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ORIGINAL RESEARCH

# Value-based process project portfolio management: integrated planning of BPM capability development and process improvement

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**Abstract** Business process management (BPM) is an important area of organizational design and an acknowledged source of corporate performance. Over the last decades, many approaches, methods, and tools have been proposed to discover, design, analyze, enact, and improve individual processes. At the same time, BPM research has been and still is paying ever more attention to BPM itself and the development of organizations' BPM capability. Little, however, is known about how to develop an organization's BPM capability and improve individual processes in an integrated manner. To address this research gap, we developed a planning model. This planning model intends to assist organizations in determining which BPM- and process-level projects they should implement in which sequence to maximize their firm value, catering for the projects' effects on process performance and for interactions among projects. We adopt the design science research (DSR) paradigm and draw from project portfolio selection as well as value-based management as justificatory knowledge. For this reason, we refer to our approach as value-based process project portfolio management. To evaluate the planning model, we validated its design specification by discussing it against theory-backed design objectives and with BPM experts from different organizations. We also compared the planning model with competing artifacts. Having instantiated the planning model as a software prototype, we validated its applicability and usefulness by

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conducting a case based on real-world data and by challenging the planning model against accepted evaluation criteria from the DSR literature.

**Keywords** Business process management · Capability development · Process decision-making · Process improvement · Project portfolio management · Value-based management

## 1 Introduction

Process orientation is an accepted paradigm of organizational design (Kohlbacher and Reijers 2013). Due to constant attention from industry and academia, the business process management (BPM) community has developed mature approaches, methods, and tools that support process discovery, design, analysis, enactment, and improvement (van der Aalst 2013). According to the 2014 BPTrends report, process improvement has been a top priority of process decision-makers for over a decade (Harmon and Wolf 2014). At the same time, the BPM community has been and still is paying ever more attention to BPM itself and the development of organizations' BPM capability (Pöppelbuß et al. 2015; Rosemann and de Bruin 2005; Trkman 2010; Zairi 1997).

In the literature, BPM capability development and process improvement are isolated topics. Research on BPM capability development splits into three streams: The first stream focuses on identifying the constituents of BPM and developing related capability frameworks (de Bruin and Rosemann 2007; Jurisch et al. 2014; van Looy et al. 2014). The common approach is to group capabilities with similar characteristics into capability areas and eventually into factors (Rosemann and vom Brocke 2015). The second stream is concerned with describing how organizations develop their BPM capability and explaining different types of BPM capability development from a theoretical perspective (Niehaves et al. 2014; Pöppelbuß et al. 2015). The third stream related to BPM capability development takes a prescriptive perspective, providing guidance on how to develop BPM in light of different organizational contexts. BPM maturity models were long-time seen as an appropriate tool for BPM capability development (Hammer 2007; Röglinger et al. 2012). However, criticized for ignoring path dependencies and for being context-agnostic, maturity models lost popularity in BPM research (Pöppelbuß et al. 2015). Despite valuable BPM capability frameworks, there is little guidance on how to develop an organization's BPM capability.

As for process improvement, many approaches are available (Zellner 2011). These approaches can be distinguished into continuous improvement and business process reengineering as well as into model- and data-based approaches, each class featuring strengths and weaknesses (van der Aalst 2013; Vergidis et al. 2008). Most process improvement approaches share the individual process as unit of analysis. They are commonly criticized for a lack of guidance on how to put process improvement into practice (Zellner 2011). Some approaches responded to this criticism. To list some recent examples: Taking a project portfolio perspective, Linhart et al. (2015) analyze which projects to implement over time to improve an individual process along established industrialization strategies. Ohlsson et al. (2014) help categorize improvement initiatives based on a process assessment heatmap and a process categorization map. Forstner et al. (2014) provide a decision framework for determining optimal changes in process capability levels, focusing on a single process and related capability areas. Some approaches also consider multiple processes. Bandara et al. (2015), for example, compile process prioritization approaches, characterizing them as too high-level to be useful or as such detailed that the mere identification of critical processes requires significant effort. Combining a multi-process and multi-project perspective, Darmani and Hanafizadeh (2013) help select processes and best practices for process reengineering, aiming for lower risk and higher success of improvement projects. Shrestha et al. (2015) provide a selection method for IT service management processes.

In a nutshell, existing approaches to process improvement and prioritization do not entwine their results with the development of an organization's BPM capability. Vice versa, the few approaches that provide guidance on how to develop an organization's BPM capability neglect the improvement of individual processes. There is a lack of prescriptive knowledge on how to develop an organization's BPM capability and improve individual processes in an integrated manner. This is why we investigate the following research question: *How can organizations develop their BPM capability and improve individual processes in an integrated manner?*

This research question is not only relevant from an academic but also from an industry perspective. For example, de Bruin and Rosemann (2007) seminal BPM capability framework, whose design involved many BPM professionals, highlights "process improvement planning" as well as "process program and project planning" as important BPM constituents. This relevance was confirmed by Lohmann and zur Muehlen (2015) as well as Müller et al. (2016) who recently investigated which BPM roles and competences are demanded by industry.

To address the research question, we developed a planning model. This planning model intends to assist organizations in determining which BPM- and process-level projects they should implement in which sequence to maximize the firm value, while catering for the projects' effects on process performance and for interactions among projects. Thereby, we adopt the design science research (DSR) paradigm and draw from project portfolio selection (PPS) as well as value-based management (VBM) as justificatory knowledge (Gregor and Hevner 2013). This study design is sensible for several reasons: First, planning models are a valid DSR artifact type (March and Smith 1995). Second, processes are typically improved, and an organization's BPM capability is typically developed via projects (Dumas et al. 2013). Third, value orientation is an accepted paradigm of corporate and process decision-making (Buhl et al. 2011; vom Brocke and Sonnenberg 2015). As the planning model relies on PPS and VBM, we refer to our approach as *value-based process project portfolio management*. With this study, we extend our prior research on the planning of BPM capability development and process improvement (Lehnert et al. 2014). We alleviate almost all simplifying assumptions, i.e., projects can now take multiple periods, be executed in parallel subject to various interactions as well as affect process performance absolutely and relatively. Furthermore, we advanced the evaluation by validating the planning model's design specification via expert interviews, by discussing the design specification against design objectives and competing artifacts, by conducting a case based on real-world data and a software prototype, and by reasoning about the model's applicability and usefulness.

Following the DSR methodology as per Peffers et al. (2008), this study discusses the identification of and motivation for the research problem, objectives of a solution, design and development, and evaluation. In Sect. 2, we provide relevant justificatory knowledge and derive design objectives (*objectives of a solution*). In Sect. 3, we outline the research method and evaluation strategy. In Sect. 4, we introduce the planning model's design specification (*design and development*). Section 5 reports on our evaluation activities (*evaluation*). We conclude in Sect. 6 by pointing to limitations and future research possibilities.

## 2 Theoretical background and design objectives

### 2.1 Business process management and capability development

Business process management is the art and science of overseeing how work is performed to ensure consistent outcomes and to take advantage of improvement opportunities (Dumas et al. 2013). From a lifecycle perspective, BPM involves the identification, definition, modeling, implementation, execution, monitoring, controlling, and improvement of processes (Dumas et al. 2013). Processes, as BPM's unit of analysis, are structured sets of activities designed to create specific outputs (Davenport 1993). They split into core, support, and management processes (Armistead et al. 1999). Core processes create value for customers, support processes ensure that core processes continue to function, and management processes help plan, monitor, and control other processes (Harmon 2010).

Business process management is closely related to capability development, a field that builds on the resource-based view of the firm and dynamic capability theory (Niehaves et al. 2014). In terms of the resource-based view, organizations are collections of resources that achieve competitive advantage if their resource configuration is valuable, rare, imperfectly imitable, and nonsubstitutable (Barney 2000). Resources are anything that can be thought of as an organization's strength or weakness (Wernerfelt 1984). They split into assets and capabilities. While assets are anything tangible or intangible an organization can use, capabilities refer to an organization's ability to perform a coordinated set of tasks for achieving a particular result (Helfat and Peteraf 2003). Processes and capabilities thus deal with the same phenomenon, the difference being that processes focus on the *how*, while capabilities emphasize the *what* (Sharp 2013). That is why capabilities are defined as collections of routines or repeatable patterns of action in the use of assets (Wade and Hulland 2004). Extending the resource-based view, dynamic capability theory poses that stable resource configurations cannot sustain competitive advantage (Teece et al. 1997). As changes in an organization's context imply changes in the resource configuration, organizations also need capabilities that facilitate and govern change. Dynamic capability theory thus distinguishes operational and dynamic capabilities (Pavlou and El Sawy 2011). Operational capabilities refer to an organization's ability to make a daily living (Winter 2003; Zollo and Winter 2002). Dynamic capabilities help integrate, build, and reconfigure operational capabilities to enhance environmental fit, effectiveness, and efficiency (Teece and Pisano 1994; Zollo and Winter 2002). As such, dynamic capabilities affect organizations indirectly via their effect on operational capabilities (Helfat and Peteraf 2003).

Joining the BPM and capability development perspectives, processes are operational capabilities, whereas BPM is a particular dynamic capability (Forstner et al. 2014; Trkman 2010). From a capability perspective, BPM "comprises the skills and routines necessary to successfully apply measures of both incremental and radical change" (Pöppelbuß et al. 2015, p. 3). Dealing with all processes of an organization, BPM also serves as infrastructure for effective and efficient work (Harmon 2010). To understand the constituents of BPM, de Bruin and Rosemann (2007) proposed the seminal BPM capability framework based on a global Delphi study. The BPM capability framework comprises 30 BPM-related capability areas grouped into 6 factors, i.e., strategic alignment, governance, methods, information technology, people, and culture (Rosemann and vom Brocke 2015). Examples for BPM capability areas are process design and modeling, process skills and expertise, process-related standards, process measures, and process values and beliefs (de Bruin and Rosemann 2007). In our study, we define the development of an organization's BPM capability as the deliberate implementation and institutionalization of distinct capability areas from the BPM capability framework by means of projects in line with the organization's objectives and context vom Brocke et al. (2014).

When quantifying the performance of processes and assessing the effects of improvement projects, performance indicators are an essential tool (Leyer et al. 2015). Process performance indicators are often grouped according to the Devil's Quadrangle, a multi-dimensional framework that comprises time, cost, quality, and flexibility as performance dimensions (Reijers and Mansar 2005). The Devil's Quadrangle is so-named as improving one performance dimension weakens at least one other, disclosing the trade-offs to be resolved during process improvement. To apply the Devil's Quadrangle, its dimensions must be operationalized via case-specific indicators (Dumas et al. 2013). Against this background, we define the following design objectives:

O.1 *Capability development*: to develop an organization's BPM capability and improve individual processes in an integrated manner, it is necessary to (a) consider projects that affect an organization's processes (operational capabilities) and projects that focus on BPM (dynamic capability). Moreover, (b) projects that influence individual processes as well as projects that affect multiple processes must be considered.

O.2 *Process performance management*: to develop an organization's BPM capability and improve individual processes in an integrated manner, process performance must be conceptualized as a multi-dimensional construct. It is also necessary to resolve trade-offs among different performance dimensions.

### 2.2 Project portfolio selection and scheduling

Regarding PPS and project scheduling, there is a mature body of knowledge that includes quantitative and qualitative approaches (Carazo et al. 2010; Frey and Buxmann 2012; Perez and Gomez 2014). Quantitative approaches typically propose planning models, whereas qualitative approaches introduce reference processes (Archer and Ghasemzadeh 1999; Jeffery and Leliveld 2004). PPS is the activity "involved in selecting a portfolio, from available project proposals […] that meets the organization's stated objectives in a desirable manner without exceeding available resources or violating other constraints" (Archer and Ghasemzadeh 1999, p. 208). The PPS process comprises five stages: pre-screening, individual project analysis, screening, optimal portfolio selection, and portfolio adjustment (Archer and Ghasemzadeh 1999). In the pre-screening stage, projects are checked for strategic fit and whether they are mandatory. During individual project analysis, all projects are evaluated individually against pre-defined performance indicators. The screening stage eliminates all projects that violate critical performance thresholds. The optimal portfolio selection stage then establishes the project portfolio that best meets the performance indicators, considering project interactions (e.g., mutual exclusion, predecessor/successor) and further constraints (e.g., latest finishing dates, restricted budgets) (Kundisch and Meier 2011; Liu and Wang 2011). Finally, decision-makers may adjust the project portfolio.

In PPS, it is mandatory to consider interactions among projects (Lee and Kim 2001). Interactions can be classified as inter-temporal vs. intra-temporal, deterministic vs. stochastic as well as scheduling vs. no scheduling (Kundisch and Meier 2011). Intra-temporal interactions affect the planning of single portfolios, whereas inter-temporal interactions influence decision-making based on potential follow-up projects (Gear and Cowie 1980). Inter-temporal interactions depend on the sequence in which projects are implemented (Bardhan et al. 2004). Interactions are deterministic if all parameters are known with certainty or were estimated as single values. Interactions are stochastic if the parameters are uncertain and follow probability distributions (Medaglia et al. 2007). Scheduling interactions occur if projects may start at different points. We specify the following design objective:

O.3 *Project portfolio selection*: to develop an organization's BPM capability and improve individual processes in an integrated manner, it is necessary to account for (1) the effects of individual projects on process performance, (2) interactions among projects, and (3) domain-specific constraints.

### 2.3 Value-based management

In economic research and practice, value orientation has prevailed as the guiding paradigm of corporate management (Buhl et al. 2011). For example, almost two-thirds of the 30 companies on the German stock index (DAX) explicitly stated in their 2013 annual reports to follow a value-based approach (Bolsinger 2015). VBM aims at sustainably increasing an organization's firm value from a long-term perspective (Ittner and Larcker 2001; Koller et al. 2010). It extends the shareholder value approach that goes back to Rappaport (1986) and was advanced by Copeland et al. (1990) as well as by Stewart (1991). Due to its long-term perspective, VBM also complies with the more general stakeholder value approach (Danielson et al. 2008). For VBM to be fully realized, all corporate activities on all hierarchy levels must be aligned with the objective of maximizing the firm value. To do so, organizations must not only be able to quantify the firm value on the aggregate level but also the value contribution of individual assets and decisions considering their cash flow effects, the time value of money, and the decision-makers' risk attitude (Buhl et al. 2011). In line with investment and decision theory, the valuation functions that are typically used for determining an organization's firm value or the value contribution of individual assets or decisions depend on the decision situation and the decision-makers' risk attitude (Buhl et al. 2011; Damodaran 2012). In case of certainty, decisions can be made based on the net present value (NPV) of future cash flows. Under risk with risk-neutral decision-makers, decisions can be made based on the expected NPV. In case of risk-averse decision-makers, alternatives can be valued via their risk-adjusted expected NPV, which can, among others, be calculated via the certainty equivalent method or a risk-adjusted interest rate (Copeland et al. 2005). These valuation functions belong to the group of discounted cash flow valuation approaches, which determine an asset's or decision's value based on the present value of associated cash flows. These approaches are most common and come "with the best theoretical credentials" (Damodaran 2005, p. 696). They have also been adopted in process decision-making (Bolsinger 2015).

In the last years, value orientation also found its way into process decision-making (vom Brocke and Sonnenberg 2015). Value-based BPM aims at increasing an organization's long-term firm value by making process- and BPM-related decisions in line with their value contribution (Buhl et al. 2011). From a valuation perspective, processes and BPM are considered as corporate assets. Ever more approaches provide economically well-founded support for BPM- and process-related decisions (Bolsinger et al. 2015). Operating on the control flow level, some approaches help compare alternative process designs and/or propose recommendations for improvement (Bolsinger 2015; Bolsinger et al. 2015; vom Brocke et al. 2010). Other approaches abstract from the control flow level, focusing on process performance and/or on process characteristics that capture how work is organized and structured (Afflerbach et al. 2014; Linhart et al. 2015). As mentioned, very few approaches analyze BPM-related decisions such as the development of an organization's BPM capability from a value orientation perspective (Lehnert et al. 2014).

In the literature, numerous paradigms relate to value-based BPM. The most prominent examples are goal-oriented BPM (Neiger and Churilov 2004a), value-focused BPM (Neiger and Churilov 2004b; Rotaru et al. 2011), value-driven BPM (Franz et al. 2011), and value-oriented BPM (vom Brocke et al. 2010). For more details on these paradigms, please refer to Bolsinger (2015). Overall, value-based and value-oriented BPM adopt the general principles of VBM. Moreover, both paradigms are not only restricted to individual processes but can also be applied to BPM-related decisions. Value-oriented BPM provides more details about the underlying cash flows, whereas value-based BPM draws on the functions introduced above for valuing and comparing decision alternatives (Bolsinger 2015). In line with our intention of developing a planning model that requires valuing and comparing many sets of scheduled BPM- and process-level projects, we adopt value-based BPM as the guiding paradigm. This leads to the following design objective:

O.4 *Value-based management*: to develop an organization's BPM capability and improve individual processes in an integrated manner, it is necessary to cater for (1) cash flow effects and (2) the time value of money. Moreover, (3) the involved decision-makers' risk attitude must be considered.

## 3 Research method and evaluation strategy

In the design and development phase of our DSR project, we combined normative analytical modeling and multi-criteria decision analysis as research methods to propose our planning model for value-based process project portfolio management. Normative analytical modeling captures the essentials of a decision problem in terms of closed-form mathematical representations to produce a prescriptive result (Meredith et al. 1989). Multi-criteria decision analysis assists with structuring decision problems, incorporating multiple criteria, resolving conflicts among these criteria, and appraising value judgments to support a deliberate and justifiable choice among decision alternatives (Keeney and Raiffa 1993). Thereby, relevant decision criteria must be identified and quantified, decision variables and constraints must be defined, and non-trivial assumptions must be made transparent (Cohon 2004). Combining both research methods is reasonable for several reasons: First, developing an organization's BPM capability and improving individual processes in an integrated manner require valuating and comparing multiple decision alternatives, i.e., sets of scheduled BPM- and process-level projects, while accounting for multiple interactions among projects. We refer to such sets of scheduled BPM- and process-level projects as project roadmaps. Second, conceptualizing process performance as a multi-dimensional construct makes it necessary to resolve conflicts (trade-offs) among performance dimensions. Third, developing an organization's BPM capability and improving individual processes is such complex that decision alternatives, i.e., project roadmaps, can be neither valuated nor compared manually. Thus, the mathematical planning model also serves as requirements specification for a software prototype.

To develop the planning model, we proceeded in line with the steps provided by Cohon (2004): We first introduce the planning model's conceptual architecture and define central constructs (Sect. 4.1). We then formulate the planning model's objective function to determine the value contribution of different project roadmaps (Sect. 4.2). This objective function operationalizes the valuation functions from the VBM domain by integrating the effects of BPM- and process-level projects on one another as well as on process performance. After that, we model the performance effects of BPM- and process-level projects in detail and show how to integrate these effects into the planning model's objective function (Sects. 4.3 and 4.4). This complies with the literature on multi-criteria decision analysis that requires proposing a mathematical function for each decision criterion. Finally, we specify interactions among projects as well as domain-specific constraints that must be considered when planning BPM capability development and the improvement of individual processes in an integrated manner (Sect. 4.5).

To demonstrate and evaluate our planning model, we followed Sonnenberg and vom Brocke's (2012) framework of evaluation activities in DSR. This framework combines two dimensions, i.e., ex-ante/ex-post and artificial/naturalistic evaluation (Pries-Heje et al. 2008; Venable et al. 2012). Ex-ante evaluation is conducted before ex-post evaluation after the artifact has been constructed, i.e., instantiated, for example, in terms of a software prototype. Naturalistic evaluation requires artifacts to be challenged by real people, tasks, or systems. Sonnenberg and vom Brocke (2012) framework comprises four evaluation activities (EVAL1 to EVAL4). EVAL1 aims at justifying the research topic as a meaningful DSR problem. It also requires deriving design objectives from justificatory knowledge to assess whether an artifact helps solve the research problem. We completed this activity in the introduction and the theoretical background. EVAL2 strives for validated design specifications. To validate the planning model's design specification, we discussed it via feature comparison against the design objectives and competing artifacts (Siau and Rossi 1998). We also validated the planning model's design specification via qualitative, semi-structured expert interviews with different organizations (Myers and Newman 2007). This helped us check how organizational stakeholders assess the design specification's understandability and real-world fidelity (Sonnenberg and vom Brocke 2012). We report the results of EVAL2 in Sect. 5.1. Activity EVAL3 strives for validated artifact instantiations. We, thus, implemented the planning model as a software prototype, which we present in Sect. 5.2. EVAL4 requires validating the instantiation's usefulness and applicability in naturalistic settings. We applied the prototype to a case based on real-world data. We also discussed the planning model's specification and instantiation against accepted evaluation criteria (e.g., effectiveness and efficiency, impact on the artifact environment and user) that have been proposed for EVAL4 purposes in the DSR literature (March and Smith 1995). This discussion partly integrates the results of EVAL2 to EVAL3. We present the results of EVAL4 in Sect. 5.3.

# 4 Design specification

## 4.1 Conceptual architecture

The planning model intends to assist organizations in determining which BPM- and process-level projects they should implement in which sequence to maximize their firm value. The planning model thereby takes a multi-process, multi-project, and multi-period perspective. On a high level of abstraction, the planning model considers an organization's status quo, admissible project roadmaps, and improved status quo candidates that can be reached by implementing admissible project roadmaps (Fig. 1). The status quo is a snapshot of the organization that contains multiple processes. Each process has a distinct performance, which is measured along multiple performance dimensions (e.g., time, cost, quality). On the central

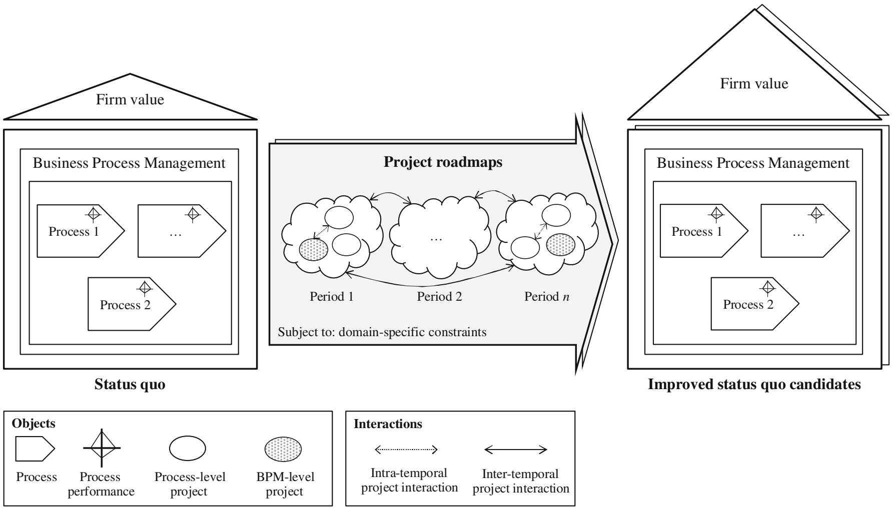


**Fig. 1** Conceptual architecture of the planning model's design specification

assumption of process orientation that all corporate activities are processes, the performance of all processes is aggregated into the organization's firm value. Thereby, trade-offs among performance dimensions are resolved. The status quo also captures the organization's BPM capability that enables efficient and effective work as well as change of existing processes.

Project roadmaps include multiple projects that split into BPM- and process-level projects. Process-level projects (e.g., adoption of a workflow management system or integration of additional quality gates) affect the performance of individual processes. BPM-level projects (e.g., trainings in process redesign methods or the adoption of a process modeling tool) help develop the organization's BPM capability by facilitating the implementation of future process-level projects or by making the execution of all processes more cost-efficient. With BPM being a dynamic capability, developing an organization's BPM capability is never an end in itself but a means for enhancing the involved processes' performance and, eventually, the organization's firm value. The projects that can be compiled into project roadmaps must be selected from pre-defined project candidates and scheduled over multiple planning periods. Project roadmaps cannot be compiled arbitrarily. They must comply with intra-temporal project interactions (e.g., two projects must not be implemented in the same period), inter-temporal project interactions (e.g., a project requires another project to be implemented first), and domain-specific constraints (e.g., limited budgets). Project interactions and constraints determine which project roadmaps are admissible. With BPM- and process-level projects having different effects on the involved processes' performance, project roadmaps do not only lead to different improved status quo candidates, i.e., distinct ways of developing the organization's BPM capability and improving individual processes; they also yield different value contributions. The planning model thus intends to identify that project roadmap whose concrete selection and scheduling of process- and BPM-level projects leads to the improved status quo candidate with the highest value contribution.

In the planning model, project roadmaps are modeled as tuples. Relating to the periods of a multi-period planning horizon, each tuple component contains a set of projects that have been scheduled to a distinct period in line with the project interactions and domain-specific constraints at hand. An example roadmap is shown in Eq. (1). This roadmap shows seven projects scheduled over six periods. Two projects (i.e., projects 1 and 4) must be implemented in the first period, whereas no projects have been scheduled to periods three and six. Project 1 takes two periods to be implemented, whereas most other projects can be implemented in a single period.

$$r = (\{1,4\},\{1,5,7\},\{\},\{2\},\{2,3,6\},\{\}) \tag{1}$$

Below, we specify the planning model's objective function that values alternative project roadmaps (Sect. 4.2). We then introduce BPM- and process-level projects with a focus on their performance effect (Sect. 4.3), before showing how to integrate these effects into the planning model's objective function (Sect. 4.4). In the end, we show which project interactions and domain-specific constraints must be considered when compiling BPM- and process-level projects into project roadmaps (Sect. 4.5).

### 4.2 Objective function

The planning model's objective function measures the value contribution of project roadmaps in terms of their NPV based on a risk-adjusted interest rate (Buhl et al. 2011). The objective function is shown in Eq. (2). The NPV integrates multiple periodic cash flows by discounting them back to the point of decision (Damodaran 2005). In each period, the cash flow is divided into investment outflows, overarching fixed outflows, and process-specific cash flows. Investment outflows accrue for implementing currently running projects. Overarching fixed outflows capture BPM-related fixed outflows for multiple processes, such as operating a center of process excellence or a modeling tool (Dumas et al. 2013). The process-specific cash flows are divided into fixed outflows and operating cash flows, which are driven by operating inflows (i.e., the sales price for core processes and the transfer price for support processes), operating outflows, and the number of instances in that period. The number of instances is mainly driven by the performance dimensions time and quality (Linhart et al. 2015). As the number of instances that a core process is executed reflects the process' external customer demand, it typically decreases with increasing time and increases with increasing quality (Anderson et al. 1994). For support processes, the number of instances reflects internal customer demand. With internal customers being bound to support processes, the number of instances per period can be seen as independent from quality and time as long as critical performance thresholds are not violated. In the planning model, fixed and investment outflows are due at the beginning of each period, whereas operating cash flows are due at the end of each period. Figure 2 (right and middle column) illustrates the basic logic of the planning model's objective function for a single process and a single period.

$$
\begin{aligned}
r^* &= \underset{r \in R}{\operatorname{argmax}} \, \mathrm{NPV}_r \\
&= \underset{r \in R}{\operatorname{argmax}} \sum_{y=0}^{Y} \left[ -\frac{O_y^{\mathrm{inv}}}{(1+z)^y} - \frac{O_y^{\mathrm{fix}}}{(1+z)^y} + \sum_{i \in I} \left[ -\frac{O_{i,y}^{\mathrm{fix}}}{(1+z)^y} + \frac{n_i\left(q_{i,y}, t_{i,y}\right)\left[I_i^{\mathrm{op}} - O_{i,y}^{\mathrm{op}}\right]}{(1+z)^{y+1}} \right] \right]
\end{aligned} \tag{2}
$$

where $r \in R$ is a distinct project roadmap from the set of admissible project roadmaps $R$, $\mathrm{NPV}_r$ is the NPV of project roadmap $r$, $y \leq Y \in \mathbb{N}$ is the period within planning horizon $Y$, $z \in \mathbb{R}_0^+$ is the risk-adjusted interest rate, $O_y^{\mathrm{inv}} \in \mathbb{R}_0^+$ is the investment outflows in period $y$, $O_y^{\mathrm{fix}} \in \mathbb{R}_0^+$ is the overarching BPM-related fixed outflows in period $y$, $i \in I$ is the distinct process from the set of processes $I$, $O_{i,y}^{\mathrm{fix}} \in \mathbb{R}_0^+$ is the process-specific fixed outflows of process $i$ in period $y$, $n_i\left(q_{i,y}, t_{i,y}\right) \in \mathbb{R}_0^+$ is the expected number of instances of process $i$ in period $y$, $q_{i,y} \in \mathbb{R}_0^+$ is the quality performance of process $i$ in period $y$, $t_{i,y} \in \mathbb{R}_0^+$ is the time performance of process $i$ in period $y$, $I_i^{\mathrm{op}} \in \mathbb{R}_0^+$ is the internal or external price for executing process $i$ once, $O_{i,y}^{\mathrm{op}} \in \mathbb{R}_0^+$ is the process-specific operating outflows of process $i$ in period $y$.

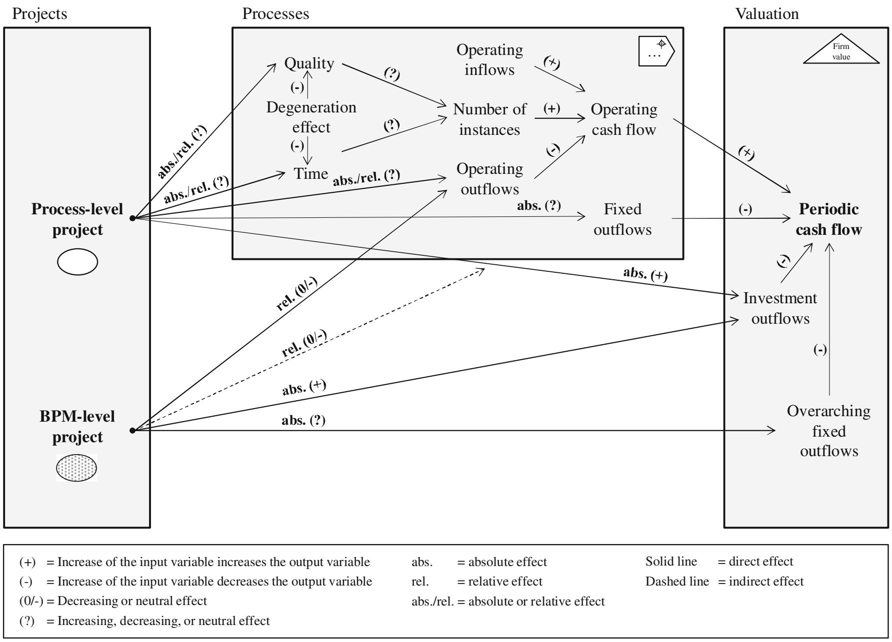


**Fig. 2** Performance effects of process- and BPM-level projects (for a single period and process)

### 4.3 Project types and performance effects

The planning model distinguishes process- and BPM-level projects. The performance effects of these project types can be relative or absolute (Linhart et al. 2015). While the absolute magnitude of some performance effects (e.g., the effects on fixed outflows) can be determined independently from prior projects, the absolute magnitude may depend on previously implemented projects for other performance effects (e.g., effects on time and quality). In the second case, implementing the same project in different periods leads to different absolute effects. In these cases, only the relative magnitude of the performance effect can be estimated independently from other projects. Together with the discounting effect, absolute and relative performance effects capture path dependencies that occur when developing an organization's BPM capability and improving individual processes in an integrated manner. Figure 2 (left and middle column) illustrates the performance effects of BPM- and process-level projects for a single process and a single period. It also shows the polarity of each effect and indicates whether it can be estimated absolutely, relatively, or both in the planning model.

Process-level projects aim at improving operational capabilities. Therefore, they can affect quality, time, operating outflows, and fixed outflows of individual processes. To cover a broad variety of effect constellations, process-level projects can influence the performance dimensions positively, negatively, or not at all. The effect on quality, time, and operating outflows can be absolute or relative, while the effect on fixed outflows can only be absolute. All process-level projects cause investment outflows—for example, the hiring of additional workers for an insurance company's claim settlement process. This project increases the periodic fixed outflows of the claim settlement process (e.g., by 50 TEUR), increases the operating outflows (e.g., by 5 %), reduces the average cycle time (e.g., by 25 %), and increases quality by ensuring fewer mistakes (e.g., by 15 %). In another example, adopting a workflow management system for claim settlement reduces the average cycle time (e.g., by 10 min) due to enhanced resource allocation and increases quality in terms of customer satisfaction (e.g., by 10 points). The project also increases the process' fixed outflows (e.g., by 15 TEUR) and operating outflows (e.g., by 100 EUR per instance) due to improved maintenance. In Fig. 2, the performance effects of process-level projects are shown via edges from the process-level project to the time, quality, operational, and fixed outflows of an individual process.

BPM-level projects aim at developing an organization's BPM capability. Thereby, they can affect the organization's processes twofold, either indirectly by facilitating the implementation of future process-level projects or directly by making the involved processes more cost-efficient (Kim et al. 2011; Pöppelbuß et al. 2015). BPM-level projects with only a direct effect make the processes under investigation more cost-efficient starting right from the next period (Kim et al. 2011). This effect is relative. For example, consider process manager training that increases the coordination among processes and ensures an end-to-end mindset. The operating outflows are likely to drop (e.g., by 5 %) despite additional overarching fixed outflows (e.g., by 20 TEUR) due to training effort. BPM-level projects with only an indirect effect make it easier to implement process-level projects. This effect becomes manifest in terms of reduced investment outflows when implementing process-level projects allocated to future periods. Again, this effect is relative. Consider the training of employees in business process reengineering (BPR) methods or process redesign patterns (Hammer and Champy 1993; Reijers and Mansar 2005). Such training allows employees to implement future process-level projects more easily. IT-related examples include the adoption of process modeling or simulation tools. Some BPM-level projects combine the direct and indirect effects. Such projects not only help implement future process-level projects but also make processes more cost-efficient. Consider, for example, Six Sigma training (Linderman et al. 2003). Six Sigma provides tools for facilitating process improvement. An approach to continuous process improvement, Six Sigma also motivates people to continuously look for more efficient ways of working. Common to all BPM-level projects is that they cause investment outflows. In Fig. 2, the direct performance effects of BPM-level projects are indicated by an edge from the BPM-level project to the operational process-specific outflows. The indirect performance effects are shown via a dashed edge that, in the sense of moderating effect, points from the BPM-level project to the investment outflow edge of the process-level project.

For the purpose of formulating the design specification of our planning model, we make the following assumption regarding the performance effects of process-level and BPM-level projects: *The quantifiable performance effects of all projects can be determined ex-ante at the individual project analysis stage of the PPS process. In some cases, such a quantification covers the effects that projects can have on the firm value only partially, as quantifying non-financial performance effects is a complex task. Performance effects become manifest immediately after a project has been completed. Only one process-level project can be implemented per period and process. If a process-level project affects a distinct performance dimension, this effect is either relative or absolute.*

### 4.4 Integrating the performance effects into the objective function

To illustrate how the quantifiable performance effects of process- and BPM-level projects can be integrated into the planning model's objective function, we offer functions for calculating the quality, time, operating outflows, and fixed outflows of individual processes as well as overarching fixed and investment outflows in a given period. These functions should be interpreted as exemplary and generic functions, as they can be adapted on the type level (e.g., by including further performance dimensions) and operationalized differently on the instance level (e.g., using different performance indicators) when applying the planning model in organizational contexts. The offered functions focus on the most prominent financial and non-financial performance dimensions as discussed in the BPM literature. Thus, these functions do not only illustrate the basic mechanics of our planning model (i.e., how the absolute and relative effects of projects cascade over time), but also serve as a starting point when customizing the planning model for application in practice as well as for structuring the discussions with industry partners when estimating project effects. The real-world fidelity of these functions has been critically reflected in EVAL2 based on expert interviews with organizational stakeholders (Sect. 5.1.2). Below, $S$ is the set of available projects and $s \in S$ is a distinct process- or BPM-level project.

The quality of a process in a given period depends on the quality at the decision point and the quality effects of all related process-level projects completed up to that period (Eq. 3). As quality usually has an upper boundary (e.g., error rate), the planning model incorporates process-specific upper quality boundaries (Leyer et al. 2015). Moreover, one must invest continuously to maintain an once-achieved quality level, i.e., process quality drops whenever the organization fails to implement a process-level project with respect to that process (Beverungen 2014). The planning model, therefore, features a process-specific degeneration effect that penalizes if the organization focuses too much on distinct processes or the BPM capability.

$$q_{i,y} = \begin{cases} q_{i,0}, & \text{if } y = 0 \\ \min\left(\left[\max\left(q_{i,y-1} + \alpha^{\text{abs.}}_{i,y-1}; 0\right)\alpha^{\text{rel.}}_{i,y-1}\right]; q_i^{\max}\right), & \text{else} \end{cases} \tag{3}$$

where $\alpha^{\text{abs.}}_{i,y-1} \in \mathbb{R}$ is the absolute effect on quality, equals $\alpha^{\text{abs.}}_s$ if a process-level project $s \in S$ with respect to process $i$ has been finished in period $y - 1$. Otherwise, the absolute effect on quality equals 0. $\alpha^{\text{rel.}}_{i,y-1} \in ]0;\infty[$ is the relative effect on quality, equals $\alpha^{\text{rel.}}_s$ if a process-level project $s \in S$ with respect to process $i$ has been finished in period $y - 1$. Otherwise, the relative effect on quality equals $\eta_i$. $\eta_i \in ]0;1]$ is the process-specific quality degeneration effect $q_i^{\max} \in \mathbb{R}^+$ is the process-specific upper quality boundary.

Time and quality can be treated similarly, the difference being that time has no upper boundary and a polarity different from quality. The time of a process at a given period depends on the time of the process at the decision time and the time effects of all completed process-level projects regarding that process (Eq. 4). Analogous to quality, the planning model incorporates a process-specific degeneration effect that occurs whenever the organization does not conduct a process-level project regarding the process at hand.

$$t_{i,y} = \begin{cases} t_{i,0}, & \text{if } y = 0 \\ \left[\max\left(t_{i,y-1} + \beta^{\text{abs.}}_{i,y-1}; 0\right)\beta^{\text{rel.}}_{i,y-1}\right], & \text{else} \end{cases} \tag{4}$$

where $\beta^{\text{abs.}}_{i,y-1} \in \mathbb{R}$ is the absolute effect on time, equals $\beta^{\text{abs.}}_s$ if a process-level project $s \in S$ with respect to process $i$ has been finished in period $y - 1$. Otherwise, the absolute effect on time equals 0. $\beta^{\text{rel.}}_{i,y-1} \in ]0;\infty[$ is the relative effect on quality, equals $\beta^{\text{rel.}}_s$ if a process-level project $s \in S$ with respect to process $i$ has been finished in period $y - 1$. Otherwise, the relative effect on time equals $\theta_i$. $\theta_i \in [1;\infty[$ is the process-specific time degeneration effect.

The operating outflows of a process in a distinct period depend on the operational outflows of that process at the decision point as well as on the effects of all BPM-level and related process-level projects that have been completed up to that period

(Eq. 5). The effects of prior BPM-level projects are relative and may reduce the operating outflows. The effects of prior process-level projects can be either relative or absolute.

$$O^{\text{op}}_{i,y} = \begin{cases} O^{\text{op}}_{i,0}, & \text{if } y = 0 \\ \left[\max\left(O^{\text{op}}_{i,y-1} + \gamma^{\text{abs.}}_{i,y-1}; 0\right)\gamma^{\text{rel.}}_{i,y-1}\right] \prod\limits_{j \in BPM^{\text{fin\_in}}_{y-1}} \varepsilon_j, & \text{else} \end{cases} \tag{5}$$

where $\gamma^{\text{abs.}}_{i,y-1} \in \mathbb{R}$ is the absolute effect on the operating outflows, equals $\gamma^{\text{abs.}}_{s}$ if a process-level project $s \in S$ with respect to process $i$ has been finished in period $y$ – 1. Otherwise, the absolute effect on the operating equals 0. $\gamma^{\text{rel.}}_{i,y-1} \in ]0;\infty[$ is the relative effect on the operating outflows, equals $\gamma^{\text{rel.}}_{s}$ if a process-level project $s \in S$ with respect to process $i$ has been finished in period $y$ – 1. Otherwise, the relative effect on the operating outflows equals 1. $\varepsilon_j \in ]0; 1]$ is the relative effect of project $j \in BPM^{\text{fin\_in}}_{y-1}$ on the operating outflows of all processes under investigation $BPM^{\text{fin\_in}}_{y-1}$ Set of BPM-level projects that have been finished in period $y$ – 1.

The process-specific fixed outflows of a process in a distinct period depend on the fixed outflows at the decision point and the effects of related process-level projects that have been finished up to that period (Eq. 6). Analogously, the overarching fixed outflows in a given period depend on the BPM-level projects that have been finished up to that period (Eq. 7).

$$O^{\text{fix}}_{i,y} = \begin{cases} O^{\text{fix}}_{i,0}, & \text{if } y = 0 \\ \max(O^{\text{fix}}_{i,y-1} + \delta_{i,y-1}; 0), & \text{else} \end{cases} \tag{6}$$

where $\delta_{i,y-1} \in \mathbb{R}$ is the absolute effect on the process-specific fixed outflows, equal to $\delta_s$ if a process-level project $s \in S$ with respect to process $i$ has been finished in period $y$ – 1. Otherwise, the absolute effect on the process-specific fixed outflows equals 0.

$$O^{\text{fix}}_{y} = \begin{cases} O^{\text{fix}}_{0}, & \text{if } y = 0 \\ \max\left(O^{\text{fix}}_{y-1} + \sum\limits_{j \in BPM^{\text{fin\_in}}_{y-1}} \epsilon_j; 0\right), & \text{else} \end{cases} \tag{7}$$

where $\epsilon_j \in \mathbb{R}$ is the absolute effect of project $j \in BPM^{\text{fin\_in}}_{y-1}$ on the overarching fixed outflows.

Finally, the investment outflows in a distinct period depend on which process- and BPM-level projects are currently running (Eq. 8). In contrast to the effects shown above, the investment outflows consider all the projects initiated, continued, or finished in the period under consideration. For process-level projects, the investment outflows also depend on the effects of all completed BPM-level projects. The investment outflows of BPM-level projects do not depend on other projects.

**Table 1** Interactions among projects and domain-specific constraints

| | | |
|---|---|---|
| Interactions among projects | | |
| Local mutual exclusiveness | $LocMutEx(s, s')$ | Either project $s$ or $s'$ can be implemented in the same period. According to assumption (A.2), all process-level projects referring to the same process are locally mutually exclusive |
| Global mutual exclusiveness | $GloMutEx(s, s')$ | Either project $s$ or $s'$ can be implemented in the same project roadmap |
| Local mutual dependency | $LocMutDep(s, s')$ | If project $s$ or $s'$ is included in a project roadmap, the other project must be included as well. The implementation of both projects must start in the same period |
| Global mutual dependency | $GloMutDep(s, s')$ | If project $s$ or $s'$ is included in a project roadmap, the other project must be included as well |
| Predecessor/successor | $PreSuc(s, s')$ | If included in a project roadmap, project $s'$ must be implemented after project $s$ has been finished |
| Project-specific constraints | | |
| Earliest beginning | $Earliest(s, y)$ | If included in a project roadmap, the implementation of project $s$ must start in period $y$ at the latest |
| Latest completion | $Latest(s, y)$ | If included in a project roadmap, the implementation of project $s$ must be finished in period $y$ at the latest |
| Mandatory project | $Mandatory(s)$ | Project $s$ must be included in each project roadmap |
| Process-specific constraints | | |
| Critical quality boundary | $QualMin(x, i, y)$ | There is a critical quality boundary $x$, which process $i$ must not fall short of in period $y$. This constraint applies particularly to support processes where the number of instances is invariant regarding quality |
| Critical time boundary | $TimeMax(x, i, y)$ | There is a critical time boundary $x$, which process $i$ must not exceed of in period $y$. This constraint applies particularly to support processes where the number of instances is invariant regarding time |
| Period-specific constraints | | |
| Periodic process-level budget | $BudPro(x, i, y)$ | In period $y$, there is a budget $x$ regarding process $i$, which the investment outflows of the currently running process-level project must not exceed |
| Periodic BPM-level budget | $BudBPM(x, y)$ | In period $y$, there is a budget $x$, which the investment outflows of all currently running BPM-level projects must not exceed |
| Overall periodic budget | $Budget(x, y)$ | In period $y$, there is a budget $x$, which the investment outflows of all currently running projects must not exceed |
| Number of projects | $NumProj(x, y)$ | In period $y$, the number of all currently running projects must not exceed $x$ (e.g., due a given number of project managers) |

$$O_y^{\text{inv}} = \sum_{j \in BPM_y^{\text{run}}} O_j^{\text{inv}} + \sum_{j \in PLP_y^{\text{run}}} O_j^{\text{inv}} \prod_{j \in BPM_{y-1}^{\text{fin\_upto}}} \zeta_j \tag{8}$$

where $O_j^{\text{inv}} \in \mathbb{R}^+$ is the investment outflows of project $j \in BPM_y^{\text{run}}$ or $j \in PLP_y^{\text{run}}$. The investment outflows of projects whose implementation takes multiple periods are split proportionately according to the number of periods. $\zeta_j \in ]0; 1]$ is the relative effect of project $j \in BPM_{y-1}^{\text{fin\_upto}}$ on the investment outflows of process-level projects. $BPM_y^{\text{run}}$ is the set of BPM-level projects currently running in period $y$, $PLP_y^{\text{run}}$ is the set of process-level projects across all processes currently running in period $y$, $BPM_{y-1}^{\text{fin\_upto}}$ is the set of BPM-level projects that have been finished up to period $y - 1$.

### 4.5 Interactions and domain-specific constraints

To restrict the set of admissible project roadmaps, the planning model allows the specification of interactions among projects and domain-specific constraints that project roadmaps must not violate. In Table 1, we compiled interaction and constraint types. While some interaction and constraint types are popular in the PPS literature (Liu and Wang 2011; Perez and Gomez 2014), we added constraint types that particularly fit the BPM context (e.g., budget per process and period, boundaries for quality and time). How many interactions and constraints are required depends on the concrete context.

## 5 Evaluation

### 5.1 Validation of the design specification (EVAL2)

#### *5.1.1 Feature comparison and competing artifacts*

To validate whether the planning model's design specification suitably addresses the research question, we discuss its characteristics against the design objectives derived from justificatory knowledge. This method is called feature comparison, an ex-ante and artificial evaluation method (Venable et al. 2012). To assess whether the planning model contributes to existing knowledge, we also discuss the features of competing artifacts against the design objectives. As competing artifacts, we selected prescriptive approaches from the BPM discipline that either take a multi-process, a multi-project, or both perspectives. We already sketched the competing artifacts when justifying the research gap in the introduction. We concede that this analysis may not include all existing approaches. However, we are confident to cover those works that represent the most recent developments.

From a stand-alone perspective, the planning model addresses all design objectives. Details are shown in Table 2. Nevertheless, future research is required with respect to some design objectives. For example, the planning model only caters

**Table 2** Results of feature comparison including competing artifacts

| | Characteristics of our planning model | Bandara et al. (2015) | Darmani and Hanafizadeh (2013) | Forstner et al. (2014) | Linhart et al. (2015) | Ohlsson et al. (2014) | Shrestha et al. (2015) |
|---|---|---|---|---|---|---|---|
| Summary | Supports the selection and scheduling of BPM- and process-level projects to develop organization's BPM capability and improve individual processes in an integrated way. Projects are compiled into project roadmaps, which are assessed via their value contribution. Our planning model takes a multi-process, multi-project, and multi-period perspective | Supports the prioritization of process improvement projects with the business value scoring (BVS) model. The BVS is a multi-dimensional, multi-level, multi-stakeholder approach in assessment. It integrates the assessment results into a single indicator to capture the business value of improvement projects | Supports the selection of processes and best practice candidates for business process reengineering. The method aims to achieve lower risk and higher probability of success for process improvement projects | Supports decisions on how to determine the optimal increase/decrease of process capability levels. The model focuses on a single core process with multiple related capability areas, which include management and support processes. The concept of projects is captured implicitly via increases/decreases of capability levels | Supports the selection and scheduling of process improvement projects along established industrialization strategies, accounting for process characteristics that reflect how work is performed and organized. Projects are compiled into improvement roadmaps, which are assessed via their value contribution | Supports the categorization of business processes and the prioritization of improvement initiatives. Central artifacts are the process assessment heatmap and the process categorization map | Supports the selection of processes for improvement in IT service management. The process selection method balances business and IT service management objectives and builds on a decision support system to recommend which processes should be considered for improvement |

**Table 2** continued

| | Characteristics of our planning model | Bandara et al. (2015) | Darmani and Hanafizadeh (2013) | Forstner et al. (2014) | Linhart et al. (2015) | Ohlsson et al. (2014) | Shrestha et al. (2015) |
|---|---|---|---|---|---|---|---|
| (O.1a) | Our planning model considers BPM- and process-level projects. These project types help develop operational capabilities (processes) and BPM as a particular dynamic capability | The focus is on an organization's individual processes. BPM is not considered | The focus is on determining best practices for selected strategic processes. BPM is not considered | Projects directly affect capability areas. The core process is affected transitively. BPM is not considered as the model builds on process maturity models | Projects can affect process performance or multiple characteristics that reflect how work is performed and organized. BPM is not considered | Projects can affect processes in terms of differentiation, formality, and value network governance such as indicated in the process categorization map. BPM is not considered | The method yields a process selection matrix without a focus on projects. It focuses on single processes. BPM is not considered |
| (O.1b) | Process-level projects affect individual processes. BPM-level projects affect all processes under investigation and/or facilitate the implementation of process-level projects in the future | Projects affect a distinct process. There are no projects that affect multiple processes | Projects affect a distinct process. There are no projects that affect multiple processes | Projects affect a distinct process. There are no projects that affect multiple processes | Projects affect a distinct process. There are no projects that affect multiple processes | Projects affect single processes. There are no projects that affect multiple processes | The focus is on individual processes. Projects are not considered |

**Table 2** continued

| | Characteristics of our planning model | Bandara et al. (2015) | Darmani and Hanafizadeh (2013) | Forstner et al. (2014) | Linhart et al. (2015) | Ohlsson et al. (2014) | Shrestha et al. (2015) |
|---|---|---|---|---|---|---|---|
| (O.2) | Our planning model accounts for the time, quality, and cost dimensions of process performance as well as for the trade-offs among these dimensions. The cost perspective is analyzed in great detail according to the VBM paradigm | The BVS gives a high-level overview of how to calculate the business value of improvement projects. It includes the six dimensions reputation, clients, business processes, financial opportunity, regulation and compliance, and human resources | Process performance is not quantified via performance indicators. 19 factors and 44 indicators are defined to determine the perceived degree of change in relation to corporate strategy | Process performance is measured in terms of the risk-adjusted expected NPV in line with the VBM paradigm. No operational performance indicators are considered | Process performance is operationalized in terms of time, quality, and costs, catering for trade-offs. For each dimension, several performance indicators are used. The cost perspective is analyzed in great detail according to the VBM paradigm | Process performance is assessed qualitatively via different color regimes in the process assessment heatmap. It covers five perspectives (i.e., positioning, relating, preparing, implementing, proving), which relate to de Bruin and Rosemann (2007) BPM capability framework | A perceived service gap is derived based on the SERVQUAL model. To do so, business drivers in the context of IT services are rated qualitatively |

**Table 2** continued

| | Characteristics of our planning model | Bandara et al. (2015) | Darmani and Hanafizadeh (2013) | Forstner et al. (2014) | Linhart et al. (2015) | Ohlsson et al. (2014) | Shrestha et al. (2015) |
|---|---|---|---|---|---|---|---|
| (O.3a) | Projects can affect the performance of individual or of all processes. They can also influence the investment outflows of future projects. Project effects on process performance can be absolute or relative | Each project is estimated based on the expected outcomes with respect to the dimensions mentioned above | Project effects are defined and evaluated based on the perceived degree of change, i.e., the difference between the weighted value of the conditions before and after project implementation | Effects of individual projects are measured via increases/ decreases of capability levels | Projects can affect the performance of an individual processes and further characteristics that reflect how work is performed and organized. Thereby, projects can transitively (but not directly) affect the investment outflows of future projects | Projects can affect processes in terms of differentiation, formality, and value network governance such as indicated in the process categorization map | The focus is on processes, not on projects. Thus, a perceived service gap is determined. No performance effects of projects are included |

**Table 2** continued

| | Characteristics of our planning model | Bandara et al. (2015) | Darmani and Hanafizadeh (2013) | Forstner et al. (2014) | Linhart et al. (2015) | Ohlsson et al. (2014) | Shrestha et al. (2015) |
|---|---|---|---|---|---|---|---|
| (O.3b) | Our planning model considers deterministic, scheduling, and intra- as well as inter-temporal interactions among projects | No interactions among projects are considered | No interactions among projects are considered | Interactions are considered implicitly via the lifecycle logic of process maturity models. There are strict predecessor/successor interactions regarding single capability areas. No further interactions are considered | The approach considers deterministic and scheduling interactions. Inter-temporal interactions are only modeled implicitly. Intra-temporal interactions are neglected due to the focus on an individual process | No interactions among projects are considered | No interactions among projects are considered |
| (O.3c) | The planning model accounts for general interactions among projects and for BPM-specific interactions | No domain-specific constraints are considered | No domain-specific constraints are considered | No domain-specific constraints are considered | Domain-specific constraints are only modeled implicitly | No domain-specific constraints are considered | No domain-specific constraints are considered |

**Table 2** continued

| | Characteristics of our planning model | Bandara et al. (2015) | Darmani and Hanafizadeh (2013) | Forstner et al. (2014) | Linhart et al. (2015) | Ohlsson et al. (2014) | Shrestha et al. (2015) |
|---|---|---|---|---|---|---|---|
| (O.4a) | Our planning model ranks project roadmaps according to their value contribution, measured in terms of the project roadmaps' NPV | The BVS aggregates qualitative estimations to a single indicator reflecting the business value of an improvement project | Projects effects are determined using non-monetary measures. The model maximizes the weighted perceived degree of change using fuzzy numbers | The planning model considers the risk-adjusted expected NPV of increasing/decreasing capability levels | Project roadmaps are ranked in line with their value contribution, measured in terms of the project roadmaps' NPV | Project effects are assessed qualitatively by positioning processes within the process categorization map. Qualitative effects are not integrated into a single numeric value | The process selection matrix builds on strategic business drivers and a service gap perception. No cash flows or other monetary performance indicators are included |
| (O.4b) | Long-term effects are considered via the NPV. Different periods in time are considered explicitly due to inter-temporal interactions among projects | Long-term effects are not considered | Long-term effects are not considered | Long-term effects are considered via the NPV. There is no distinction between different periods in time | Long-term effects are considered via the NPV. Different periods in time are considered explicitly. Inter-temporal project interactions are only modeled implicitly | Long-term effects are not considered | Long-term effects are not considered |

**Table 2** continued

| | Characteristics of our planning model | Bandara et al. (2015) | Darmani and Hanafizadeh (2013) | Forstner et al. (2014) | Linhart et al. (2015) | Ohlsson et al. (2014) | Shrestha et al. (2015) |
|---|---|---|---|---|---|---|---|
| (O.4c) | Our planning model accounts for the decision-makers' risk attitude using a risk-adjusted interest rate | The decision-makers' risk attitude is not covered explicitly | The approach aims at maximizing the weighted perceived degree of change considering the risk of differing scenarios and the change tolerance of the company | Risk is considered using the risk-adjusted expected NPV. Expected value and risk are considered explicitly via the certainty equivalent method | The decision-makers' risk attitude is captured using a risk-adjusted interest rate | Risk is not considered | No risk attitude is included. However, in the determination of the business drivers with the balance score card, it is possible to weight dimensions differently |

for deterministic interactions among projects, where stochastic interactions are possible from a theoretical perspective (O.3b). The planning model also captures risk and the decision-makers' risk attitude rather implicitly in terms of a risk-adjusted interest rate (O.4c). The value contribution's expected value and risk could be considered more explicitly, e.g., by means of the certainty equivalent method. Finally, the planning model treats the processes under investigation as independent (O.1a). In reality, however, processes are often interconnected. We will revert to these limitations and ideas for future research in the conclusion.

Compared to the competing artifacts, our planning model is the first approach to integrate the development of an organization's BPM capability with the improvement of individual processes. Other approaches either focus on the prioritization of multiple improvement projects for individual processes or on the prioritization of multiple processes for improvement purposes. Considering multiple processes, multiple projects, and multiple periods, our planning model extends the existing approaches particularly by considering the projects' absolute and relative performance effects as well as interactions among projects in great detail. Treating different planning periods individually, the planning model explicitly captures the long-term effects of BPM- and process-level projects, particularly the indirect effects of BPM capability development on process improvement. Further, the planning model proposes a continuous calculation logic that aggregates investment outflows and performance effects across multiple processes, projects, and periods into the value contribution, an integrated performance indicator that complies with the principles of VBM. As already mentioned in the stand-alone analysis, compared to some competing artifacts, the planning model handles risk and the involved decision-makers' risk attitude rather implicitly. Most competing artifacts, however, do not cater for risk at all. Based on this analysis, we conclude that the planning model answers the research question and provides an incremental contribution to the prescriptive body of knowledge related to BPM capability development and process decision-making.

### *5.1.2 Expert interviews with organizational stakeholders*

To complement feature comparison from a naturalistic perspective, we interviewed experts from two organizations. These interviews helped assess how organizational stakeholders think about the planning model's understandability and real-world fidelity. To cover different views, we chose experts from two organizations that strongly differ in terms of their organizational setup as well as in the way how and motivation behind why they conduct BPM. In each organization, we interviewed those two experts that where the most involved in the development of the organizations' BPM capability and the coordination of process improvement projects, i.e., with process project portfolio management. In each organization, we interviewed both experts simultaneously in a qualitative, semi-structured interview along the components of the planning model (Myers and Newman 2007). Each interview took about 2 h and was attended by at least two researchers. After the interviews, we provided the experts with a prior version of the planning model's design specification and asked for comments regarding real-world fidelity and understandability. After careful deliberation and additional literature work, we included selected comments (e.g., additional interactions types, degeneration effects on selected performance dimensions) in the design specification as shown in Sect. 4, before proceeding with instantiating the artifact in terms of a software prototype.

The first organization (PRODUCT) is an owner-managed, medium-sized company with about 150 employees and annual sales of about 40 million Euros. Founded in the 1980s, PRODUCT produces professional defibrillators for the international market and considers itself as the industry's innovation leader. We interviewed PRODUCT‘s enterprise architect and the head of the IT department, the two executives most involved in process improvement and BPM capability development. At PRODUCT, investment decisions are prioritized and approved ad hoc by the management board. In the last years, PRODUCT experienced considerable growth, which is why it started to institutionalize its management processes. As a driver of BPM, PRODUCT‘s products and processes are more and more required to comply with the industry's quality management standards when applying for calls for tenders. As PRODUCT has just started to work on BPM, it focuses on fundamental capability areas, such as process design and modeling, enterprise process architecture, and process measures. As most of PRODUCT‘s processes are not executed within an automated workflow environment, data for process performance indicators are collected manually. The same holds true for PRODUCT‘s project and project portfolio management activities.

The second organization (SERVICE) provides banks from the German-speaking countries with IT services and process support, including data and call center operations, shared support processes, and core banking processes. SERVICE has about 3000 employees and earns about 720 million Euros per year. What is special about SERVICE is that it serves as the banks' BPM enabler and, thus, focuses on the banks' processes at least as much as on its own. We interviewed the enterprise architect responsible for developing SERVICE‘s BPM capability with respect to IT topics and the product manager in charge of developing SERVICE‘s BPM capability related to business topics. As SERVICE operates almost all processes of many banks, it must prioritize between 60 and 100 process- and BPM-level projects per year. SERVICE selects and schedules projects twice a year. It has two budgets, one for process-level and one for BPM-level projects. The budget for process-level projects is 16 times higher than the budget for BPM-level projects. More than 50 % of both budgets are spent on mandatory projects to comply with regulations. Overall, SERVICE's BPM capability is very well-developed. As SERVICE operates most processes in an automated workflow environment and regularly reports to its customers, process performance data can be collected automatically. The same holds true for project management data.

The experts of both organizations agreed with the idea of our planning model as well as with its design specification, deeming the planning model a valid solution to addressing the problem of how to develop an organization's BPM capability and improve individual processes in an integrated manner. As for real-world fidelity, the experts agreed that the planning model, due to the covered process and project types, interactions and constraints as well as performance dimensions, covers all constellations that typically occur in their organizations. Table 3 shows some

**Table 3** Highlights from the expert interviews

| | PRODUCT | SERVICE |
|---|---|---|
| Processes | For many support processes, it was impossible to unambiguously determine the number of instances because of the high level of abstraction used for process modeling | The number of instances of most processes is driven by quality and time. Some processes are only driven by quality, others only by time |
| | Process quality was consistently measured in terms of maturity levels | The performance indicators used to operationalize quality and time strongly depend on the process at hand |
| | | The company must continuously invest to keep up with its customers' increasing quality expectations (degeneration effects) |
| Projects | There are BPM-level projects without positive effects that must be implemented before any other BPM-level project | There are process-level projects (pioneer projects) without positive effects that must be implemented before any other process-level project related to the process in focus |
| | The implementation of a project takes between 3 months and 1 year. | |
| | Process-level projects and BPM-level projects are often implemented simultaneously (e.g., process modeling training and process analysis projects) | The implementation of a project takes either one or two periods according to the company's PPS cycle. Longer projects are not allowed |
| | | Only one process-level project can be implemented per process and period |
| Interactions and constraints | There is a global budget based on which BPM-level projects are funded and several (department-) specific budgets are used to fund process-level projects | There are many regulatory projects per period. These projects must be finished in a predetermined period at the latest |
| | To comply with the industry's quality management standards, selected support and all core processes must not violate predetermined quality boundaries. There is no such boundary for time | There are sequences of BPM-level and process-level projects that reach up to five periods in the future |
| | | There is one budget for process-level projects and another budget for BPM-level projects |

highlights from the interviews. The experts also confirmed that the planning model's specification is understandable for experienced industry experts such as those involved in process decision-making. Taking the results of feature comparison and the expert interviews together, we considered the planning model's design specification as valid from an ex-ante evaluation perspective. We reflect on further results from the expert interviews, which go beyond real-world fidelity and understandability, in Sect. 5.3.2.

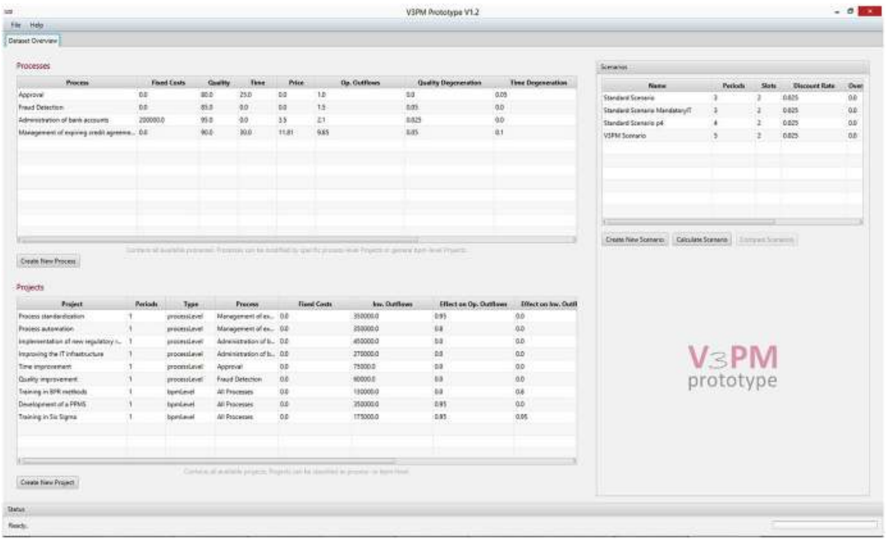


**Fig. 3** Software prototype—input data section

## 5.2 Prototype construction (EVAL3)

To provide a proof of concept and enable an application in naturalistic settings, we instantiated the planning model as a software prototype (Lehnert et al. 2016). Using the prototype requires creating relevant processes and projects as well as all needed performance effects in the prototype's user interface (Fig. 3 on the left). Afterward, process and project datasets (e.g., with optimistic and pessimistic effects, including the processes of one or several departments) can be combined to scenarios (Fig. 3 on the right). Each scenario requires further information about the interactions and constraints to be considered as well as about relevant general settings (e.g., risk-adjusted interest rate, number of periods in the planning horizon). For each scenario, the software prototype generates all admissible roadmaps and calculates their NPV together with various intermediate results. The results are summarized in a scenario analysis section as illustrated in Fig. 4.

In the scenario analysis section, the prototype offers analysis and visualization functionality that helps understand the roadmaps that are associated with the scenario in focus. In the upper part of the user interface, the prototype shows the optimal (or currently selected) project roadmap and its NPV. In the middle, the prototype shows how the involved processes' performance that is measured in terms of time, quality, operating outflows, and fixed outflows evolves over the periods when implementing the projects included in the selected roadmap. On the bottom, the prototype provides information about relevant interactions and constraints, about how many roadmaps violate these restrictions, and about the cash flow development. On the right part, the prototype also includes a project-to-process relationship graph that captures interdependencies among processes and projects. The graph can


**Fig. 4** Software prototype—scenario analysis section

be interactively traversed by the prototype user. Below this graph, the prototype shows a list of all admissible roadmaps associated with the selected scenario sorted by descending NPV. The scenario analysis section is also the starting point for more detailed analyses, i.e., robustness analysis, project success analysis, and roadmap comparison. We sketch the most important functionality below:

- The *robustness check* calculates how strongly the value contribution of the optimal roadmap is affected by variations in the input parameters. To do so, the robustness check compares the value contributions of the 50,000 best project roadmaps with that of the optimal project roadmap. For each of these roadmaps, different value contributions are calculated by varying all project-related input parameters ceteris paribus in the range from −2 to +2 % (in 1 % steps). Finally, the robustness is reported as the fraction of parameter variations where the originally optimal roadmap still ranks higher than the competing 50,000 roadmaps.
- The *robustness analysis* enables more specific analyses than the *robustness check* by varying a selected parameter of a single process, project, or from the general setting in a range between −10 and +10 % ceteris paribus. Besides the effects on the value contribution, the robustness analysis shows for the selected parameter setting which roadmaps have a higher value contribution than the originally optimal roadmap.
- The *project success analysis* helps identify which parameters of a distinct project most strongly influence the value contribution of the entire roadmap. Therefore, all project parameters are modified in a given range.
- The *roadmap comparison* compares two different roadmaps, a functionality that is based on the visualization provided by the general scenario analysis section

(Fig. 4). For example, trends in quality and time or periodic cash flows can be compared automatically.

Process decision-makers can use the software prototype to calculate, analyze, and compare scenarios with different process, project, and interaction datasets. The prototype's analysis functionality helps gain in-depth insights into the project roadmaps associated with a distinct scenario and provides the opportunity to better understand intra- as well as inter-temporal interactions. As the prototype is able to handle several processes and projects, the prototype also assists process decision-makers in determining a concrete plan for developing an organization's BPM capability and improving individual processes in an integrated manner given a concrete organizational context.

## 5.3 Validation of applicability and usefulness (EVAL4)

### *5.3.1 Case based on real-world data*

To show that the planning model and the software prototype are applicable in naturalistic settings, required data can be gathered, and analyses can be conducted, we present a case that builds on anonymized and slightly modified data collected at SERVICE. For this case, we focused on four processes and nine projects (Tables 4, 5, 6). The core processes are (I) "Management of expiring credit agreements" and (II) "Administration of bank accounts". The support process (III) "Approval" helps reach an approval in case an employee does not have enough decision rights. The support process (IV) "Fraud detection" is used if anomalies within payment transactions are detected to retard the execution of payments while they are verified by customers.

Regarding data collection, SERVICE disposes of data regarding the number of instances, cash outflows per instance, and inflows per process, because it operates processes as service provider for banks in an automated workflow environment. Regarding data about process time and quality, SERVICE provided us with their estimation of each process' status quo. As SERVICE plans projects twice a year, it

**Table 4** Processes within the case

| Process | Demand logic | Price and billing | Constraints | Degeneration |
|---|---|---|---|---|
| (I) | Driven by quality and time | Pay per execution | – | – |
| (II) | Constant | Fixed price per account | $QualMin\ (80\,\%, II, all)$ | Quality |
| (III) | Constant | No price, as process is integrated in core process | $TimeMax\ (60\,\text{min}, III, all)$ | Time |
| (IV) | Constant | No price, as process is integrated in core process | $QualMin\ (70\,\%, IV, all)$ | Quality |

**Table 5** Process-level projects considered in the case

| Project | Description/effects | Affected process | Interactions/constraints |
|---|---|---|---|
| (1) | *Process standardization*<br>Increases quality and reduces operating outflows | (I) | *PreSuc* $(s_1, s_2)$ |
| (2) | *Process automation*<br>Reduces time, increases quality, and reduces operating outflows | (I) | *PreSuc* $(s_1, s_2)$ |
| (3) | *Implementation of new regulatory requirements*<br>No effects on process performance | (II) | *Latest* $(s_3, 3)$, *Madatory* $(s_3)$ |
| (4) | *Improving the IT infrastructure*<br>Reduces fixed outflows | (II) | – |
| (5) | *Time improvement*<br>Reduces time | (III) | – |
| (6) | *Quality improvement*<br>Increases quality | (IV) | – |

**Table 6** BPM-level projects considered in the case

| Project | Description/effects | Interactions/constraints |
|---|---|---|
| (7) | *Training in BPR methods*<br>Indirect effect on operational capabilities as such training allows implementing future process-level projects more easily | *LocMutEx* $(s_7, s_8)$ |
| (8) | *Development of a process performance measurement system*<br>Direct effects on operational capabilities reduce operating outflows of all processes under investigation | *LocMutEx* $(s_7, s_8)$ |
| (9) | *Training in Six Sigma*<br>Combination of direct and indirect effects. Indirect effects affect future process-level projects, direct effects reduce operating outflows of all processes | – |

also disposed of data of many process- and BPM-level projects implemented over the last years. It was challenging to derive data on the performance effects of each project. For process-level projects, we estimated data about effects on time and outflows based on similar projects. Quality effects were estimated based on separate expert interviews. The same holds true for BPM-level projects. Due to this uncertainty, we analyzed optimistic and pessimistic scenarios such as shown below. At SERVICE, a period lasts 6 months. The planning horizon amounts to five periods with a risk-adjusted interest rate of 2.5 % per period. In each period, the budget is limited to 750,000 EUR, and the maximum number of projects is two. To increase readability, we only show some input data here. All other input data are contained in

**Table 7** Optimal project roadmaps from the scenario analysis

| | Optimal project roadmap/value contribution | | Description |
|---|---|---|---|
| (A) General case | Opt. | Project roadmap: ({1, 9}, {2, 4}, {3} , {6}, {})<br>NPV: 2.50 million EUR<br>Robustness: 100 % | General case<br>About 240,000 project roadmaps meet the interactions and constraints<br>The interactions and constraints reduce the potential project roadmaps as follows:<br>*LocMutEx* $(s_7, s_8)$: 180,000<br>*PreSuc* $(s_1, s_2)$: 1,290,000<br>*Latest* $(s_3, 3)$and *Mandatory* $(s_3)$: 650,000<br>*Budget* $(750,000, ALL)$: 150,000<br>*QualMin* $(70\,\%, IV, ALL)$: 190,000 |
| | Pess. | Project roadmap: ({1, 9}, {2}, {3} , {6}, {})<br>NPV: 1.20 million EUR<br>Robustness: 90.8 % | |
| (B) Overall budget | Opt. | Project roadmap: ({1, 7}, {2}, {3} , {6}, {})<br>NPV: 2.23 million EUR<br>Robustness: 98.2 % | Overall budget is reduced by one-third<br>About 40,000 project roadmaps meet the interactions and constraints<br>About 480,000 project roadmaps violate the constraint: *Budget* $(500,000, ALL)$ |
| | Pess. | Project roadmap: ({4, 9}, {1}, {3} , {6}, {})<br>NPV: 1.09 million EUR<br>Robustness: 84.1 % | |
| (C) Latest finish | Opt. | Project roadmap: ({3, 9}, {1, 4}, {2} , {6}, {})<br>NPV: 1.92 million EUR<br>Robustness: 100 % | Project (3) must be already finished period 1<br>About 80,000 project roadmaps meet the interactions and constraints<br>About 1,000,000 project roadmaps violate the constraints *Latest* $(s_3, 1)$and *Mandatory* $(s_3)$ |
| | Pess. | Project roadmap: ({3, 9}, {1}, {} , {6}, {})<br>NPV: 1.02 million EUR<br>Robustness: 93.4 % | |
| (D) Critical quality boundary | Opt. | Project roadmap: ({1, 9}, {2, 6}, {3} , {}, {})<br>NPV: 2.37 million EUR<br>Robustness: 100 % | Minimum quality of process (IV) is increased<br>About 120,000 project roadmaps meet the interactions and constraints<br>About 410,000 project roadmaps violate the constraint *QualMin* $(80\,\%, \mathrm{IV}, ALL)$ |
| | Pess. | Project roadmap: ({1, 9}, {2, 6}, {3}, {}, {})<br>NPV: 1.19 million EUR<br>Robustness: 90.8 % | |

the Appendix. Figure 3 illustrates how process and project data are represented in the software prototype.

To generate and value project roadmaps, we used the planning model's software prototype. We analyzed eight scenarios to provide adequate insights and decision support (Table 7). For each scenario, the preferred alternative was the project roadmap with the highest value contribution. The starting point of our analysis was a general case (A) with an optimistic and a pessimistic scenario. This case led to about 2.70 million potential project roadmaps whereof about 2.46 million project roadmaps were not admissible due to the underlying interactions and constraints. Using the general case as foundation, we calculated three further cases (B) to (D), varying one constraint per case ceteris paribus. For each scenario, we performed a robustness check based on planning model prototype, calculating how strongly the value contribution of the optimal project roadmap is affected by varying the input parameters. Figure 4 shows the prototype's scenario analysis section for the optimistic scenario of general case A.

Consider the optimistic scenario of case (A): The optimal project roadmap ({1, 9}, {2, 4}, {3}, {6}, {}), which is also shown in Fig. 4, includes six projects and implies a value contribution of about 2.50 million EUR. The corresponding worst project roadmap, i.e., ({3, 5}, {6}, {}, {1, 4}, {2, 8}), would lead to a value contribution of about -260,000 EUR. In the optimal case, project (9) is scheduled for period 1, as its direct and indirect effects strongly influence future processes and projects. Project (1) is scheduled for period 1 as well. This is not only rooted in the strong effects of project (1), but also in the strong effects of project (2), which can only be implemented after project (1). Project (3) is scheduled for period 3, which is the latest possible period according to the constraints. This is reasonable from an economic perspective as project (3) has no positive effects. Project (6) is implemented in period 4, because process (IV) would fall short of its critical quality boundary otherwise. Project (5), in contrast, is not included in the optimal project roadmap as the critical time boundary of process (III) is never violated due to the low degeneration effect and the good time-performance at the decision point. Based on Fig. 4, it can also be seen how the involved processes' performance evolves over time while implementing the projects included in the optimal project roadmap.

As the other cases were calculated ceteris paribus by varying only one constraint each, we restrict our discussion to the most significant changes. In case (B), the overall budget is reduced by one-third. Consequently, much more project roadmaps violate the budget restriction. The BPM-level projects require a big share of the overall budget. Only project (7), which has the lowest investment outflows of all BPM-level projects, is included in the optimal project roadmap. Project (4), which positively affects the value contribution, cannot be implemented due to the reduced budget. In total, the value contribution of case (B) is lower than that of the general case even if less projects are implemented and less investment outflows are caused. In case (C), the earlier due date of the mandatory project (3) influences the entire optimal project roadmap. Although the optimal project roadmap includes the same projects as in case (A), its value contribution is much lower. In case (D), project (6) replaces project (4), as process (IV) violates the critical quality boundary already in the third period.

This case showed that the planning model yields interpretable results for planning the development of an organization's BPM capability and process improvement in an integrated manner. Moreover, the prototype enabled to consistently determine optimal project roadmaps for different cases based on real-world data. The experts at SERVICE appreciated the prototype's scenario analysis functionality, especially the ability to simulate changes in the deadlines of mandatory projects and changes in the overall budget of future periods. The experts already expected a big amount of

**Table 8** Discussion of usefulness

| Criterion | Characteristics of the planning model and the software prototype |
|---|---|
| Applicability (model and instantiation) | The case based on real-world data, which we presented in Sect. 5.3.1, illustrated that the planning model is applicable in naturalistic settings. As the planning model's calculation logic is complex and the number of possible project roadmaps heavily grows with the number of considered processes, projects, and planning periods, the planning model could not be applied without the software prototype. The expert interviews revealed that the planning model particularly fits organizations that aspire a well-developed BPM capability and are willing to invest accordingly. For instance, the planning model is oversized for PRODUCT, while it perfectly fits SERVICE. Organizations that plan to apply the planning model also require some areas of their BPM capability to be developed beforehand, including process metrics and enterprise process architecture |
| | Another issue with impact on applicability is that the planning model requires collecting and estimating input data regarding processes, projects, interactions, and constraints. According to the interviews, SERVICE disposed of most input data and only had to estimate project effects. PRODUCT's experts indicated that the required data can also be collected in non-automated environments. To cope with estimation inaccuracies, which are inevitable in naturalistic settings, the software prototype implements robustness check and analysis functionality, as discussed in Sect. 5.2. Applying the planning model should not be an one-off initiative. Rather, the planning model should be applied repeatedly. A knowledge base should be built to institutionalize data collection routines and collect best practices |
| Impact on the artifact environment and users (model and instantiation) | The planning model impacts how users think about how to develop their organization's BPM capability and to improve individual processes in an integrated manner. On the one hand, the planning model's formal design specification provides insights into central constructs and mechanisms of integrated BPM capability development and process improvement. On the other, the prototype's visualization and analysis functionality helps users understand the situation and possibilities for action in their organizations. The experts from SERVICE and PRODUCT agreed that the planning model enhances the organizations' process decision-making capabilities |
| Fidelity with the real-world phenomena (model) | Based on the covered process and project types, interactions, and constraints as well as performance dimensions, the planning model can handle many different constellations that occur in naturalistic settings. This has been confirmed by the experts from PRODUCT and SERVICE |

**Table 8** continued

| Criterion | Characteristics of the planning model and the software prototype |
|---|---|
| Internal and external consistency (model) | The planning model is internally consistent as it has been designed deductively and as its components are modular such that side effects cannot occur. Further, the planning model's design specification is available in terms of mathematical formulae, a property that facilitates checking internal consistency. As for external consistency, the planning model does not contradict accepted knowledge from other disciplines, such as BPM, PPS, or VBM. Rather, the planning model was built based on knowledge from these disciplines as justificatory knowledge. These disciplines also served as foundation for deriving our design objectives |
| Effectiveness and efficiency (instantiation) | The experts we interviewed, particularly those from SERVICE based on whose data we applied the planning model, agreed that the software prototype can be effectively used to plan the development of an organization's BPM capability and the improvement of individual processes in an integrated manner. As for efficiency, we conducted performance tests with the prototype on regular work stations such as used in business environments. The prototype efficiently processes industry-scale problems as long as the number of planning periods, which is the most influential driver of problem complexity, is not too large. As the number of planning periods is rather small in naturalistic settings (i.e., between 2 and 8 according to our experiences), this limitation does not heavily restrict the prototype's efficiency. For example, the case presented in Sect. 5.3.1 required 26 s to determine admissible project roadmaps and to calculate the corresponding value contributions. The robustness check of the optimal project roadmap took about 3 min, being limited to the best 50,000 project roadmaps. Another driver of the problem complexity is the amount of available projects, which increases the amount of admissible project roadmaps over-proportionally. To reduce this complexity, it is important to include only those projects that already passed the first three stages of Archer and Ghasemzadeh's (1999) PPS process and to consider all the known constraints in the prototype, as these considerably reduce the amount of admissible project roadmaps |

admissible project roadmaps but were really surprised about the factual amount. The prototype's analysis functionality (e.g., robustness checks) further increased the decision-makers' confidence in the proposed project roadmaps. In the case at hand, the experts at SERVICE realized that, at the start of the planning horizon, the implementation of projects 1 and 9 is robust, as in the expected general case A, both the optimistic and pessimistic case support this decision with high robustness values.

#### 5.3.2 Discussion Against Evaluation Criteria

As final step, we discuss the planning model‘s applicability and usefulness based on criteria that were compiled and assessed by Sonnenberg and vom Brocke (2012) as valid for evaluation activity EVAL4. In line with the nature of the planning model and the software prototype we developed, we focus on evaluation criteria that relate to the artifact types' model and instantiation. On the one hand, this discussion indicates that the planning model and the prototype address all criteria. On the other, it becomes evident that in order for the planning model to be applicable in a utility-creating manner, some prerequisites must be met. Detailed results are shown in Table 8.

## 6 Conclusion

### 6.1 Summary and contribution

In this study, we investigated how organizations can develop their BPM capability and improve individual processes in an integrated manner. Adopting the DSR paradigm, our artifact is a planning model that assists organizations in determining which BPM- and process-level projects they should implement in which sequence to maximize their firm value, while catering for the projects' effects on process performance and for interactions among projects. With the planning model building on PPS and VBM, we refer to our approach as value-based process project portfolio management. BPM-level projects aim at developing an organization's BPM capability. They can influence operational processes by facilitating the implementation of future process-level projects or by making processes more cost-efficient starting from the next period. Process-level projects improve the cost, quality, and time of individual processes. The planning model recommends selecting those process- and BPM-level projects that, scheduled in a particular way, create the highest value contribution, which is measured in terms of the respective project roadmap's NPV. By differentiating between multiple periods, the planning model captures the long-term effects of BPM- and process-level projects on process performance and on one another as well as interactions among projects. The planning model thereby deals with path dependencies that most likely occur when developing an organization's BPM capability and improving individual processes in an integrated manner. We evaluated the planning model by discussing its design specification against theory-backed design objectives, comparing the design specification with competing artifacts, and discussing the design specification with subject matter experts from different organizations. We also validated the planning model's applicability and usefulness by conducting a case based on real-world data as well as by discussing the planning model and the software prototype against established evaluation criteria from the DSR literature.

Our planning model contributes to the prescriptive body of knowledge related to BPM capability development and process decision-making. It is the first approach to integrate the development of an organization's BPM capability with the improvement of individual processes. Competing artifacts either focus on the prioritization of multiple improvement projects for individual processes or on the prioritization of multiple processes for improvement purposes. In line with dynamic capability theory, reasoning about the development of an organization's BPM capability only makes sense when considering how BPM affects processes. The reason is that BPM is a dynamic capability, which is known to affect organizations only indirectly via operational capabilities, i.e., processes. Incorporating that and formalizing how decisions on BPM as a dynamic capability affect (decisions on) processes as an organization's operational capabilities, the planning model applies knowledge from dynamic capability in a novel way. To the best of our knowledge, dynamic capability theory has so far only been applied to BPM-related research problems for descriptive purposes. Finally, the planning model is the first to integrate multiple processes, multiple projects, and multiple periods. It thereby links the three disciplines BPM, PPS, and VBM. Whereas research has been conducted at the intersection of any pair of these disciplines, this is not the case for the entire triad.

### 6.2 Limitations and future research

While validating the planning model's design specification, applicability, and usefulness, we identified limitations and directions in which the planning model can be further developed. Below, we present these limitations together with ideas for future research.

Regarding its design specification, the planning model only caters for deterministic interactions among projects, captures risk and the decision-makers' risk attitude rather implicitly via a risk-adjusted interest rate, and treats the processes in focus as independent. Deterministic interactions among projects can be substituted by stochastic interactions. In this case, it would be necessary to model the effects of BPM- and process-level projects as random variables with individual probability distributions. Risk and the decision-makers' risk attitude can be addressed more explicitly by modeling the value contribution's expected value and risk separately, e.g., based on the certainty equivalent method. In this case, it would be necessary to estimate probability distributions for all periodic performance indicators. As for interactions among processes, the planning model could incorporate interactions such as typically captured in process architectures. Another extension would be explicitly differentiating multiple capability areas as included in de Bruin and Rosemann (2007) BPM capability framework and, correspondingly, modeling the effects of BPM-level projects in greater detail. For future research, we recommend deliberating which of these limitations regarding the planning model's design specification should be incorporated. When extending the planning model, however, one has to keep in mind that models are purposeful abstractions from the real world that need not necessarily capture all the complexity of the real world. It is imperative to assess carefully whether the gained increase in closeness to reality outvalues the related increases in complexity and data collection effort. For example, instead of incorporating stochastic interactions, it is possible to leverage the scenario analysis functionality implemented in the prototype.

As for the planning model's applicability and usefulness, we concede that—despite various simulation runs based on artificial data—we applied the planning model only once based on real-world data. While this case corroborated that relevant input data can be gathered and that the planning model offers useful guidance, we neither have substantial experience in data collection routines nor about reference data to calibrate the planning model for various application contexts. Future research should, thus, focus on conducting more real-world case studies in different organizational contexts and on setting up a respective knowledge base. Case studies will not only help gain experience regarding data collection but also identify how the planning model's design specification must be tailored to fit additional contexts. To facilitate additional case studies, we also recommend further developing the prototype, such that it can be used more conveniently in naturalistic settings, provides more sophisticated analysis functionality, and can be extended more easily for future evaluation purposes.



## Appendix

See Tables 9, 10 and 11.

**Table 9** Processes

| $i$ | $O_{i,0}^{\text{fix}}$ | $n_i$ | $q_{i,0}$ (%) | $t_{i,0}$ (min) | $I_i^{\text{op}}$ | $I_{i,0}^{\text{op}}$ | $\eta_i$ (%) | $q_i^{\max}$ (%) | $\theta_i$ (%) |
|---|---|---|---|---|---|---|---|---|---|
| (I) | 0 € | $48{,}000\left(\ln q + e^{\frac{1}{t}}\right)$ | 90 | 30 | 11.81 € | 9.85 € | 5 | 100 | 10 |
| (II) | 200,000 € | 200,000 | 95 | – | 3.50 € | 2.10 € | 2.5 | 100 | – |
| (III) | 0 € | 300,000 | 80 | 25 | – | 1.00 € | – | 100 | 5 |
| (IV) | 0 € | 4,000 | 85 | – | – | 1.50 € | 5 | 100 | – |

**Table 10** Process-level projects

| $s$ | $O_s^{\text{inv}}$ | $\alpha_s$ | | $\beta_s$ | | $\gamma_s$ | | $\delta_s$ | |
|---|---|---|---|---|---|---|---|---|---|
| | | Opt. | Pess. | Opt. | Pess. | Opt. | Pess. | Opt. | Pess. |
| 1 | 350,000 € | 1.1 | 1.05 | – | – | 0.95 | 0.95 | – | – |
| 2 | 350,000 € | +10 % | +3 % | −10 min | −3 min | 0.8 | 0.95 | – | – |
| 3 | 450,000 € | – | – | – | – | – | – | – | – |
| 4 | 270,000 € | – | – | – | – | – | – | −120,000 € | −80,000 € |
| 5 | 75,000 € | – | – | 0.7 | 0.8 | – | – | – | – |
| 6 | 60,000 € | +30 % | +20 % | – | – | – | – | – | – |

**Table 11** BPM-level projects

| $s$ | $O_s^{inv}$ | $\varepsilon_s$ | | $\zeta_s$ | | $\epsilon_s$ | |
|---|---|---|---|---|---|---|---|
| | | Opt. | Pess. | Opt. | Pess. | Opt. | Pess. |
| 7 | 130,000 € | – | – | 0.80 | 0.85 | – | – |
| 8 | 350,000 € | 0.95 | 0.97 | – | – | – | – |
| 9 | 175,000 € | 0.95 | 0.97 | 0.95 | 0.97 | – | – |

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