and specifically illustrated in table 2, numerous approaches exist in the literature that consider project interactions by some means, but there is little consistency in the terminologies used. Often, the same terminology is used to describe differing types of interactions, or related types of interactions are denoted by diverging terminologies. For example, Santhanam et al. [25] refer to *technical interdependencies* "if one project necessitates the implementation of a related project" [25], whereas Aaker et al. [1] refer to *technical interdependencies* "when the success or failure of one project significantly enhances or retards the progress of other projects" [1]. Additionally, if the conduction of related projects requires less resources than it would have if the projects where conducted separately, Nelson [23] denotes this as *overlap interdependency*, whereas Lee et al. [17] call this type of interaction *resource interdependency*. Further, in numerous approaches, only a subset of the discussed interactions are considered in the actual modeling approaches (see table 2).

Different modeling approaches are based on a variety of diverse modeling assumptions. These assumptions strongly influence both which types of interactions are considered and how these types of interactions are considered within PPS approaches in the literature. In the following section we discuss three major dimensions of modeling assumptions as indicated by the results of our literature review. Subsequently, we position our framework with respect to the discussed dimensions.

2.3 Dimensions of IT/IS PPS in the presence of project interactions

The interactions identified in the literature review generally can be categorized into interactions that just affect the planning decision of the actual portfolio (e.g. interactions among scarce resources required in more than one project) and interactions that influence the decision-making today based on potential follow-up projects in future runs of project portfolio planning. In the following, the first kind of interactions is referred to as *intratemporal interactions* (e.g. addressed by [13]), whereas the second kind is denoted as *intertemporal interactions* (e.g. considered by [4]). This distinction provides the first of the dimensions illustrated in figure 1.

The second dimension is concerned with the assumption about just one or multiple future states of the world. Hence, this dimension addresses the assumption of certainty or uncertainty embedded in the relevant planning parameters. In the first case, all parameters of interest (e.g. project success or resource consumption) are assumed to be known with certainty or have been estimated as a single value (e.g. by using the expected value) at the time the actual portfolio is planned. We denote this as *deterministic*[4]. In the second case, several factors may influence e.g. a project's benefits or costs. This results in uncertain parameters that are subject to some kind of probability distribution (e.g. as in [21]). Therefore, if uncertainty is explicitly considered within an approach, we denote this approach as *stochastic* (see figure 1).

As mentioned by Archer et al. [2], "many portfolio selection techniques do not consider the time-dependent resource requirements of projects, and most implicitly assume that all projects selected will start immediately". Under this assumption, the actual planning horizon is assumed to be a *single point in time*, and possible *scheduling constraints* among projects are neglected during the selection process (as e.g. in [12] or [25]). In some recent approaches, the planning horizon is considered to be a time period of a distinct length (as e.g. in [21]). In these approaches, *scheduling constraints* among projects as well as distinct types of interactions are considered.

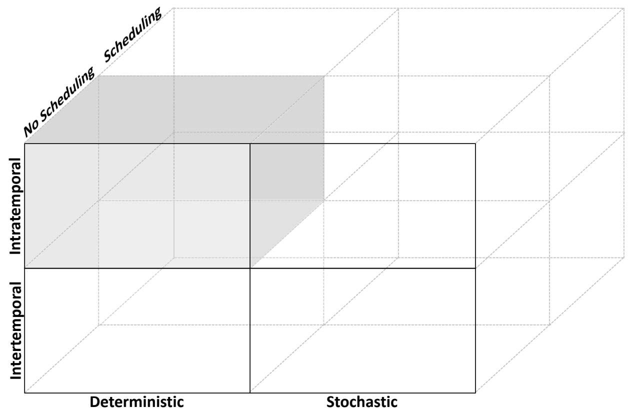

Figure 1: Dimensions of IT/IS PPS in the presence of project interactions

According to our findings and in line with Archer et al. [2], most of the articles identified in the literature solely consider intratemporal interactions and do not address scheduling constraints among projects.

Because of the diversity in the terminology particularly among the group of articles focusing on intratemporal interactions and the difficulty in adequately considering interactions already in this relatively well-defined setting, in a first step, we focus on the identification and description of intratemporal interactions without considering scheduling constraints among projects. Further, we refer to the deterministic case described above (this corresponds to the highlighted cubicle in figure 1) since that constitutes a prerequisite in order to discuss also the stochastic case.

To our best knowledge no contribution exists, which classi-

[4]An expected value may implicitly consider multiple future states of the world. Yet, if the use of the same expected value as a model parameter leads to the identical optimization results, we still denote this model as deterministic.

Article	Year	Journal	Application	Mentioned types of interactions	Explicit modeling provided	Objective function
Weingartner [27]	1966	MS	General projects / Capital budgeting	Mutual exclusivity	yes	Single-criteria
				Contingent/Compound projects	yes	
				Pair-wise second order effects	yes	
				Interrelation in success probability	yes	
Aaker et al. [1]	1978	IEEET	R&D projects	Overlap in project resource utilization	yes	Single-criteria
				Technical interdependencies	yes	
				Effect interdependence	yes	
Gear et al. [13]	1980	DS	R&D projects	(Internal) Resource interdependencies	no	Single-criteria
				(Internal) Benefit interdependencies	no	
				External interdependencies	yes	
Fox et al. [12]	1984	MS	R&D projects	Cost/Resource utilization interactions	no	Single-criteria
				Outcome, technical or probability interactions	no	
				Impact interactions	no	
				Present Value interactions	yes	
Nelson [23]	1986	EJOR	Manufacturing Systems	Overlap interdependencies	yes	Single-criteria (aggregated)
				Technical interdependencies	yes	
				Effect interdependencies	yes	
De Maio et al. [8]	1994	EJOR	New Product Development	Resource interdependencies	yes	Multi-criteria
				(Input/Output) Commonality interdependencies	yes	
				(Input/Output) System integration interdependencies	yes	
				(Input/Output) Technological prerequisites	yes	
				(Input/Output) Market interactions	yes	
Santhanam et al. [25]	1996	EJOR	IT/IS projects	Resource interdependencies	yes	Single-criteria
				Benefit interdependencies	yes	
				Technical interdependencies	yes	
Lee et al. [17]	2001	IJPM	IT/IS projects	Technical interdependencies	yes	Multi-criteria
				Resource interdependencies	yes	
				Benefit interdependencies	yes	
Klapka et al. [15]	2002	EJOR	R&D and IS projects	Synergistic effects	yes	Multi-criteria
				Contingency between projects	yes	
				Benefit interdependencies	yes	
				Risk interactions	no	
Bardhan et al. [4]	2004	JMIS	IT/IS projects	Soft dependencies	yes	Single-criteria
				Hard dependencies	yes	
				Interdependencies	yes	
Cho et al. [7]	2004	EJOR	R&D projects	Cost interaction effects	no	Multi-criteria
				Positive synergy interaction effects	no	
				Technology interaction effects	yes	
Doerner et al. [9]	2006	EJOR	R&D projects	Synergy effects	yes	Multi-criteria
				Cannibalism effects	yes	
Eilat et al. [10]	2006	EJOR	R&D projects	Resource interactions	yes	Multi-criteria
				(Competitive/Complementary) Benefit interactions	yes	
				Outcome interactions	yes	
Medaglia et al. [21]	2007	EJOR	R&D projects	Resource interdependencies	no	Multi-criteria
				Benefit interdependencies	no	
				Technical interdependencies	no	
Liesiï¿½ et al. [19]	2008	EJOR	General projects	Mutual exclusivity	yes	Multi-criteria
				Synergetic-/Cannibalization effects	yes	
				Follow-up projects	yes	

Table 2: Interactions in the literature in chronological order

fies the types of interactions discussed in the literature and which provides a unified terminology and structure for intratemporal, deterministic project interactions in the context of IT/IS projects. The resulting framework provides a good starting point to extend our work with respect to the dimensions described above, which will be subject to further research.

3. FRAMEWORK

A constituting characteristic of *IT/IS projects* is that they comprise substantial changes in the information and communication system of an organization. These changes occur as a result of a transformation process in which certain inputs are transformed into pre-defined outputs. The inputs – or resources (including e.g. technologies, workforce, and equipment) – needed to conduct a project in general induce monetary costs, whereas the outputs produced can be interpreted as services (e.g. a webshop functionality or a new reporting system) that can deliver direct monetary benefits (by e.g. selling them[5]), indirect benefits (by e.g. granting competitiveness or improving business process efficiency), or provide a basis and become resources for other projects (e.g. infrastructure services)[6]. Therefore, we distinguish between the *transformation level* and the *economic effect level* (see figure 2[7]). We denote the effect an interaction causes on the economic effect level as *interaction effect*. In cases where an interaction restricts the number of feasible portfolio choices (e.g. if projects must not be selected together for some reason), we denote this as *constraint effect*.

In the following, we classify intratemporal interactions among IT/IS projects identified in the literature with respect to the transformation level and the economic effect level within a deterministic context. Interactions and constraint effects can only occur on the transformation level, whereas interaction effects purely take effect on the economic effect level. Among resources and outputs, three types of interactions can occur. *Resource-Resource interactions* arise solely among the resources, whereas *Output-Output interactions* occur just among the projects' outputs. *Output-Resource interactions* occur among the outputs and the resources. To keep it simple in a first step, on the economic effect level we distinguish just between (monetary) *costs* and (monetary) *benefits*[8]. In the following, along with a description for each of the different types of interactions, we provide a short example and discuss the specific forms this particular type of interaction can adopt, as well as the effects this interaction is expected to have. Further, in table 3 we provide an assignment of the contributions found in the literature to the different types of interactions, if the considered interaction in a contribution in substance corresponds to our understanding.

[5]This is, however, not our typical view of an IT/IS project. Still, a project's output may turn out to be so beneficial that an organization decides to sell the service in the market.

[6]When we speak of benefits, we speak of net benefits including possible costs evoked e.g. by maintenance.

[7]In figure 2, the numberings at the arrows representing the types of interactions correspond to the numberings provided along with the descriptions of the corresponding interactions in this section.

[8]It would be comparably easy, though, to include multi criteria instead of just benefits as objectives, but we feel that there is no additional value to it at this point of the reasoning.

3.1 Resource-Resource interactions

Competitive resource utilization interactions (1a)

Description: Projects require the same resource and therefore the amount of resource required for the joint implementation of the related projects is greater than the sum of the resources required if the projects would have been implemented separately.

Example: A staff member shared among different projects may need some time to mentally switch between the projects. This may result in set-up costs which could have been saved if the staff member would only be employed in one project at a time.

Forms of appearance: This interaction affects all related projects in some way, which we denote as symmetric.

Interaction effect: Costs increase. Due to diseconomies of scale in the resource utilization, additional resources may have to be procured to conduct the related projects.

Constraint effect: In case scarce resources may not be made available, such interactions may also inhibit the selection of distinct projects.

Complementary resource utilization interactions (1b)

Description: Projects require the same resource and therefore the amount of resource required for the joint implementation of the related projects is less than the sum of the resources required if the projects would have been implemented separately.

Example: A staff member shared among different projects may benefit from his knowledge of a specific programming language required in more than one project. This may reduce the effort and working time (e.g. due to learning effects) needed by this staff member.

Forms of appearance: This interaction affects all related projects in some way, which we denote as symmetric.

Interaction effect: Costs decrease due to economies of scale.
Constraint effect: None.

Apparently, the types of interaction presented above result in similar interaction effects, merely affecting the costs in different directions. For further modeling purposes they may be subsumed by the term *resource utilization interactions*.

3.2 Output-Output interactions

Competitive output interactions (2a)

Description: In the outputs of two or more projects there is an overlap in the provided services.

Example: The implementation of two distinct Enterprise Resource Planning (ERP) systems in an organization will result in redundant functionality.

Forms of appearance: Can be either symmetric, so that all projects in this relationship are affected, or asymmetric, so that a project influences other projects, but is not influenced by the other projects itself. As a special symmetric form of this interaction, projects can become mutually exclusive[9] (as

[9]The simultaneous conduction of two or more interrelated projects may lead to a situation where the projects technically could be conducted in parallel, but become "economi-

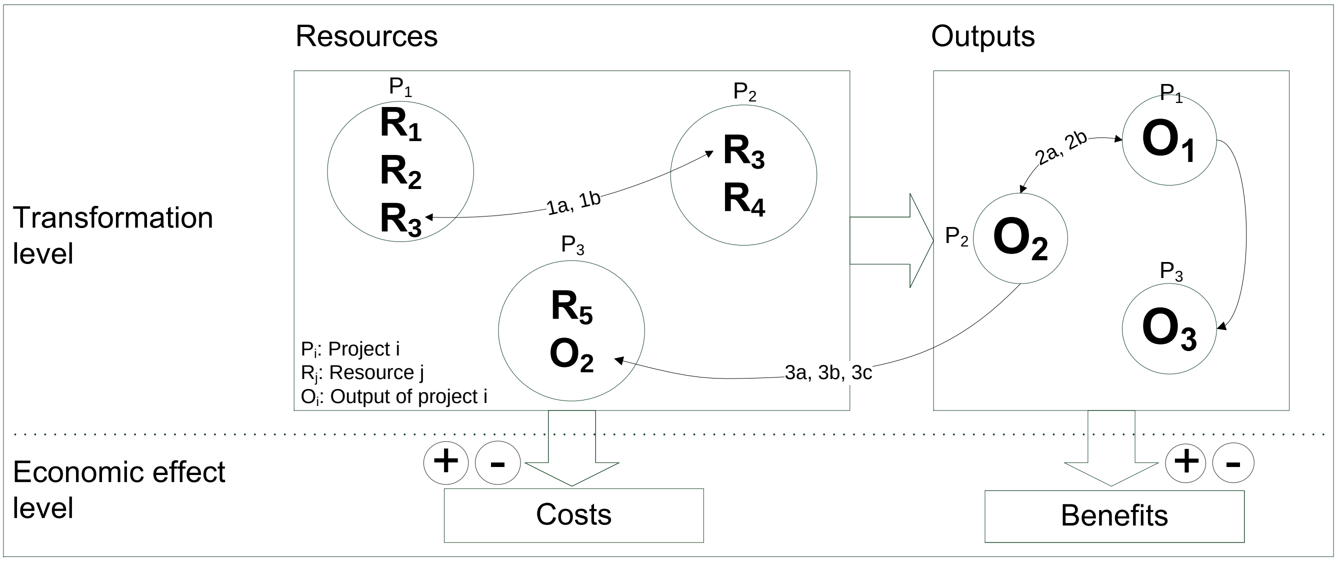

Figure 2: Interactions and their effects in IT/IS project portfolios

in the example above).

Interaction effect: Benefits decrease (in the symmetric or asymmetric case).

Constraint effect: Restricts the solution space in the mutual exclusive case, otherwise none.

Complementary output interactions (2b)

Description: The services produced as outputs of two or more projects complement each other in a way that the combined services consumption constitutes a new, enhanced service.

Example: A calendar functionality and an address book functionality as outputs of two projects are two distinct services that may be used separately. However, if offered in an organization in a bundle, the calendar entries (e.g. meetings) may be enriched with address book information (location, phone number etc.). And the address book functionality may be enriched by providing the information about the latest meetings with each person in the address book. This may constitute a new or at least enhanced service from the point of view of the user.

Forms of appearance: Can be either symmetric, so that all projects in this relationship are affected (as in the example above), or asymmetric, so that a project influences other projects, but is not influenced by other projects itself.

Interaction effect: Benefits increase due to economies of scope.

Constraint effect: None.

3.3 Output-Resource interactions

This type of resource interaction can be intratemporal as well as intertemporal. In the following, we only consider intratemporal Output-Resource interactions (among projects *whithin the same* portfolio), while intertemporal Output-Resource interactions (among *multiple consecutive* portfolios) will be the subject of future work. For intratemporal Output-Resource interactions, we assume for that the Output of a project has to be available at the time the dependend project is completed. Thereby, scheduling within a portfolio is neglected for simplification.

Binary contingency interaction (3a)

Description: A project cannot stand alone and requires the outputs of other projects as mandatory resources.

Example: The implementation of an ERP system may require the installation of computer hardware to be completed, whereas the hardware can be installed without the ERP system.

Forms of appearance: Is asymmetric, so that a project's output is required as a mandatory resource by other projects, but is not influenced by other projects itself.

Interaction effect: None.

Constraint effect: Necessitates the selection of distinct projects if related projects are selected.

Continuous competitive contingency interactions (3b)

Description: An influenced project may stand alone, but the outputs of related projects deteriorate the resource requirements/utilization of the influenced project.

Example: A project implements new reporting guidelines for projects resulting in increased reporting efforts per project and thereby reduced available working time for project team members.

Forms of appearance: Is asymmetric, so that a project influences other projects, but is not influenced by the other projects itself.

Interaction effect: Costs increase.

Constraint effect: May inhibit the selection of distinct projects, if related projects are selected.

cally" mutual exclusive. For modeling purposes it still seems favorable to consider this being a constraint effect.

Continuous complementary contingency interaction (3c)

Description: An influenced project may stand alone, but the outputs of projects with interactions to the influenced project improve the resource requirements/utilization of the influenced project.

Example: A project implements new reporting guidelines for projects that provide more transparency in the staffing of projects. This results in a more efficient assignment of team members to projects.

Forms of appearance: Is asymmetric, so that a project influences other projects, but is not influenced by the other projects itself.

Interaction effect: Costs decrease.

Constraint effect: None.

3.4 Discussion

Table 3 provides an assignment of the interactions and the corresponding contributions identified in the literature to the different types of interactions described above. If the description provided for an interaction in an article semantically matches our understanding for this type of interaction, the contribution is allocated to the column marked as "Completely". If there is an overlap between the semantic concept described in an article and our definition, but the description leaves considerable freedom for further (different) interpretations, we assigned that article to the column "partly". Articles which do not provide a description or definition of a type of interaction at all or which leave too much freedom for interpretation are not included in table 3.

As illustrated by table 3, *complementary resource utilization interactions* appear to be relatively well recognized in the literature. This does not seem to apply to *competitive resource utilization interactions*. We suppose that this is – at least partially – attributable to the circumstance that positive effects resulting from resource sharing seem to be recognized more intuitively than negative effects. Yet, disregarding these negative effects may lead to the underestimation of the overall portfolio costs. In the worst case, if the over-utilization of a critical resource (e.g. an employee with a unique skill set working at maximum capacity) is neglected, this may result in an infeasible portfolio choice. In line with [25], we think that the identification and assessment of interactions among (at least some) typical IT/IS resources (as e.g. hard- and software) is comparably well supported by the literature, for example by estimation techniques for software reusability.

In the case of *Output-Output interactions*, a number of approaches can be found that either consider *complementary* or *competitive output interactions*. Nevertheless, only few contributions explicitly combine both of these types of interactions in their modeling approaches (e.g. [10], [19]). In our perception, the identification and assessment of Output-Output interactions generally inhere an increased level of difficulty in comparison to Resource-Resource interactions. These difficulties have to be tackled in future research to avoid an over-/underestimation of the portfolio benefits.

Output-Resource interactions are considered either in the form of *binary contingency*, or typically seem to be recognized in the literature with respect to temporal or stochastic considerations.

Utilizing the presented framework, a decision-maker may be better able to identify the different types of interactions prevalent in her IT/IS project environment. In conjunction with table 3, the decision-maker may also select the most appropriate optimization model from the literature to consider these specific types of interactions. Generally, the article of Eilat et al. [10] exhibits the largest intersections with the superset of interactions identified and described in this article. However, the model presented in [10] solely considers interactions among pairs of projects and therefore seems to be of limited use for some IT/IS PPS problems ([14], [25]). Still, due to the adoption of the *everything as a service* (XaaS) paradigm [18], hard- and software are becoming increasingly available as services that can be bought on the market based on the actual demand. This might reduce the importance of resource sharing and thus reduce the importance of higher-order interaction effects with respect to resources in the future.

4. CONCLUSIONS

Adequately considering interactions among IT/IS projects is an important requirement for value-based IT/IS PPS. In order to have a starting point for the development or selection of adequate optimization models, we accomplished a comprehensive literature review. Along with Benaroch and Kauffman who state that "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" [6] we found that some contributions in the *Production and Operations Management* discipline and in the *Project Management* discipline already provide very useful fundamentals for the description and modeling of these project interactions (see table 2 and section 2.2). But due to some unique characteristics of IT/IS PPS problems, they have to be adapted for an application in business practice. Furthermore, we also found a few articles in *Information Systems* journals, that already address some of these unique characteristics. Generally, it became apparent that the literature lacks a common terminology and common semantics with respect to project interactions. For a unification of the terminology and semantics of interactions in the context of IT/IS projects we identified three relevant classification dimensions of IT/IS PPS. Based on these dimensions and the results of the integrative literature review, we presented a framework that structures deterministic, intratemporal interactions and thereby provides valuable insights for decision-makers to identify interactions among IT/IS project proposals.

For researchers, the framework may serve as a starting point to both the extension of existing optimization models and the development of new ones that consider all of the identified interactions. Besides interaction and constraint effects, the next step will be to include also scheduling constraints into the framework. As a prerequisite, a classification scheme for resources and outputs has to be developed. For instance, while some resources may be shared others can only be consumed exclusively. This distinction will have an important impact on the setup of a modeling and optimization approach. Further, at this time the framework only

	Description in article semantically corresponds to the classification used in the proposed framework			
Interaction	Completely		Partly	
Resource-Resource:				
Competitive Resource utilization			Resource interactions	[10]
			Cost/Resource utilization interactions	[12]
			(Internal) Resource interdependencies	[13]
Complementary resource utilization	Overlap in project resource utilization	[1]		
	Resource interdependencies	[17], [25]		
	Overlap interdependencies	[23]		
			(Input/Output) Commonality interdependencies	[8]
			Resource interactions	[10]
			Cost/Resource utilization interactions	[12]
			(Internal) Resource interdependencies	[13]
			Synergetic effects	[19]
Output-Output:				
Competitive output	Competitive benefit interactions	[10]		
			Effect interdependencies	[1]
			Impact interactions	[12]
			(Internal) Benefit interdependencies	[13]
			Cannibalism effects	[19]
Mutual exclusivity[10]			Mutual exclusive projects	[27]
Complementary output	(Complementary) Benefit interactions	[10]		
	Benefit interdependencies	[17], [25]		
	Effect interdependencies	[23]		
			Synergetic effects	[19]
			Pair-wise second order effects	[27]
Output-Resource:				
Binary contingency	Technical interdependencies	[21], [25]		
	Contingent/Compound projects	[27]		
Continuous competitive contingency			Technical interdependencies	[1],[17]
			Outcome interactions	[10]
			Outcome, technical or probability interactions	[12]
Continuous complementary contingency	Technical interdependencies	[23]	Technical interdependencies	[1],[17]
			Outcome interactions	[10]
			Outcome, technical or probability interactions	[12]

Table 3: Semantical and terminological comparison of interactions in the literature

accounts for deterministic parameters and does not consider uncertainty and the potential for risk diversification. This will be also the subject of further research. In addition, the detailed assessment of each of the identified interactions – especially among more than two projects – can become very expensive in business practice. This investment is obviously only justified, if the benefits outweigh the costs. Therefore, it has to be assessed empirically, which of the identified types of interactions typically have a major impact on the actual PPS and which can be neglected. Finally, intertemporal interactions shall also be included into the framework.

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[10] Mutual exclusivity represents a special type of competitive output interactions as described in section 3.3.