5-15-2012

IT PROJECT PORTFOLIO MANAGEMENT - A STRUCTURED LITERATURE REVIEW

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Abstract

Recent years have seen an increasing interest in IT project portfolio management. Consequently, a considerable number of respective practices and approaches have been published. However, these contributions are scattered through a large number of journals and conferences and address very different topics. Therefore, this contribution sets out to locate the relevant body of literature related to IT project portfolio management in a structured way and to integrate the existing findings. We discuss the relationship between IT project portfolio management and other kinds of project portfolio management in order to shape the profile of this field of research. In this context we highlight strong interdependencies and a specific governance context as key characteristics of IT project portfolio management. In order to identify success factors and contingency factors we analyze contributions of empirical nature. Additionally, we investigate mathematical approaches and decision support systems in regard to their potential to effectively support IT project portfolio management. Finally, we provide a research agenda with the intention of motivating and directing further contributions in this field.

Keywords: Information Technology, Project Portfolio Management, Project Selection, Resource Allocation, Literature Review, State of the Art

1 Introduction

As organizations increasingly engage in projects to reach their business objectives (Blomquist & Müller, 2006; de Reyck et al., 2005) the effective management and coordination of these projects has become an important task in recent years. At the same time, IT investments have increased (Cho & Shaw, 2009) and IT projects today present a major proportion of the internal initiatives conducted in many companies. Thus, the management of IT projects in a portfolio context is an important task in contemporary organizations and a relevant topic for information systems research (Burke & Shaw, 2008, p. 1).

The concept of project portfolio management, hereafter referred to as PPM, has originally been introduced in the context of construction projects, new product development projects and research & development projects (Blomquist & Müller, 2006, p. 53). The field of IT project portfolio management (IT PPM) has to a large extent been motivated by McFarlan (1981). In recent years IT projects more and more moved into the focus of researchers concerned with PPM. Today, there is a growing body of literature regarding IT PPM. However, the contributions are scattered between different disciplines (operations research, project management, information systems research, etc.). Thus, the integration of this body of literature seems to be a valuable undertaking.

The knowledge of the existing literature in a particular field of research is a fundamental requirement for every scholar of information systems research (Webster & Watson, 2002, p. xiii). However, as the amount of literature steadily increases, it is often time consuming and difficult to oversee and to correctly classify the relevant publications. For this purpose, structured literature reviews have become an important groundwork. In emerging fields of research, like IT PPM, a literature review can assist in consolidating and integrating the state of the art. Furthermore, the analysis of limitations of current contributions can help to provide directions for additional research and, thus, to draw a research agenda for other researchers (vom Brocke et al., 2009, p. 8).

In this contribution we set out to provide an overview of existing publications in the field of IT PPM. Thereby, we aim at integrating the scattered findings. With the intention of supporting researchers contributing to this field, we analyze the existing body of literature in respect to key findings and future directions. We discuss achievements, but also common drawbacks and finally aim at providing a research agenda and guidelines for the publication of future contributions in this field. In order to derive relevant implications for practitioners we identify success factors and problem areas in IT PPM and analyze to which extent current optimization models, frameworks and decision support systems provide assistance to IT PPM stakeholders.

To conduct the structured literature review presented in this contribution we followed the steps described in the process framework proposed by vom Brocke et al. (2009, p. 8). Thus, the remainder of this article is structured as follows: First, we describe the scope of our literature review. Then, we lay out the methodology by describing the literature search process in detail. In the main part of our contribution we present an analysis and synthesis of the identified literature. Following, we outline a research agenda. We conclude with a brief summary, a discussion of the limitations of our study and an outlook.

2 Review Scope

A taxonomy for literature reviews has been proposed by Cooper (1988, p. 109). We employ this framework as demonstrated by vom Brocke et al. (2009, p. 8) to characterize the scope of our literature review (see Figure 1). The categories highlighted in dark grey in Figure 1 display the major direction of our contribution. Categories in light grey are also covered but not in the focal point of the study. For a detailed description of the different categories we refer to vom Brocke et al. (2009).

Characteristics		Categories			
(1)	focus	research outcomes	research methods	theories	applications
(2)	goal	integration	criticism	central issues	
(3)	organisation	historical	conceptual	methodological	
(4)	perspective	neutral representation		espousal of position	
(5)	audience	specialised scholars	general scholars	practitioners/ politicians	general public
(6)	coverage	exhaustive	exhaustive and selective	representative	central/pivotal

Figure 1. Review scope (schema adapted from vom Brocke et al., 2009, p. 8)

Due to the high relevance in the investigated literature, a main focus of our contribution lies on the examination of research outcomes regarding governance requirements for IT PPM. Additionally, we analyze the suitability of optimization models and decision support systems designed to select, manage and control IT projects in a portfolio context. Note that in regard to algorithms and models we concentrate on their applicability and not on implementation details or solvability considerations.

Our main goal is to integrate the existing findings but we also take a critical view on the identified contributions by highlighting general shortcomings. The organization of the review is conceptual. However, we do not apply a predefined concept but derive concepts from the contributions under investigation. Thereby, we aim at a neutral representation, though the categorization of the identified contributions might to a certain extent be subjective to our interpretation. We tried to gain exhaustive coverage of the literature. However, in the following we do not discuss all identified publications in detail but highlight certain aspects by referring to a selection of contributions.

3 Literature Search Process

According to vom Brocke et al. (2009, p. 9) it is recommendable to begin a literature review with a conception and working definitions of the key terms. Therefore, we first consulted theme-specific books (e.g. Artto et al., 2001; Bonham, 2005; Dye & Pennypacker, 1999; Meredith & Mantel, 2006; Reiss, 1996) and a number of research articles in order to identify the relevant keywords. After investigating the initial sources we discussed relevant terms and their relationships and derived a common understanding. In an iterative process we searched through databases with different combinations of search terms and analyzed the resulting collections of contributions. Based on these experiments, we derived the final search expressions used to identify the relevant articles. We connected key terms by logical expressions and used wildcards to account for different spellings and endings. As an example, a search expression created for the EBSCOhost database is provided in the following (the search expressions for other databases slightly differ):

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"project portfolio management" OR (project AND (portfolio OR program* OR multi*) AND (budget* OR select* OR prioriti* OR evaluat* OR “resource management” OR “resource allocation” OR governance))
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We searched directly for the term “project portfolio management” but also used a combined expression in order to find relevant contributions including related terms. Note that we did not restrict the search to contributions focused on IT projects during this phase. We first wanted to investigate if there are major differences between the management of IT projects and other projects in a portfolio context and, hence, initially regarded a broad range of contributions concerned with PPM in general.

A common way to limit the number of articles included in a review is to consider only contributions published in top ranked journals (vom Brocke et al., 2009, p. 9). However, for a literature review regarding IT PPM this approach did not seem to be advisable. A number of publications in this field of research have been published in specialized project management journals that often do not appear in the relevant journal rankings. Nevertheless, these journals include relevant and often cited publications. Therefore, we decided not to select certain journals ex ante, but to incrementally exclude contributions not meeting common quality criteria or not fitting into the scope of the review. For quality reasons we only included peer-reviewed articles with references available and excluded work-in-progress. As the role and characteristics of IT projects have significantly changed over time we limited the time horizon of our investigation to contributions published since 1990.

The following databases were searched by title and abstract: EBSCOhost (Business Source Premier and EconLit databases), ISI Web of Knowledge (Web of Science database), Science Direct and JSTOR. Taken together these databases allow for searching of more than 3,000 journals in the information systems domain, including the top 25 MIS journals listed by the AIS. As recommended by Webster & Watson (2002, p. xvi) we also searched through conference proceedings via the AIS Electronic Library with the same selection criteria as for the journal articles. The following conference proceedings were included: AMCIS, ACIS, ECIS, HICSS, ICIS and PACIS.

From the initial keyword search we retrieved 1,808 contributions. We read the title and abstract and eliminated publications obviously not related to IT PPM or not meeting the quality requirements mentioned above. We then intensively studied the full text and excluded publications not conferrable to the field of research. From the resulting 84 contributions we excluded another 33 due to further refinements. In this step we removed nearly identical publications written by the same group of authors. From these redundant articles we only kept the most recent and elaborate versions. Finally, we, again, critically reviewed the selected contributions in regard to the affiliation to IT PPM.

During our keyword search we recognized that a great variety of different terms is used in the relevant contributions to describe the project portfolio context. Due to this heterogeneous terminology we decided to additionally conduct a forward and backward search (as recommended by Webster & Watson, 2002, p. xvi). To conduct the backward search we extracted the contributions listed in the reference lists of the articles identified so far. For the forward search we employed the ISI Web of Knowledge and Google Scholar to retrieve the publications citing the identified articles. Again, we first identified potentially relevant contributions by reading title and abstract, before studying the full text to come to a final decision. Table 1 presents a summarizing overview of the literature search process, including the time span of the different phases. During the time frame of the study we also made use of automated database alerts to take new contributions published during this time interval into account.

Phase:	Number of journal contributions remaining:	Number of conference papers remaining:	Begin:	End:
Initial search (keywords)	1619	189	2011-06-20	2011-06-29
Initial Screening (title & abstract)	206	42	2011-06-29	2011-07-14
Intensive screening (full text)	67	17	2011-07-15	2011-10-04
Refinements	40	11	2011-10-04	2011-10-24
Forward and backward search	47	12	2011-10-25	2011-11-09

Table 1. Literature search process

4 Literature Analysis and Synthesis

In the following we discuss and analyze the identified contributions (a complete list of the publications included in the sample is provided in Appendix A). Figure 2 displays key characteristics of the sample.

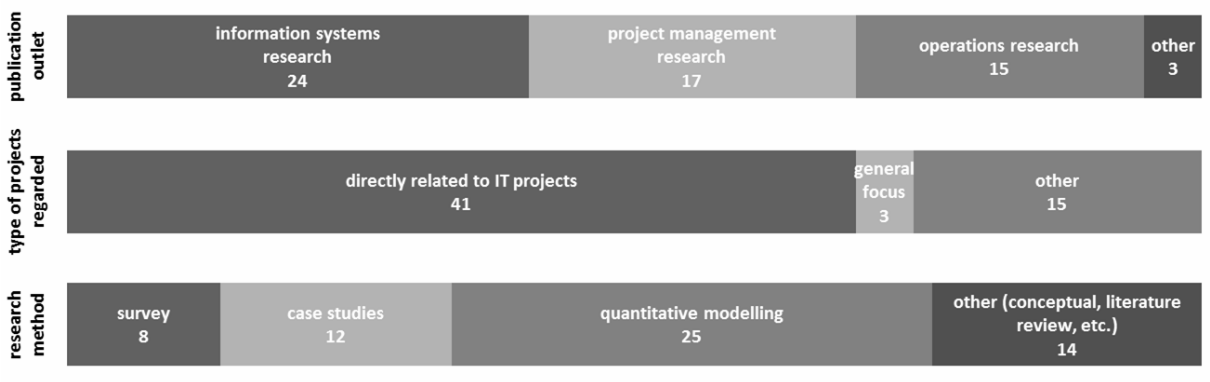

Figure 2. Characterization of the sample

The analysis of the publication outlets shows that IT PPM is especially discussed in three different research disciplines. Contributions published in operations research journals, of course, primarily cover optimization models and mathematical approaches. However, mathematical models are also frequently presented in IS and project management journals. Governance aspects regarding IT PPM are discussed in IS journals and conferences as well as in the project management literature.

The majority of the identified contributions is explicitly concerned with IT projects. Three contributions cover projects in general, without further specifying the type of projects regarded. The remaining contributions discuss other types of projects like R&D projects, but are conveyable to IT PPM.

Regarding the research methods employed, many contributions are based on quantitative modeling, usually combined with a case study or a numerical example for exemplification. Twenty contributions are empirical. The remaining publications are mainly of conceptual nature. They typically rely on theme-specific literature reviews or are argumentative.

To guide the further analysis and synthesis of the identified contributions we formulated a number of central questions, which we want to answer in the following sections:

- What is the difference between IT projects and other types of projects in a PPM context?
- Which success factors and contingency factors in regard to IT PPM have been identified so far?
- Which mathematical approaches and decision support systems have been proposed so far in order to support IT PPM and what are the characteristics of these approaches?
- How has the field of research evolved in recent years?
- Which future directions can be identified?

4.1 Specific characteristics of IT project portfolios

In order to shape the contours of the field of research we wanted to appraise in which respect IT PPM differs from other portfolio management disciplines like financial portfolio management, new product portfolio management or R&D PPM. Therefore, we analyzed the introductions and literature review sections of the identified contributions.

While there is agreement that there are major differences between the management of financial securities and the management of IT projects in a portfolio (Burke & Shaw, 2008; Cho & Shaw, 2009; Verhoef, 2002), there are different perceptions regarding the compatibility of IT PPM, new product portfolio management and R&D PPM. Some authors point at the similarities (e.g. Drake & Byrd, 2006; Klapka & Pinos, 2002), but others argue that there are major differences (Kundisch & Meier, 2011a, 2011b; Santhanam & Kyparisis, 1995, 1996). By analyzing these different perceptions, we come to the conclusion that some findings from other project portfolio management disciplines indeed can be conveyed to the IT PPM context (e.g. findings regarding resource interdependencies).

Therefore, a number of approaches originally designed for new product and R&D project selection can also be applied to IT project selection. However, most approaches are specifically designed for a context that does not fit to the IT PPM context.

Instead of providing a final conclusion regarding the relationship between IT projects and other kinds of projects, we would like to highlight some characteristics of IT projects discussed in the investigated contributions. First of all, it should be mentioned that IT projects underlie strong interdependencies and interactions of different kinds (a taxonomy for different kinds of interdependencies between IT projects has recently been proposed by Kundisch & Meier (2011a)). Moreover, IT projects are selected and executed in a specific governance context, inter alia influenced by the special relationship between business and IT (Thomas et al., 2007). Other major characteristics of IT projects are internal sponsorship (Meskendahl, 2010, p. 808) and the distinct skills and resources required to conduct an IT project (Cho & Shaw, 2009, p. 2). This is related to specific technical requirements connected with IT projects (intensively discussed by Verhoef (2002)). Furthermore, a high optional value (Bardhan et al., 2004; Kenneally & Lichtenstein, 2002) and difficult assessment of IT projects (Lanzinner et al., 2008), combined with a high level of uncertainty, have frequently been reported.

At this point we want to highlight that the term "IT project" in our understanding does not necessarily refer to a project conducted for IT. Instead, in the context of IT project portfolio management the relevant criteria for the categorization of a project as an IT project seems to be that a significant share of IT resources (human or technical) is required to accomplish the project.

4.2 Governance, success factors and contingency factors

A considerable part of the identified contributions is concerned with governance aspects regarding PPM. In recent years, a number of predominantly empirical contributions have been published. These are in particular concerned with success factors, contingency factors as well as risks and challenges regarding the implementation and governance of PPM functions. Note that some of these contributions do not specifically focus on IT projects, but investigate project portfolio organizations in general. To take account of this circumstance, we use the term PPM if not all cited contributions refer to IT PPM in particular.

The increasing number of publications concerned with governance of PPM environments is inter alia motivated by the previous overweight of contributions covering mathematical models. Many of these models, primarily concerned with project selection, were rather theoretical and not derived from practical demands. Thomas et al. (2007, p. 2), for example, put it this way:

"The conclusion is that the key to more effective IT project evaluation is not more formal and sophisticated methods, but rather, more effective governance structures and decision processes."

In recent years, the investigation of PPM governance has made significant progress. Influencing factors in regard to project portfolio efficiency and success have been identified inter alia by Jeffery & Leliveld (2004), de Reyck et al. (2005), Martinsuo & Lehtonen (2007), Thomas et al. (2007), Müller et al. (2008), Jonas (2010) and Meskendahl (2010). Maturity models and implementation plans for IT PPM have been proposed by Jeffery & Leliveld (2004) and de Reyck et al. (2005). Finally, risks and problem areas in PPM have been discussed, for example, by Drake & Byrd (2006) and Elonen & Artto (2003).

Table 2 presents an overview of success factors identified and discussed in the analyzed contributions (crosses in brackets mark success factors only partly covered by the respective publication). Explanations of these success factors are provided in Appendix B. Note that this is not an exhaustive list of all success factors mentioned in the relevant literature. However, Table 2 summarizes success factors discussed in contributions explicitly concerned with IT PPM success and may therefore be a good starting point for scholars as well as practitioners.

	Strategic fit / Strategic alignment	Consideration of project interdependencies	Centralized view	Financial analysis	Top-leadership commitment	Accountability for results	Portfolio segmented by asset classes	Risk analysis / portfolio balance	Measurement of costs and benefits	Consideration of multiple constraints (budget capacity, staff capabilities, etc.)
Jiang & Klein, 1999a	X		(X)							
Elonen & Artto, 2003	X				(X)				(X)	(X)
Jeffery & Leliveld, 2004	X		X	X			X	X	(X)	
de Reyck et al., 2005	X	X	X	X	X	X	X	X	X	X
Thomas et al., 2007	X				X	X			X	
Müller et al., 2008	X									
Jonas, 2010					X					
Meskendahl, 2010	X	X					X	X		

Table 2. Overview of success factors identified in empirical studies and literature reviews

Especially the importance of the adherence to IT and business strategy in the context of project selection has frequently been highlighted. Note that the success factors listed in Table 2 should not be regarded in isolation. Jeffery & Leliveld (2004) and de Reyck et al. (2005) emphasize that IT PPM success is explained by combinations of these success factors. Consequently, they have introduced the concept of maturity levels composed of success factors and different degrees of fulfillment.

Furthermore, different contingencies have to be regarded in the PPM context. Contingency factors identified in the investigated literature are listed in Table 3 together with the dependent variables that are influenced. Especially organizational and cultural factors are frequently mentioned.

Contribution	Dependent variable	Contingency factors
Jiang & Klein, 1999a	Importance of internal, external and project metrics	- IS strategic relevance - Political environment - Past experience
Blomquist & Müller, 2006	Program and portfolio management (roles, responsibilities, practices)	- Project type - Organizational environment
Martinsuo & Lehtonen, 2007	Portfolio management efficiency	- Single-project management - Project management efficiency
Müller et al., 2008	Portfolio success	- Project type - Internal dynamics - Governance types - Geographical location
Prifling, 2010	Project portfolio management and risk management in IT projects	- Organizational culture
Meskendahl, 2010	Business success (influenced by project portfolio success)	- Strategic orientation

Table 3. Contingency factors identified in empirical studies and literature reviews

While a significant number of success and contingency factors have been identified and investigated in literature, the comparison of the dependent variables and contingency factors in Table 3 shows that current contributions are partly disconnected. Thus, further empirical studies integrating these findings based on large-scaled surveys would be an important contribution.

4.3 Mathematical approaches and decision support systems

As highlighted above, a large fraction of the investigated contributions contains descriptions of mathematical models and decision support systems intended to support different IT PPM-related processes. In total we identified 23 such publications which we will discuss in the following.

Most of the identified models and approaches (20 out of 23) are designed to support the selection of a portfolio of projects out of a given set of candidate projects (project portfolio selection). Moreover, two approaches (Cho & Shaw, 2009; Stummer & Vetschera, 2003) are concerned with the distribution of resources between different decision making units (budgeting). Only one approach (Heimerl & Kolisch, 2010) is specifically focused on human resource allocation and project scheduling while three contributions (Gutjahr & Reiter, 2010; Gutjahr et al., 2010; Stummer et al., 2009) introduce integrated approaches that cover both, project selection as well as project scheduling and staff assignment. These integrated approaches appear to be very promising because interconnections between the different tasks are regarded.

We constructed a concept matrix (Webster & Watson, 2002, p. xvii) in order to classify the identified approaches according to a number of factors often included in IT PPM decision making. The complete concept matrix is displayed in Appendix C. Here, we only provide an aggregated overview of the degree of consideration of the identified factors. Figure 3 depicts how many of the 23 contributions, assessed in the concept matrix, consider the respective factor.

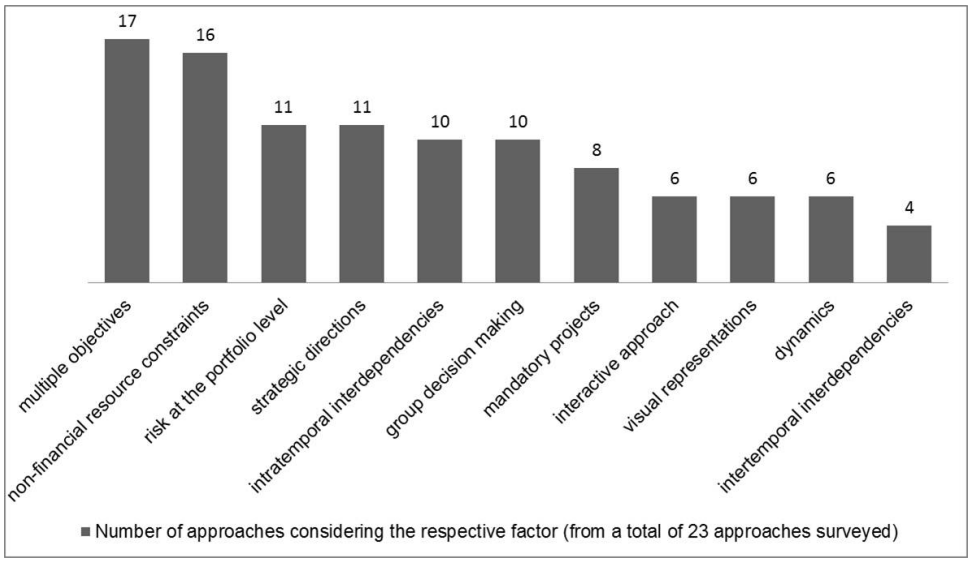

Figure 3. Consideration of requirements by the investigated approaches

To further explain the results presented in Figure 3 we would like to discuss some of these requirements and their realization in the investigated approaches in more detail.

The importance of considering different kinds of benefit criteria – tangible and intangible, qualitative and quantitative – has frequently been highlighted (for example by Chou et al., 2006). Consequently, most approaches are capable of considering multiple objectives. Financial constraints (costs) are discussed in nearly all contributions, although not always addressed explicitly. Many approaches also cover non-financial resources. Yet, resource constraints are often treated abstractly. If resource constraints are explicitly discussed, especially the scarcity of human resources with specific skills is emphasized (e.g. Gutjahr & Reiter, 2010; Stummer & Vetschera, 2003; Stummer et al., 2009).

Although the concept of PPM is strongly built on the finding that risks have to be considered at the portfolio level and IT projects contain significant risks, only about half of the investigated approaches account for the non-additive character of risks. Some contributions even do not discuss risks at all.

Moreover, although empirical contributions highlight the adherence to corporate and IT strategy as a very important success factor, only eleven approaches consider strategic alignment in detail.

As indicated in section 4.1, interdependencies are an eminent characteristic of IT projects. Consequently, more than half of the approaches (14 of 23) are capable to consider interdependencies. However, usually only intratemporal interdependencies are incorporated while only four approaches account for intertemporal interdependencies. The latter approaches in particular make use of real options theory (Angelou & Economides, 2008; Bardhan et al., 2004, 2006).

It has been criticized that most approaches for project selection are inflexible as they confront the user with a single solution without allowing for adjustments and alternatives (Ghasemzadeh & Archer, 2000, p. 74). This also holds true for the majority of the investigated approaches. Yet, at least six decision support systems have been proposed that allow for user-interaction and the same number of approaches employs visualizations to assist the user in assessing alternatives.

Moreover, it has often been highlighted that IT PPM is a dynamic process characterized by frequent changes caused by the arrival of new projects, changing input and output parameters, the necessity to re-assess projects and to re-allocate resources (e.g. Blichfeldt & Eskerod, 2008; Blomquist & Müller, 2006; Urli & Terrien, 2010). These dynamics are considered by six approaches - at least partly. However, especially the combination of dynamic changes and interdependencies seems to be difficult to address in mathematical models. This apparently remains an issue to be solved.

Finally, we want to point out that a relatively large number (10 out of 23) of approaches is capable to support group decision making. Some of these approaches also discuss and take account of the organizational environment in which budgets are assigned, projects selected and resources allocated. In particular, decentralized decision constellations are discussed in at least four of the contributions (Heimerl & Kolisch, 2010; Oral et al., 2001; Phillips & Bana e Costa, 2007; Stummer & Vetschera, 2003). This development is quite encouraging as it shows that the organizational and social aspects of the application context, which have been intensively discussed in empirical studies, are more and more taken into account by researchers concerned with decision support for IT PPM.

5 Research Agenda

In the following we will briefly discuss evolutions of the field as well as propositions for future research derived from an analysis of future work outlined in the investigated contributions. A complete overview of the identified proposals is presented in Appendix D.

In 1999 Archer and Ghasemzadeh stated the following about project selection techniques at this point in time:

"Many of these techniques are not widely used because they are too complex and require too much input data, they provide an inadequate treatment of risk and uncertainty, they fail to recognize interrelationships and interrelated criteria, they may just be too difficult to understand and use, or they may not be used in the form of an organized process." (Archer & Ghasemzadeh, 1999, p. 207)

In the same contribution Archer and Ghasemzadeh propose the development of decision support systems addressing these shortcomings. In the following years a number of integrated systems relying on process models and allowing for user interaction have been presented. This emergence of decision support systems is a consequent development as they seem to be more accepted in practice than complex and rigid optimization models.

At this point, it is important to mention that the requirements for optimization models as well as decision support systems should be derived based on theoretically sound approaches. This has frequently been disregarded. In this respect, some recent contributions concerned with IT PPM have employed design science approaches (e.g. Ahlemann, 2009; Stewart, 2008; Zheng & Vaishnavi, 2011). This seems to be a promising pathway towards a more rigorous methodical foundation.

Important attributes of mathematical models and decision support systems have been briefly discussed above. In regard to these attributes, it can be concluded based on the analyzed contributions that future decision support systems for IT PPM should take account of different kinds of interdependencies and at the same time should support a dynamic process of project selection and resource allocation. Furthermore, the user should have the opportunity to interact with the system. As group decisions are very common in practice they should be supported. In this regard, it is necessary to study the organizational context in which IT PPM is embedded in order to ensure that the decision model is suitable for the environment at hand. This is why design science research seems to be appropriate for the construction and evaluation of such group decision support systems for IT PPM.

A major trend in recent years has been the growing body of contributions concerned with the governance context of IT PPM. This development has been triggered by the perception that previous research was too much limited to project selection and resource allocation without taking the organizational environment into account. Today, a significant number of empirical contributions concerned with governance issues and success factors for IT PPM exist. Yet, the few large scaled empirical surveys published so far cover varying concepts and are only loosely integrated. Therefore, we recommend further surveys building on a unified framework. Moreover, as governance structures in PPM functions underlie frequent changes, longitudinal studies seem to be promising (Jonas, 2010).

From our own insight into IT PPM practices (Frey & Buxmann, 2011) we recommend further research regarding the relationship between IT PPM and related areas like IT service management and enterprise architecture management. Although these interrelationships are relevant in practice, they have been hardly covered in existing contributions. Furthermore, decentralized and federal decision making settings – although covered in a number of contributions – should be investigated and discussed in more detail due to their high pervasiveness in practice.

6 Conclusion, Limitations and Outlook

This contribution provides an exhaustive and structured overview of the existent literature in regard to IT PPM. The structured analysis reveals which areas have hardly been covered in previous literature and consequently which gaps should be closed in future. In particular the consideration of interdependencies and dynamic environments in a common framework, the conduction of additional design science studies and the integration of existent empirical findings seem to be promising pathways.

Our analysis is not without limitations. Although we followed a structured process to identify contributions covering the topic, we still may have missed some relevant articles. As the discussion of the relationship between R&D and IT PPM shows, it is difficult to draw a clear line between IT PPM and related fields. In this respect, the selection of the contributions, though conducted in a rigorous way, is subjective to a certain extent. Furthermore, the categorization of the identified contributions is also subjective, although we spent a significant effort to verify our appraisals.

Drawing a conclusion from our investigation of the relevant literature it should be stated that the field of research has made significant progress in recent years. A large range of topics has been covered and especially a large number of governance aspects have recently been addressed. However, the field of research has to get more mature regarding methodology and theoretical foundation. We hope that the literature review provided in this contribution will support researchers in adding innovative and rigorously derived findings to the current body of knowledge.

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Appendix A – Overview of the identified contributions

Identified contributions (ordered by year):					
Ward, 1990	Schniederjans & Santhanam, 1993	Platje et al., 1994	Santhanam & Kyparisis, 1995	Santhanam & Kyparisis, 1996	Shoval & Giladi, 1996
Archer & Ghasemzadeh, 1999	Farbey et al., 1999	Jiang & Klein, 1999a	Jiang & Klein, 1999b	Ghasemzadeh & Archer, 2000	Lee & Kim, 2000
Lee & Kim, 2001	Oral et al., 2001	Irani et al., 2002	Kenneally & Lichtenstein, 2002	Klapka & Pinos, 2002	Verhoef, 2002
Elonen & Artto, 2003	Engwall & Jerbrant, 2003	Stummer & Vetschera, 2003	Bardhan et al., 2004	Jeffery & Leliveld, 2004	de Reyck et al., 2005
Bardhan et al., 2006	Benaroch et al., 2006	Blomquist & Müller, 2006	Chou et al., 2006	Drake & Byrd, 2006	Eilat et al. 2006
Martinsuo & Lehtonen, 2007	Phillips & Bana e Costa, 2007	Thomas et al., 2007	Angelou & Economides, 2008	Blichfeldt & Eskerod, 2008	Burke & Shaw, 2008
Lanzinner et al., 2008	Müller et al., 2008	Peters & Verhoef, 2008	Stewart, 2008	Ahlemann, 2009	Ajjan, 2009
Chen & Cheng, 2009	Cho & Shaw, 2009	Diepold et al., 2009	Patanakul & Milosevic, 2009	Stummer et al., 2009	Gutjahr et al., 2010
Gutjahr & Reiter, 2010	Heimerl & Kolisch, 2010	Jonas, 2010	Meskendahl, 2010	Prifling, 2010	Urli & Terrien, 2010
Frey & Buxmann, 2011	Hsu et al., 2011	Kundisch & Meier, 2011a	Kundisch & Meier, 2011b	Zheng & Vaishnavi, 2011	

Appendix B – Description of the success factors included in Table 2

Success factor	Description
Strategic fit / Strategic alignment	IT projects have to match with the IT strategy and, therefore, need to be evaluated with regard to the IT strategy (Jiang & Klein, 1999a, p. 171). Thomas et al. state the following: *"If projects are not aligned to strategy, decision making is not tied to the direction of the company, and resources may not be used effectively."* (Thomas et al., 2007, p. 10) In this context business representatives and IT representatives should frequently discuss alignment between IT strategy and business strategy (Jeffery & Leliveld, 2004, p. 43).
Consideration of project inter-dependencies	Different kinds of interdependencies between projects within the portfolio have to be taken into account in order to exploit synergy potentials (Meskendahl, 2010, p. 809).
Centralized view	To gain a complete overview of the project portfolio all projects have to be in one database and all IT spending has to be tracked centrally (Jeffery & Leliveld, 2004, p. 43; de Reyck et al., 2005, p. 526).
Financial analysis	Companies with a high level of maturity in regard to project portfolio management constantly evaluate projects with financial tools like ROI, Payback Period, NPV etc. (Jeffery & Leliveld, 2004, p. 43; de Reyck et al., 2005, p. 530).
Top-leadership commitment	Top-leadership commitment is vital for effective evaluation practices (Thomas et al., 2007, p. 9f.). Furthermore, top management commitment usually has a positive effect on project portfolio success, though it can also have a negative effect if the project portfolio management process is impeded by top management intervention (Jonas, 2010, p. 825)
Accountability for results	Effective IT evaluation practices require that business managers are held accountable for project results (Thomas et al., 2007, p. 8; de Reyck et al., 2005, p.532).
Portfolio segmented by asset classes	In order to maintain a balance between different classes of projects (for example infrastructure projects and strategic projects) it is important to divide projects into different categories (Jeffery & Leliveld, 2004, p. 43; de Reyck et al., 2005, p. 529).
Portfolio balance / Risk analysis	A particular important factor to consider when balancing a project portfolio is the risk level of the projects included (Meskendahl, 2010, p. 809). Therefore, a thorough analysis of risks at the single project level as well as at the portfolio level is required (de Reyck et al., 2005, p. 526).
Measurement of costs and benefits	The ability to measure costs and benefits is of vital importance as it is a prerequisite inter alia for consistent decision making and corporate learning (Thomas et al., 2007, p. 11). However, the ability to measure project benefits is a challenge that requires sufficient training (de Reyck et al., 2005, p. 532).
Consideration of multiple constraints (budget capacity, staff capabilities, etc.)	The main motivation to take a portfolio perspective on projects is that project resources are limited. While the financial capacity is usually closely monitored other resources like the available staff and the associated capabilities are often ignored in immature portfolio management regimes. However, shortage of these resources can impose significant restrictions on portfolios and the projects contained therein (de Reyck et al., 2005, p. 530).

Appendix C – Concept matrix for contributions describing optimization models and decision support systems

Reference (ordered by year)	characterization of the approach	main focus	0bjectives	non-financial resource constraints	risk at the portfolio level	strategic directions	intratemporal interdependencies	group decision making	mandatory projects	interactive approach	visual representations	dynamics	intertemporal interdependencies
Schniederjans & Santhanam, 1993	Linear 0-1 goal programming	Multi-objective, resource constrained project selection	Multi-objective model (aggregated objective function)	X		X			X				
Santhanam & Kyparisis, 1995	Nonlinear 0-1 goal programming	Incorporation of benefit, resource and technical interdependencies into a multi-objective project selection model	Multi-objective model (aggregated objective function)	X			X		X				
Santhanam & Kyparisis, 1996	Nonlinear 0-1 programming	Incorporation of benefit, resource and technical interdependencies into a single-objective	Single-objective model	X			X		X				

		project selection model											
Ghasemzadeh & Archer, 2000	Different approaches - e.g. AHP and 0-1 integer programming	Decision support for several steps of the framework proposed by Archer & Ghasemzadeh, 1999	Multi-objective model (aggregated objective function)	X	(X)			X	X	X	X	(X)	
Lee & Kim, 2000	Combination of ANP and 0-1 goal programming	Designed for multi-criteria group decisions; interdependencies are taken into account	Multi-objective model (aggregated objective function)	X			X	X	X				
Lee & Kim, 2001	Combination of ANP, Delphi method and 0-1 goal programming	Multi-criteria group decisions; interdependencies are regarded	Multi-objective model (aggregated objective function)	X			X	X	X				
Oral et al., 2001	Mixed-integer programming problem	Reaching consensus between several decentralized decision authorities	Multi-criteria disaggregative approach					X					
Klapka & Pinos, 2002	Nonlinear 0-1 goal programming	Decision support system considering synergistic effects of second- and third-orders and hierarchical interdependencies between projects	Multi-objective model (aggregated objective function)	X			X		X	X	X	(X)	X
Stummer & Vetschera, 2003	Goal programming	Group decision making with multiple criteria in decentralized settings / allocation of shared resources	Multi-objective model (aggregated objective function)	X		(X)		X		X		(X)	
Bardhan et al., 2004	Real options portfolio	Focus on intertemporal	Single-objective model		(X)								X

	optimization algorithm	interdependencies	(discounted cash flow plus real options)										
Bardhan et al., 2006	Real options portfolio optimization algorithm	Focus on intertemporal interdependencies	Single-objective model (discounted cash flow plus real options)		X								X
Chou et al., 2006	Fuzzy multi-criteria decision model	Evaluation criteria for IT/IS investments; inclusion of different stakeholders into the evaluation process	Multi-objective model (aggregated objective function)		(X)	(X)		X				(X)	
Eilat et al., 2006	Data envelopment analysis (DEA), balanced scorecard	Multi-criteria group decisions; interdependencies are taken into account.	Multi-objective model (aggregated objective function)	(X)	X	X	X	X					
Angelou & Economides, 2008	Combination of real options and the analytic hierarchy process (AHP)	Focus on intertemporal interdependencies (via real options) in a multi-criteria decision making setting integrating qualitative and quantitative criteria	Multi-objective model (aggregated objective function)		(X)	X							X
Chen & Cheng, 2009	Group multi-criteria decision-making method based on fuzzy logic (the projects are divided into five different evaluation classes)	Support of group decision-making in a fuzzy environment	Multi-objective model (aggregated objective function)		X	X		X				(X)	

Cho & Shaw, 2009	Calculation of the efficient frontier (for budget allocation)	Synergies between different IT-investment units; allocation of budgets to different units; risk-return perspective	Proportion of investment for different IT investment units		X	(X)	X				(X)		
Stummer et al., 2009	Interactive approach based on the determination of Pareto-efficient portfolios	Decision support combining project portfolio selection, staff assignment and scheduling of project proposals; competence development is also taken into account	Multi-criteria disaggregated approach	X		(X)				X	X		
Gutjahr et al., 2010	Multi-objective programming model for determining Pareto-efficient portfolios (solved with a meta-heuristic)	An approach combining project portfolio selection, staff assignment and scheduling of project proposals; competence development is also taken into account	Multi-criteria disaggregated approach	X		(X)		X					
Gutjahr & Reiter, 2010	Bi-objective stochastic optimization problem for determining Pareto-efficient portfolios (combination of Monte-Carlo simulation and optimization)	An approach combining project portfolio selection, staff assignment and scheduling of project proposals; competence development is also taken into account; uncertainty and interdependencies between projects are considered	Multi-criteria disaggregated approach	X	X	X	X						
Heimerl & Kolisch, 2010	Mixed-integer linear	Efficient scheduling of	Minimize labor cost	X									

	program	human resources with different skills and efficiencies in a multi-project environment											
Urli & Terrien, 2010	Multi-objective non-linear integer program (solved with a meta-heuristic)	Identification of efficient portfolios in order to support group decision making (a two-stage approach is presented)	Multiple objectives (aggregated objective function)	X	X		X	X		(X)	(X)		
Kundisch & Meier, 2011a	Tailored mathematical decision model	Identification of resource interactions (allocation, performance and sourcing interactions); presentation of a project selection model that takes account of these interactions	Single deterministic benefit value	X			X		X				
Zheng & Vaishnavi, 2011	Visual exploration approach based on the concept of multidimensional perceptual maps	Interactive portfolio selection approach based on visual representations	Multi-criteria disaggregated approach	(X)	X	(X)				X	X	(X)	

Legend:
X : the particular factor is considered
(X): the particular factor is partly considered

Appendix D – Future research

As the following appendix is ordered chronologically, the evolution over time can be followed to a certain extent.

Contribution	Proposition for future work
Santhanam & Kyparisis, 1996	Santhanam and Kyparisis propose *"[…] the development of a DSS that can help managers analyze the IS project selection problem and make an appropriate decision."* (p. 394)
Archer & Ghasemzadeh, 1999	Archer and Ghasemzadeh demand for further research into *"[…] the generic requirements for decision support in project portfolio selection […."* (p. 215). They propose to focus at the requirements of decision makers and the available data.
Jiang & Klein, 1999a	Jiang and Klein recommend **longitudinal studies** in order to examine dynamics in IS planning activities.
Ghasemzadeh & Archer, 2000	Ghasemzadeh and Archer propose additional research regarding the evaluation of **project risks and their impact on portfolio selection**. Furthermore, the authors want to investigate **group support system environments**.
Oral et al., 2001	Oral et al. name several extensions to their model: **Incorporating interactions, multi-period cases and contingency requirements between the projects**.
Irani et al., 2002	Irani et al. recommend further application of **fuzzy logic for IT/IS evaluation**.
Kenneally & Lichtenstein, 2002	The authors propose an analysis (empirical study) of the **interaction between projects** and remark that a definition of **interacting options** is required.
Engwall & Jerbrant, 2003	Engwall and Jerbrant conclude that *"[…] research on multi-project management has to go beyond resource allocation and start addressing incentive structures, accounting systems, and other deeply embedded features of the organization."* (p. 408)
Stummer & Vetschera, 2003	Stummer and Vetschera suggest adapting models to a **federal decision making setting** with an additional decision maker on an upper level.
Bardhan et al., 2006	Bardhan et al. propose further **sensitivity analyses** and a **Monte-Carlo simulation** in order to assess the impact of **volatilities** and the robustness of the solution. Furthermore, the **development of policies** to guide managers in regard to resource allocation decisions is also proposed.
Blomquist & Müller, 2006	Blomquist and Müller recommend **further (empirical) investigations with special focus on geographical and industry particularities**. They conclude that their study *"[...] opens the discussion of whether portfolio management could, in fact, be studied in isolation or only in combination with other line management tasks."* (p. 64)
Eilat et al., 2006	Eilat et al. note that a **dynamic version** of the selection model presented in the paper would be a possible extension.

Martinsuo & Lehtonen, 2007	Martinsuo and Lehtonen propose **further studies on contingency factors** relevant to portfolio management efficiency. They also propose **additional large-scale studies** to investigate the impact of further project management factors on portfolio management efficiency.
Blichfeldt & Eskerod, 2008	Blichfeldt and Eskerod make a claim for a **normative theory** focusing on how companies can improve their project portfolio management.
Lanzinner et al., 2008	Lanzinner et al. mention **problem governance structures** and a **formal feedback process between value tracking and capital budgeting** as general problem areas.
Müller et al., 2008	Müller et al. conclude that the results of their study support a **contingency perspective** and recommend further studies regarding context factors for portfolio management.
Ajjan, 2009	Ajjan et al. propose to investigate **differences in opinions of senior business and IT managers**.
Chen & Cheng, 2009	Chen and Cheng recommend the development of a **decision support system in a fuzzy environment** as possible future work.
Cho & Shaw, 2009	Cho and Shaw suggest the analytical identification of conditions where **IT synergy enhancement** leads to better IT portfolios.
Diepold et al., 2009	Diepold et al. propose further research on the consideration of **intratemporal interdependencies** among projects and on **multiple real options within an IT project**. In this context, compound options, deferral options and abandonment options are mentioned.
Gutjahr et al., 2010	Six topics for future research are identified: **Developing tools for collecting data, incorporating precedence relations between tasks or projects, account for uncertainty (stochastic extension), account for a long term planning horizon (strategic planning), develop a dynamic optimization model, employ exact methods to solve the described model**.
Patanakul & Milosevic, 2009	Patanakul and Milosevic offer the framework derived in this contribution as a **foundation for a large sample study**. They state: "All propositions are testable and can be deployed to research hypotheses for the future empirical research." (p. 230)
Stummer et al., 2009	Stummer and Kiesling mention **robust portfolio modeling** and **contingent portfolio programming** as future directions. Furthermore, they highlight **group decision-making** and **negotiation analysis**.
Gutjahr & Reiter, 2010	Gutjahr and Reiter recommend to enhance their current model by incorporating a **dynamic way of assigning personnel to tasks and to account for changes in staff**.
Jonas, 2010	Jonas suggests **conducting a longitudinal study** focusing on the impact of management involvement.
Meskendahl, 2010	Meskendahl recommends **empirical validation** and enhancement of his conceptual model.
Prifling, 2010	Prifling proposes to conduct **quantitative research** in order to show that his findings in regard to the influence of **organizational culture** are valid. Furthermore, he mentions that *"research on organizational culture and/or the organizational context in which IT projects are carried out is still scarce." (p. 4)*
Urli & Terrien, 2010	Urli and Terrien suggest the expansion of their model by incorporating **project portfolio dynamics**.

Frey & Buxmann, 2011	Frey and Buxmann demand for an **integrated view on different fields of activities** in IT PPM. They propose to **categorize different governance structures** in regard to IT project portfolio management.
Hsu et al., 2011	Hsu et al. suggest further studies taking into account the **user and organizational perspective**.
Kundisch & Meier, 2011a	In this contribution Kundisch and Meier inter alia recommend to evaluate the identification process presented in their study by conducting **design science research**.
Kundisch & Meier, 2011b	Kundisch and Meier propose a number of enhancements of their work: **Inclusion of scheduling constraints, classification scheme for resources and outputs, consideration of uncertainty and the potential for risk diversification, intertemporal interactions**. Furthermore, they propose to **consider the identified interactions in future decision models**.

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