Process Project Portfolio Management – Considering Process and Project Interactions in Process Decision-Making

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Abstract

As an academic and industrial discipline, Business Process Management (BPM) strives for two objectives: improving an organization's business processes and developing the BPM capability itself. While business process improvement and BPM capability development have been extensively studied during recent years, both streams have thus far been treated in isolation. With BPM providing an infrastructure for efficient and effective work, there is an obvious connection with business process improvement. Against this backdrop, this dissertation makes the case for research located at the intersection of business process improvement and BPM capability development and refers to this research field as process project portfolio management. Therefore, the objective of this dissertation is to investigate process and project interactions in process decision-making along an integrated planning of process improvement and BPM capability development.

The first chapter illustrates the need for research at the intersection of business process improvement and BPM capability development. Furthermore, it structures the research field of process project portfolio management, presents the scope and research objectives of the dissertation, and presents the author's individual contribution to the included research papers.

The second chapter draws from knowledge related to BPM, project portfolio management, and performance management to structure the research field of process project portfolio management. This chapter builds the theoretical foundation for the dissertation. Moreover, it proposes a research agenda, including both exemplary research questions and potential research methods, highlighting the interdisciplinary research approach of this dissertation.

The third chapter focuses on the integrated planning of the improvement of individual processes and the development of an organization's BPM capability. It presents a planning model that assists organizations in determining which BPM capability and process improvement 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. This chapter draws from justificatory knowledge from project portfolio selection and value-based management. The planning model is evaluated by discussing the design specification against theory-backed design objectives and with BPM experts from different organizations, comparing the planning model with competing artifacts, and challenging the planning model against accepted evaluation criteria from the design science research literature based on a case using real-world data. Further, in this chapter the Value-Based Process Project Portfolio Management (V3PM) software tool is presented, that effectively and efficiently selects one project portfolio for which

the net present value takes the highest value. It is designed to fulfil a twofold objective: the scientific perspective in terms of an adequate evaluation for the planning model as well as the user's point of view in terms of a first step towards a full-featured version for decision support in daily business operations. Therefore, in this chapter also the application's architecture is described, focusing on the data management, the roadmap engine, and the graphical user interface as well as on its usefulness and practical applicability for decision support.

The fourth chapter investigates the interconnectedness of processes. Although the literature offers numerous approaches that support process prioritization, they have been characterized either as too high-level to be useful or such detailed that the mere identification of critical processes requires significant effort. Moreover, existing approaches to process prioritization share the individual process as unit of analysis and neglect how processes are interconnected. This drawback systematically biases process prioritization decisions. Therefore, the fourth chapter proposes the ProcessPageRank (PPR), an algorithm based on the Google PageRank that ranks processes according to their network-adjusted need for improvement. To do so, the PPR draws from process performance management and business process architectures as well as from network analysis, particularly Google's PageRank, as justificatory knowledge. The PPR is evaluated by validating the design specification with a panel of BPM experts, implementing a software prototype, applying the PPR to five process network archetypes, and conducting an in-depth interview with a BPM expert from a global online retailer.

The fifth chapter focuses on BPM as a corporate capability. As work is rapidly changing due to technological, economic, and demographic developments, also BPM capability has to evolve in light of the future of work. Despite the obvious connection between the future of work and BPM, neither current initiatives on the future of BPM nor existing BPM capability frameworks account for the characteristics of the future of work. Hence, the fifth chapter derives propositions that capture constitutive characteristics of the future of work and map these to the six factors of Rosemann and vom Brocke's BPM capability framework. On this foundation, it is discussed how BPM should evolve in light of the future of work. Moreover, overarching topics are distilled which will reshape BPM as a corporate capability in the future.

Finally, the sixth chapter summarizes the key findings of this dissertation and concludes with opportunities for future research.

Table of Contents

Please note: References are provided at the end of each chapter and each research paper, respectively.

Index of Research Papers

This dissertation contains the following research papers:

Research Paper 1: Lehnert, M., Linhart, A., & Röglinger, M. (2016a). Exploring the Intersection of Business Process Improvement and BPM Capability Development – A Research Agenda. *Forthcoming in Business Process Management Journal.*

(VHB-JOURQUAL 3: Category C)

Research Paper 2: Lehnert, M., Linhart, A., & Röglinger, M. (2016b). Value-based Process Project Portfolio Management: Integrated Planning of BPM Capability Development and Process Improvement. *Business Research, 9(2), Seite 377-419.*

(VHB-JOURQUAL 3: Category B)

Research Paper 3: Lehnert, M., Linhart, A., Manderscheid, J., & Svechla, M. (2016c). V3PM: A Decision Support Tool for Value-based Process Project Portfolio Management. In *Proceedings of the 24th European Conference on Information Systems (ECIS).*

(VHB-JOURQUAL 3: Category B)

Research Paper 4: Lehnert, M., Röglinger, M., Seyfried, J., & Siegert, M. (2015). ProcessPageRank - A Network-based Approach to Process Prioritization Decisions. In *Proceedings of the 23rd European Conference on Information Systems (ECIS), Paper 118.*

(VHB-JOURQUAL 3: Category B)

Research Paper 5: Lehnert, M., Röglinger, M., & Seyfried, J. (2016d). Prioritization of Interconnected Processes – A PageRank-based Approach. *Working Paper. Under review, second review round (Major revision): Business & Information Systems Engineering.*

(VHB-JOURQUAL 3: Category B)

Research Paper 6: Kerpedzhiev, G., Lehnert, M., & Röglinger, M. (2016). The Future of BPM in the Future of Work. *In Proceedings of the 24th European Conference on Information Systems (ECIS).*

(VHB-JOURQUAL 3: Category B)

I. Introduction

1. Motivation[1]

Business Process Management (BPM), as an academic and industrial discipline, strives for two overarching objectives: improving an organization's business processes and developing the BPM capability itself (Rosemann & Vom Brocke, 2015). Improving an organization's processes positively affects process performance and directly contributes to achieving organizational goals. Developing an organization's BPM capability, by contrast, helps establish an infrastructure for efficient and effective work, and enables improving business processes more easily in the future (Lehnert, Linhart, & Röglinger, 2016b; Niehaves, Poeppelbuss, Plattfaut, & Becker, 2014). BPM capability development indirectly contributes to achieving organizational goals, a phenomenon that causes a trade-off between business process improvement and BPM capability development in both the short-term and the long-term (Lehnert et al., 2016b). During the past two decades, business process improvement and BPM capability development have been researched widely. As for process improvement, many mature techniques have been proposed for process analysis, (re-) design, and optimization, including continuous improvement and radical reengineering approaches, model- and data-based approaches as well as qualitative and quantitative approaches (Van der Aalst, 2013; Vanwersch et al., 2016; Vergidis, Tiwari, & Majeed, 2008; Zellner, 2011). As for BPM capability development, researchers have structured BPM into capability areas and proposed capability frameworks, investigated how organizations develop their BPM capability, and proposed related methods (Darmani & Hanafizadeh, 2013; Jurisch, Palka, Wolf, & Krcmar, 2014; Lehnert et al., 2016b; Pöppelbuß, Plattfaut, & Niehaves, 2015; Rosemann & Vom Brocke, 2015; Van Looy, De Backer, & Poels, 2014). Both streams, however, have thus far been treated in isolation. What is missing is an exploration of the intersection of business process improvement and BPM capability development.

Therefore, the objective of this dissertation is to investigate the intersection of business process improvement and BPM capability development. As BPM provides an infrastructure for efficient and effective operational work the connection with business process improvement is obvious. Thus, the dissertation focuses on the integration of process and project interactions in process decision-making about the planning of business process improvement and BPM capability development, particularly when and how organizations should improve individual

[1] Sections I.1 and I.2 are a for the introduction customized, partly shortened, and partly extended version of sections II.1 and II.3 of research paper 1 (Lehnert, Linhart, & Röglinger, 2016a).

processes and develop their BPM capability. According to prior research, it is the integrated planning of business process improvement and BPM capability development where both streams have the closest interaction (Darmani & Hanafizadeh, 2013; Lehnert et al., 2016b; Linhart, Manderscheid, Röglinger, & Schlott, 2015). As processes are improved and capabilities are developed through projects, this dissertation draws from knowledge related to project portfolio management when reasoning about the integrated planning of business process improvement and BPM capability development (Darmani & Hanafizadeh, 2013). As process improvement directly affects process performance and BPM capability development does so indirectly, this dissertation also relies on the performance management body of knowledge (Leyer, Heckl, & Moormann, 2015; Pöppelbuß et al., 2015). In sum, this dissertation refers to the research field located at the intersection of business process improvement and BPM capability development as *process project portfolio management*. The dissertation aims to extend BPM research by integrating new interdisciplinary topics, e.g., portfolio theory, performance management, and network analysis. Moreover, the dissertation intends to structure the research field of *process project portfolio management* and proposing new planning and decision models to consider process and project interactions in process decision-making. In addition, the dissertation aims to investigate BPM as a corporate capability and discusses how BPM need to evolve in light of the future of work. To address this research gap an integrative approach by combining design-oriented and explanation-oriented research methods is essential (Buhl & Lehnert, 2012). Thus, the dissertation applies different research and evaluation methods, like structured literature reviews, interviews, surveys with experts from industry and academia, prototyping, argumentative deductive analysis, and normative analytical modeling to create planning and decision models.

This dissertation is cumulative, as six research papers build the main body of this work. The first chapter presents the research field of *process project portfolio management* in general (section I.2), discusses the scope (section I.3) and the research objectives (section I.4) of this dissertation. Therefore, it serves as starting point for the following six research papers (chapter II – V), for which the individual contribution of the author to the included research papers is presented in section I.5. The sixth chapter summarizes the key findings of this dissertation and concludes with opportunities for future research.

2. Research Context - Structuring the Field of Process Project Portfolio Management

This section structures the research field of *process project portfolio management*, which will also serve to structure the scope and the objectives of this dissertation. In line with the interdisciplinary focus of this dissertation, Figure 1 includes three layers, i.e., a BPM, a project portfolio management, and a performance management layer. The BPM layer and the performance management layer refer to temporal snapshots of the organization or the organizational entity in focus. That is, they reflect the status quo or potential target states. The project portfolio management layer covers the transformation from the status quo to potential target states through the implementation of project roadmaps.

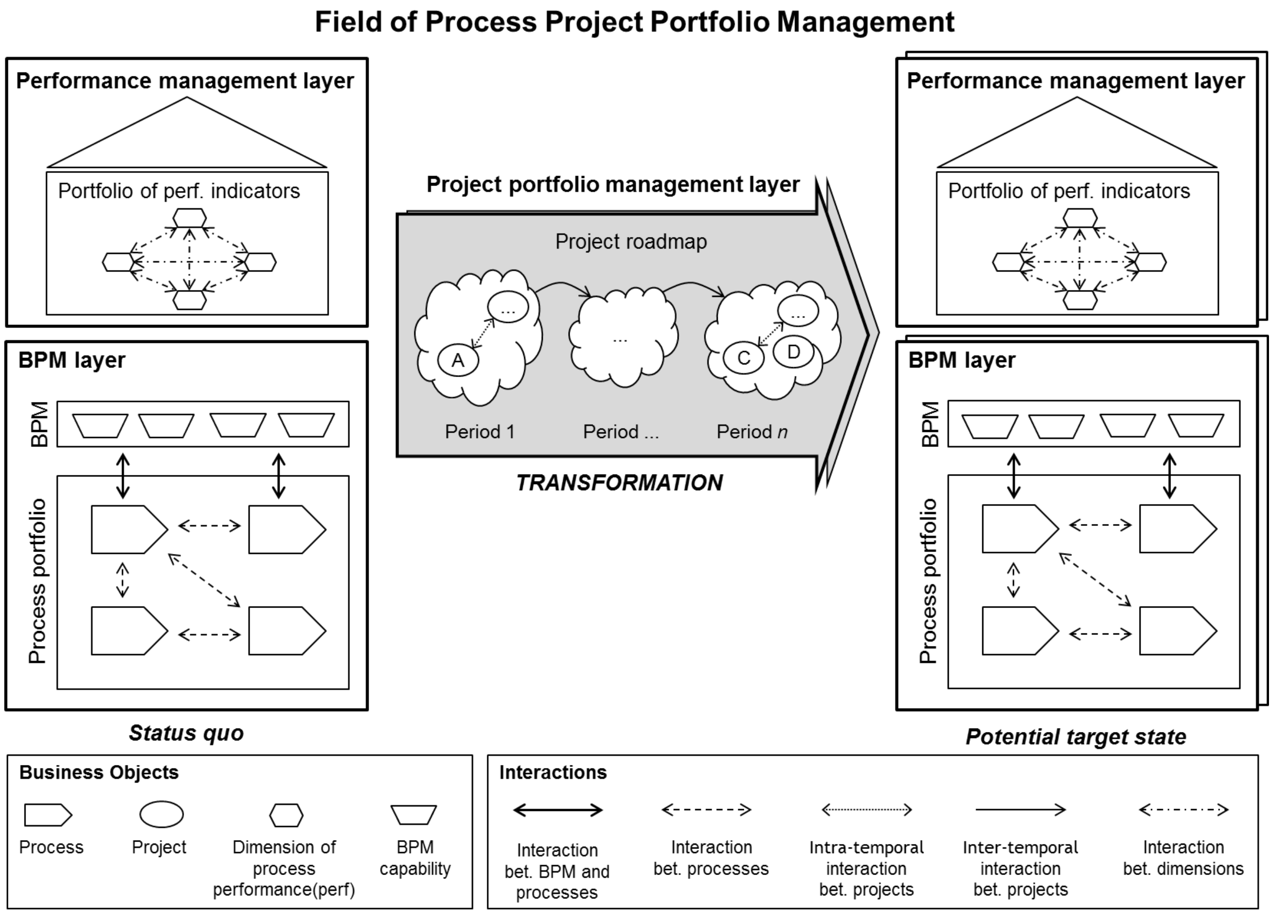

Figure 1. Structuring the field of process project portfolio management

Project roadmaps include a selection of process improvement and BPM projects scheduled over multiple periods, accounting for interactions and constraints. Thus, each roadmap reflects a distinct way of developing the organization's BPM capability and improving individual processes, leading to distinct target states. To identify the most desirable target state and compile the corresponding project roadmap, *process project portfolio management* must account for multiple business objects (e.g., processes, BPM capability areas, projects, performance dimensions) and for interactions among these objects (e.g., interactions among processes, interactions among projects, or interactions among BPM capability areas and processes). This is followed by information about the relevant business objects and their interactions structured along these three layers:

The BPM layer includes the organization's process portfolio as well as relevant areas of the organization's BPM capability. The process portfolio encompasses core and support processes as well as the interactions among them, as processes may require the output of other processes to continue their execution or may just trigger the execution of other processes (Dijkman, Vanderfeesten, & Reijers, 2016). The BPM layer also includes interactions among distinct areas of the organization's BPM capability as well as the processes from the process portfolio. With BPM serving as an infrastructure for efficient and effective work as well as for improving existing processes more easily, there is an interaction between how an organization's BPM capability is developed and how processes are performed (Niehaves et al., 2014). The development of the BPM capability relates to the deliberate implementation and institutionalization of selected capability areas of a BPM capability framework (see the framework proposed by Rosemann and vom Brocke (2015) for a representative example). For instance, strengthening the capability area "process design and modelling" helps redesign processes more easily in the future, whereas "process-related standards" contribute to establishing and complying with process standards across the organization. Moreover, the capability area "process measures" enables process performance measurement as well as goal-oriented redesign.

The project portfolio management layer deals with the transformation of the status quo into potential target states. It includes the projects available to improve individual processes (i.e., process improvement projects) and to develop the organization's BPM capability (i.e., BPM projects). Process improvement projects (e.g., adoption of a workflow management system) help develop the organization's operational capabilities by improving particular processes (Winter, 2003). BPM projects aim to develop BPM as a dynamic capability (Pöppelbuß et al., 2015). As such, they can facilitate the improvement of processes in the future (e.g., training on process modeling or redesign methods) or make the execution of existing processes more cost-efficient starting from the next period (e.g., implementation of process performance indicators). To compile process improvement and BPM projects into project roadmaps, projects must be selected from a list of predefined project candidates that meets the organization's stated objectives in a desirable manner (Archer & Ghasemzadeh, 1999). Therefore, all project candidates are checked in a pre-screening stage for their strategic fit. Project roadmaps cannot be compiled arbitrarily based on the project candidates. 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 for different processes). Project interactions and constraints determine which project roadmaps – and thereby, which potential target states – are admissible (Liu & Wang, 2011; Müller, Meier, Kundisch, & Zimmermann, 2015). Considering these interactions and constraints, project roadmaps can be valued in line with how they affect the performance of the process portfolio.

The performance management layer focuses on monitoring the performance of processes and estimating the effects of process improvement and BPM projects. This layer includes relevant performance dimensions that help conceptualize process performance as a multidimensional construct (Leyer et al., 2015). These performance dimensions have to be operationalized by adopting performance indicators (Dumas, La Rosa, Mendling, & Reijers, 2013). This layer also accounts for the interactions among the performance dimensions that may be complementary or conflicting (Franco-Santos, Lucianetti, & Bourne, 2012). To assess and compare the effects of project roadmaps, process performance must be integrated across performance dimensions and aggregated across all processes from the process portfolio. One option for doing so is to calculate the value contribution of process portfolios as well as changes in the value contribution due to the implementation of project roadmaps in line with value-based BPM (Buhl, Röglinger, Stöckl, & Braunwarth, 2011; Vom Brocke & Sonnenberg, 2015).

In sum, the integrated planning of business process improvement and BPM capability development takes a multi-process, multi-project, and multi-period perspective that requires accounting for multiple business objects as well as for various interactions among these objects. Integrated planning also requires combining knowledge from BPM, project portfolio management, and performance management. As BPM- and process improvement projects have direct and indirect effects on process performance as well as, in the case of BPM projects, on other projects, project roadmaps lead to different target states. Thus, determining the most desirable target state and respective roadmap for process improvement and BPM projects is an essential challenge of *process project portfolio management*.

3. Scope of the Dissertation

As outlined *process project portfolio management* includes several research areas and, as discussed detailed in the second chapter, a huge number of research questions need to be answered to define and deeply understand *process project portfolio management*. Even though the scope of this dissertation is narrowed to the integration of process and project interactions in process decision-making, there remain various research questions within each of the affected areas that are not feasible to investigate within a single dissertation. Therefore, the scope of this dissertation requires further delimitation. Figure 2 illustrates the research scope based on the field of *process project portfolio management*, which was presented in section I.2. Each chapter II - V includes one or two research papers which focusses on a specific aspect in the field of *process project portfolio management*. In section I.4 the research objectives and the research context of every chapter are presented in detail.

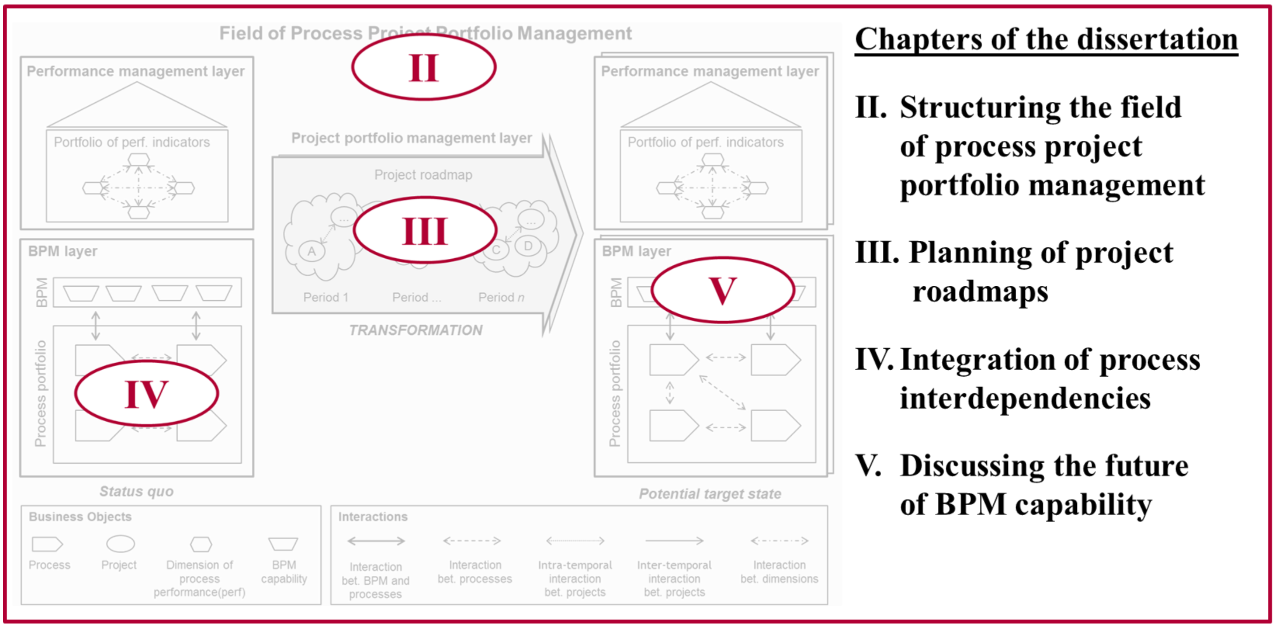

Figure 2. Scope of the dissertation in the field of process project portfolio management

4. Research Objectives

This dissertation includes six research papers, which are embedded in the subsequent chapters. This section links each research paper to the dissertation's research context of *process project portfolio management* (cf. Figure 2) and outlines the research objectives.

Exploring the Intersection of Business Process Improvement and BPM Capability Development (Chapter II)

The second chapter includes the research paper Lehnert et al. (2016a) and aims to structure the research field of *process project portfolio management* as well as to propose a research agenda by combining the research areas BPM, project portfolio management, and performance management. The research paper investigates the intersection of business process improvement and BPM capability development and builds the theoretical foundation for this dissertation. The proposed research agenda introduces also some of the research questions which will be answered in the third, fourth, and fifth chapter. However, there still remain various research questions of this research agenda that are not feasible to investigate within a single dissertation. As parts of the research paper Lehnert et al. (2016a) already were presented in section I.1 and I.2, I refrain from further statements about the research papers content.

The second chapter addresses to the following research questions:

- How to structure the research field of *process project portfolio management*?
- How can a research agenda, exemplary research questions and potential research methods address the integrated planning of business process improvement and BPM capability development?

Value-based Process Project Portfolio Management (Chapter III)

The third chapter includes the two research papers Lehnert, Linhart, and Röglinger (2016b) as well as Lehnert, Linhart, Manderscheid, and Svechla (2016c), and extends my further research from Lehnert et al. (2014). Both papers are located in the project portfolio management layer and focus on the integrated planning of project roadmaps. In detail, Lehnert et al. (2016b) develops a planning model that supports organizations to plan the development of their BPM capability and the improvement of individual processes in an integrated manner. The developed planning model takes a multi-process, multi-project, and multi-period perspective and assists organizations in determining which 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. To evaluate the planning model, its design specification was validated by discussing it against theory-backed design objectives and with BPM experts from two organizations. The planning model was also compared with competing artifacts. With the implementation of a first software prototype, the applicability and usefulness was validated by conducting a case based on real-world data and by challenging the planning model against accepted evaluation criteria from the design science research (DSR) (Gregor & Hevner, 2013). Lehnert et al. (2016c) builds on the results of Lehnert et al. (2016b) and focusses on the specification and development of the Value-based Process Project Portfolio Management (V3PM) tool, which calculates scenarios of non-trivial complexity in a multi-project, multi-process and multi-period perspective to plan process improvement as well as BPM capability development. With enhancing the prototype that resulted from Lehnert et al. (2016b), it was my aim to design a useful and easy-to-use decision support tool that effectively and efficiently calculates the net present value of a huge number of BPM roadmaps derived from different scenarios. Besides the identification of the optimal BPM roadmap the V3PM tool also includes analysis functionalities, e.g. for robustness checks of project roadmaps. Moreover, following DSR in Lehnert et al. (2016b) the V3PM tool presented in Lehnert et al. (2016c) is used both for incorporating a proof of concept and for preparing an application in naturalistic settings to validate its usefulness.

The third chapter addresses to the following research questions:

- How can organizations develop their BPM capability and improve individual processes in an integrated manner?
- How to design a tool that generates, calculates, and analyzes project roadmaps for an integrated planning of BPM capability development and process improvement?

Integration of Process Interdependencies in Process Prioritization Decisions (Chapter IV)

The fourth chapter contains the two research papers Lehnert, Röglinger, Seyfried, and Siegert (2015) and Lehnert, Röglinger, and Seyfried (2016d). Thereby Lehnert et al. (2016d) is a follow-up paper on Lehnert et al. (2015). This chapter focuses on the interconnectedness of processes in process portfolios and therefore is located in the BPM layer. The interconnectedness among processes result from the fact that processes may require the output of other processes to continue or complete their execution or may just trigger the execution of other processes. Therefore, the redesign of a process will also influence interconnected processes and process prioritization decisions should incorporate these network effects, i.e. with the calculation of a network-adjusted need for improvement of a process. Hence, the fourth chapter introduces the ProcessPageRank (*PPR*) algorithm, which applies justificatory knowledge from process performance management and business process architectures as well as from network analysis, particularly Google's PageRank. The research papers describe how to transform a business process architecture into process networks and derive which information on process performance and interconnectedness needs to be added to process networks to apply the *PPR* algorithm. Thereby, the process performance is interpreted as a multi-dimensional construct and integrates the performance dimensions cost, time, and quality. Based on the process-individual process performance the *PPR* algorithm calculates a network-adjusted need for improvement of processes for prioritization decisions between process improvement projects. Hereby the *PPR* integrates the amount and the intensity of process dependencies, also distinguishing the specific behavior of dependencies regarding the performance dimensions cost, time, and quality. This leads to a network-adjusted process ranking for a process portfolio to support process decision-making.

The fourth chapter addresses to the following research questions:

- How can process portfolios be transformed to process networks?
- How can processes be prioritized in line with their interconnectedness?

The Future of BPM in the Future of Work (Chapter V)

The fifth chapter of this dissertation is equivalent to Kerpedzhiev, Lehnert, & Röglinger (2016) that is published in the proceedings of the 24rd European Conference on Information Systems (ECIS). This research paper aims for a better understanding of BPM as a corporate capability and to discuss how BPM must be transformed to address future challenges. In result of that, this chapter focuses on the potential target state of BPM capability in the BPM layer.

Because of contemporary technological, demographic, and economic developments the nature of work is changing rapidly. New digital affordances, such as virtual collaboration tools as well as mobile applications and devices, enable innovative collaboration models and emancipate work from context factors such as time and location (Allen, 2015; Brynjolfsson & McAfee, 2014; McAfee, 2009). Moreover, the customer demand is changing, e.g. with an increasing need for information intensive services. This requires new forms of worker collaboration, such as cross training of workers (Buhl, Krause, Lehnert, & Röglinger, 2015). These changes call to adapt BPM as a corporate capability. Therefore, this research paper accounts for the characteristics of the future of work based on a structured literature review and compiles 23 propositions that capture constitutive features of the future of work. A panel of BPM experts mapped these propositions to the six factors of Rosemann and vom Brocke's (2015) BPM capability framework (strategic alignment, governance, methods, information technology, people, and culture), which captures how BPM is conceptualized today. Based on the mapping of propositions to BPM factors, the research paper discusses how the capability areas of the BPM framework should evolve in light of the future of work and distills overarching topics which will reshape BPM as a corporate capability.

The fifth chapter addresses to the following research questions:

- What are constitutive characteristics of the future of work?
- How to map these characteristics onto BPM capability?
- How does BPM as a corporate capability need to evolve in light of the future of work?

5. Individual Contribution to the Included Research Papers

The six research papers included in this dissertation were compiled in the following project settings:

Research paper 1 (Lehnert et al., 2016a), forming the basis for sections I.1, I.2, and the second chapter, was developed with two co-authors. I was the designated leading author, who developed the paper's basic conception and was responsible for the content development of the paper. I largely performed the written elaboration and was responsible for following core elements of the paper: I designed, structured, and described the action field of *process project portfolio management* as well as derived the exemplary research questions for future BPM research. Moreover, I elaborated the motivation and the conclusion of the paper. Even if large parts of the paper were conducted by myself, both co-authors were involved in each part of the project to discuss and improve the paper.

Research paper 2 (Lehnert et al., 2016b), forming the basis for the first part of the third chapter, was written with two further co-authors and builds on another research project (Lehnert et al., 2014), which is not included in this dissertation. The conference paper Lehnert et al. (2014) was presented by me at the 12th International Conference on Business Process Management at the Eindhoven University of Technology. The results of the discussion during my talk were incorporated in the extended version of the research project Lehnert et al. (2016b). The co-authors and me jointly developed the paper's basic conception and elaborated the paper's content together. I strongly contributed to the proposed planning model, including the specification of the planning model's objective function, the deriving of performance effects, and the definition of project interactions and domain-specific constraints. Furthermore, I had a main role in preparing and executing the evaluation of the paper, especially regarding the development and application of the software prototype by conducting a case based on real-world data. Thus, I was substantially involved in each part of the project. Research paper 3 (Lehnert et al. 2016c), forming the basis for the second part of the third chapter, was developed in a research team of four researchers. It presents the development of a V3PM tool that builds on the planning model of research paper 2 (Lehnert et al., 2016b). Based on my idea for additional analysis functionalities, I put together the paper team for this project. As I was the most experienced researcher in the team at the time of writing the paper, I guided the paper process and was in lead for the functional specification of the software prototype. In sum, we jointly elaborated the paper's content. I also presented the developed software prototype at the European Conference on Information Systems (ECIS) in Istanbul.

Research paper 4 (Lehnert et al., 2015), forming the basis for the first part of the fourth chapter, was developed with three co-authors. The team jointly conceptualized and elaborated the paper's structure and content. Together, we conducted the requirements to integrate the interconnectedness of processes into process prioritization decisions, elaborated how to transform business process architectures into process networks, and proposed the *PPR* algorithm. Therefore, I was involved in each part of the project. The paper was presented by me at the European Conference on Information Systems (ECIS) in Münster. Research paper 5 (Lehnert et al., 2016d), forming the basis for the second part of the fourth chapter, is a follow-up paper on the latter one. However, the research project was conducted with two co-authors, as one co-author of Lehnert et al. (2015) dropped out. In this research project, we incorporated the feedback during my talk in Münster as well as further developed the process-specific need for improvement as a multi-dimensional construct, substantiated the interconnectedness between processes, and improved the evaluation of the paper. I especially was involved in conceptualizing and elaboration the multi-dimensional construct to measure the need for improvement as well as in the further development of the *PPR* algorithm. Overall, the co-authors contributed equally to the paper's conception and elaboration.

Research paper 6 (Kerpedzhiev et al., 2016), forming the basis for the fifth chapter, was written within an author team of three. Based on the first idea of the paper that was provided by one of the co-authors, the team jointly conceptualized and elaborated the paper's content. One of the co-authors and I were each responsible for carrying out the literature review on the „future of work". The results of the literature reviews were combined and discussed within the whole author team in a series of iterative workshops. To derive implications for the BPM factors and capability areas in light of the future of work, we performed again a series of iterative workshops within the whole author team. I strongly contributed to the elaboration of section 4 of the research paper, especially how business process management as a corporate capability needs to evolve in light of the future of work. Thus, I was involved in each part of the project. I also presented research paper 6 (Kerpedzhiev et al., 2016) at the European Conference on Information Systems (ECIS) in Istanbul.

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II. Exploring the Intersection of Business Process Improvement and BPM Capability Development

Research Paper 1: Exploring the Intersection of Business Process Improvement and BPM Capability Development – A Research Agenda

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Submitted to: Forthcoming in Business Process Management Journal

Abstract: As an academic and industrial discipline, Business Process Management (BPM) strives for two objectives: improving an organization's business processes and developing the BPM capability itself. While business process improvement and BPM capability development have been extensively studied during recent years, both streams have thus far been treated in isolation. With BPM providing an infrastructure for efficient and effective work, however, there is an obvious connection with business process improvement. Against this backdrop, we make the case for research located at the intersection of business process improvement and BPM capability development. We focus on the integrated planning of business process improvement and BPM capability development as, according to our industry experience and prior research, this is where both streams have the closest interaction. We refer to the research field located at the intersection of business process improvement and BPM capability development as *process project portfolio management*. Drawing on knowledge from BPM, project portfolio management, and performance management, this study structures the research field of *process project portfolio management* and proposes a research agenda, including both exemplary research questions and potential research methods. With this study, we would like to set the scene for interdisciplinary BPM research and contribute to the ongoing discussion about the future of BPM.

Keywords: Business Process Management, Business Process Improvement, Capability Development, Process Project Portfolio Management, Project Portfolio Management, Performance Management, Research Agenda

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1. Introduction

> *"Business process management (BPM) consolidates how to best manage the (re-) design of individual business processes and how to develop a foundational Business Process Management capability in organizations catering for a variety of purposes and contexts."* (Rosemann & Vom Brocke, 2015, p. x)

Business Process Management (BPM), as an academic and industrial discipline, strives for two overarching objectives: improving an organization's business processes and developing the BPM capability itself (Rosemann & Vom Brocke, 2015). Improving an organization's processes positively affects process performance and directly contributes to achieving organizational goals. Developing an organization's BPM capability, by contrast, helps establish an infrastructure for efficient and effective work, and enables improving business processes more easily in the future (Lehnert, Linhart, & Röglinger, 2016; Niehaves, Poeppelbuss, Plattfaut, & Becker, 2014). BPM capability development indirectly contributes to achieving organizational goals, a phenomenon that causes a trade-off between business process improvement and BPM capability development in both the short-term and the long-term (Lehnert et al., 2016).

During the past two decades, business process improvement and BPM capability development have been researched widely. As for process improvement, many mature techniques have been proposed for process analysis, (re-) design, and optimization, including continuous improvement and radical reengineering approaches, model- and data-based approaches, as well as qualitative and quantitative approaches (Van der Aalst, 2013; Vanwersch et al., 2016; Vergidis, Tiwari, & Majeed, 2008; Zellner, 2011). As for BPM capability development, researchers have structured BPM into capability areas and proposed capability frameworks, investigated how organizations develop their BPM capability, and proposed related methods (Darmani & Hanafizadeh, 2013; Jurisch, Palka, Wolf, & Krcmar, 2014; Lehnert et al., 2016; Pöppelbuß, Plattfaut, & Niehaves, 2015; Rosemann & Vom Brocke, 2015; Van Looy, De Backer, & Poels, 2014). Both streams, however, have thus far been treated in isolation. What is missing is an exploration of the intersection of business process improvement and BPM capability development.

In this study, we make the case for research located at this intersection. As BPM provides an infrastructure for efficient and effective operational work, the connection with business process improvement is obvious. We focus on the integrated planning of business process improvement and BPM capability development, particularly when and how organizations should improve

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individual processes and develop their BPM capability. According to our experience and prior research, it is the integrated planning of business process improvement and BPM capability development where, in our opinion, both streams have the closest interaction (Lehnert et al., 2016; Linhart, Manderscheid, Röglinger, & Schlott, 2015). We have seen many organizations pool their competence areas to improve single processes and develop the BPM capability. As processes are improved and capabilities are developed through projects, we draw from knowledge related to project portfolio management when reasoning about the integrated planning of business process improvement and BPM capability development (Darmani & Hanafizadeh, 2013). As process improvement directly affects process performance and BPM capability development does so indirectly, we also rely on the performance management body of knowledge (Leyer, Heckl, & Moormann, 2015; Pöppelbuß et al., 2015). In sum, we refer to the research field located at the intersection of business process improvement and BPM capability development as *process project portfolio management*. Figure 1 illustrates the related research areas, each of which has a mature body of knowledge, and the intersections among these areas. In line with the interdisciplinary nature of our study, we focus on the intersection areas (4) to (7) as well as on the organizational context (8) to inspire new ways of BPM research.

In this study, we aim to structure process project portfolio management and propose a research agenda, combining the research areas of BPM, project portfolio management, and performance management. We complement existing initiatives on the future of BPM (Kerpedzhiev, Lehnert, & Röglinger, 2016; Recker, 2014; Recker & Mendling, 2016; Rosemann, 2014; Van der Aalst, 2013; Vom Brocke et al., 2011). These initiatives cover the BPM discipline's entire scope (Recker & Mendling, 2016; Van der Aalst, 2013), propose innovative or interdisciplinary topics (Rosemann, 2014; Vom Brocke et al., 2011), or offer recommendations for future research strategies, methods, and evaluations (Recker, 2014). Rosemann (2014), for example, makes the case for ambidextrous BPM, value-driven BPM, and customer process management. Van der Aalst (2013) highlights process modeling languages, process enactment infrastructures, process model analysis, process mining, and process reuse as the BPM discipline's key concerns. In contrast to these initiatives, we investigate a specific field, i.e., the intersection of business process improvement and BPM capability development using BPM, project portfolio management, and performance management as our theoretical lenses.

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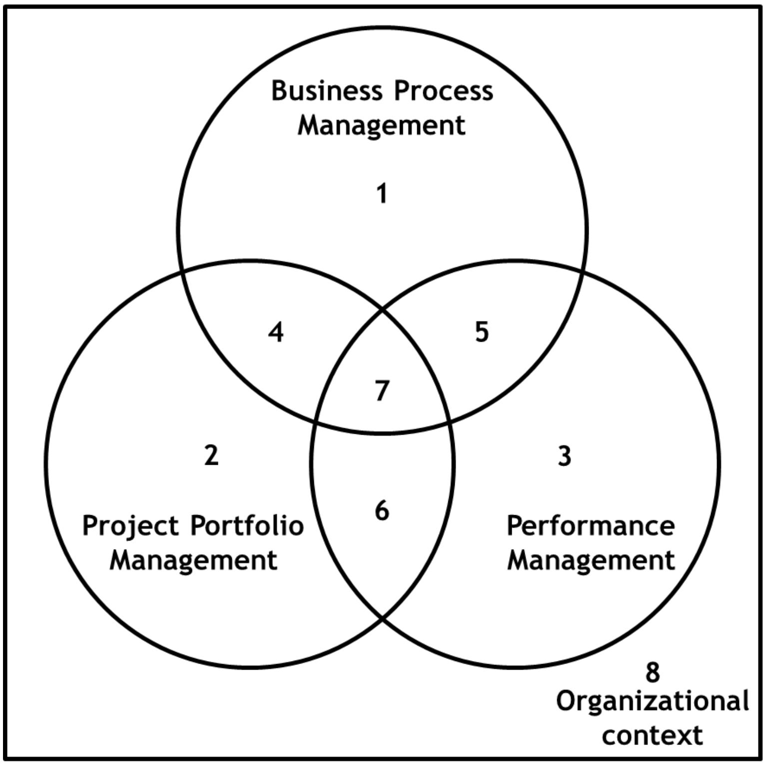

Figure 1. Research areas related to process project portfolio management

The remainder of this paper is organized as follows. Section 2 provides the theoretical background on the three research areas related to process project portfolio management, namely BPM, project portfolio management, and performance management. We thereby draw from knowledge compiled in selected prior publications (Lehnert et al., 2016; Linhart et al., 2015). Section 3 structures the field of process project portfolio management. In section 4, we propose on exemplary research questions located at the intersections of the above-mentioned research areas. We conclude in section 5 by summarizing key results and pointing out the limitations of our study.

2. Theoretical background

2.1. Business Process Management

BPM is "the art and science of overseeing how work is performed in an organization to ensure consistent outcomes and to take advantage of improvement opportunities" (Dumas, La Rosa, Mendling, & Reijers, 2013, p. 1). Consequently, BPM strives for two objectives: improving individual processes and developing the BPM capability (Rosemann & Vom Brocke, 2015). BPM combines knowledge from information technology (IT) and the management sciences (Van der Aalst, 2013). From a lifecycle perspective, BPM involves activities such as the identification, definition, modeling, implementation and execution, monitoring, control, and

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improvement of processes (Dumas et al., 2013). Dealing with all organizational processes, BPM can be interpreted as an infrastructure for effective and efficient work (Harmon, 2014). Processes are split into core, support, and management processes (Armistead, Pritchard & Machin, 1999). Core processes are collections of events, activities, and decision points involving actors and objects that collectively lead to valuable outcomes (Dumas et al., 2013). Support processes ensure that core processes continue to function, whereas management processes plan, organize, communicate, monitor, and control corporate activities (Harmon, 2014).

Within the BPM lifecycle, business process improvement, also referred to as process redesign, is a fundamental activity (Sidorova & Isik, 2010; Vergidis et al., 2008; Zellner, 2011). The body of knowledge on business process improvement provides numerous approaches and classifications. The most fundamental classification is that into continuous process improvement and business process reengineering, where the first entails incremental process change and the second focuses on radical process change (Niehaves, Plattfaut, & Sarker, 2011; Trkman, 2010; Vom Brocke et al., 2011). Van der Aalst (2013) proposes a complementary classification into model- and data-based approaches. Data-based approaches support business process improvement, while processes are executed by discovering bottlenecks, waste, or deviations. Data-based approaches thus benefit from the extensive research on process mining (Van der Aalst et al., 2013). Model-based approaches, which can in turn be split into quantitative and qualitative approaches and build on the results of data-based approaches, support process improvement (Van der Aalst, 2013; Vergidis et al., 2008). Vergidis et al. (2008) classify process improvement approaches based on whether they use diagrammatic, mathematical, or execution-oriented process models. Diagrammatic models, for instance, allow for observational analysis, mathematical models for validation, verification, and optimization, and execution-oriented models enable simulation and performance analysis.

The majority of business process improvement approaches focus on the improvement of single processes and the performance effects of process improvement projects on processes (Forstner, Kamprath, & Röglinger, 2014; Linhart et al., 2015). These approaches are commonly criticized for a lack of guidance on how to put process improvement into practice (Zellner, 2011). Few approaches account for multiple processes or interactions among processes (Lehnert, Röglinger, Seyfried, & Siegert, 2015). These approaches help prioritize processes and improvement projects by identifying strategic important processes or processes that have a high need for improvement (Bandara, Guillemain, & Coogans, 2015; Lehnert et al., 2015; Ohlsson, Han, Johannesson, Carpenhall, & Rusu, 2014). When prioritizing processes or improvement

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projects, extant approaches determine a process' need for improvement by using performance indicators (e.g., related to performance dimensions such as time, quality, or cost) or non-performance-related process characteristics (e.g., ecological, social, and cultural indicators) (Leyer et al., 2015; Vom Brocke & Sonnenberg, 2015). Further, interactions among processes (e.g., specialization, decomposition, use, and trigger) are captured by using information from business process architectures (Dijkman, Vanderfeesten, & Reijers, 2016; Malinova, Leopold, & Mendling, 2014).

In addition to business process improvement, BPM is closely related to capability development, a field that builds on the resource-based view and on dynamic capability theory (Niehaves et al., 2014). 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). Investigating BPM from a capability perspective is popular (Forstner et al., 2014; Niehaves et al., 2014; Rosemann & Vom Brocke, 2015; Trkman, 2010; Van Looy et al., 2014). According to the resource-based view, capabilities refer to the ability to perform a set of tasks for achieving a particular result (Helfat & Peteraf, 2003). From a dynamic capability theory perspective, capabilities are split into operational and dynamic capabilities (Pavlou & El Sawy, 2011). Operational capabilities refer to an organization's basic functioning; dynamic capabilities help integrate, build, and reconfigure operational capabilities to increase their environmental fit as well as their effectiveness and efficiency (Kim, Shin, Kim, & Lee, 2011; Winter, 2003). In the literature, processes and their execution are equated with operational capabilities, whereas BPM is treated as a specific dynamic capability (Forstner et al., 2014; Pöppelbuß et al., 2015). Hence, BPM capability development contributes only indirectly to achieving corporate goals.

Research on BPM as a corporate capability follows three streams (Kerpedzhiev et al., 2016). The first stream focuses on the structuration of the BPM capability and the development of capability frameworks (Jurisch et al., 2014; Rosemann & Vom Brocke, 2015; Van Looy et al., 2014). The common approach is to group capabilities into capability areas and eventually into factors (Rosemann & Vom Brocke, 2015). Jurisch et al. (2014), for instance, derive the process management as well as IT and change management capabilities needed for business process change. Van Looy et al. (2014) present six capability areas with 17 sub-areas for business process maturity. Another popular BPM capability framework is that by Rosemann and Vom Brocke (2015). The second research stream is concerned with describing how organizations typically develop their BPM capability and how different BPM capability development types can be explained from a theoretical perspective (Niehaves et al., 2014; Pöppelbuß et al., 2015).

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The third research stream related to BPM capability development takes a prescriptive perspective, providing methods and recommendations on how to develop BPM in different organizational contexts (Darmani & Hanafizadeh, 2013; Linhart et al., 2015; Lehnert et al., 2016).

2.2. Project Portfolio Management

Within project portfolio management, project portfolio selection and project scheduling are two established research streams, where scheduling can be performed either after project portfolio selection or simultaneously (Carazo et al., 2010; Lehnert et al., 2015), using both quantitative and qualitative approaches (Carazo et al., 2010; Frey & Buxmann, 2012; Perez & Gomez, 2014). Quantitative approaches typically refer to decision or optimization models, whereas qualitative approaches propose reference processes and classifications (Archer & Ghasemzadeh, 1999; Jefferey & Leliveld, 2004).

Project portfolio selection 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 & Ghasemzadeh, 1999, p. 208). The reference process of project portfolio selection comprises five stages: pre-screening, individual project analysis, screening, optimal portfolio selection, and portfolio adjustment (Archer & 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 against predefined performance indicators. The screening stage eliminates all projects that violate critical thresholds based on these predefined performance indicators. The portfolio selection stage identifies the most suitable project portfolio considering trade-offs among the performance indicators, interactions among projects (e.g., mutual exclusion), and domain-specific constraints (e.g., latest finishing dates, restricted budgets) (Kundisch & Meier, 2011; Liu & Wang, 2011). If performed simultaneously, scheduling is included in project portfolio selection. Finally, decision-makers may adjust the optimal project portfolio.

In project portfolio selection and project scheduling, it is a challenging but necessary requirement to consider interactions among projects (Lee & Kim, 2001). The literature focuses on interactions among IT/information systems projects, as these typically involve interactions among several projects. Interactions can be classified according to three dimensions, namely inter-temporal vs. intra-temporal, deterministic vs. stochastic, and scheduling vs. no scheduling interactions (Kundisch & Meier, 2011). Intra-temporal interactions affect the planning of single portfolios, whereas inter-temporal interactions influence decision-making based on potential

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follow-up projects (Gear & Cowie, 1980). Inter-temporal interactions depend on the sequence in which projects are implemented (Bardhan, Sougstad, & Sougstad, 2004). Interactions are deterministic if all parameters are assumed to be known with certainty or were estimated as single values. Interactions are stochastic if the parameters are uncertain and follow some probability distribution (Medaglia, Graves, & Ringuest, 2007). Scheduling interactions occur if projects may start at different points.

2.3. Performance Management

Performance management aims to take effective corporate action and evaluate whether organizations are operating in line with their corporate goals (Frolick & Ariyachandra, 2006). Performance measurement is the process of quantifying the efficiency and effectiveness of corporate action to deliver the information required for performance management (Neely, Gregory, & Platts, 1995). Performance measurement heavily relies on performance measurement systems, which comprise interacting performance indicators and provide supporting processes and IT infrastructure (Franco-Santos, Lucianetti, & Bourne, 2012). Readers more interested in performance management may have a look at Neely (2005).

From the perspective of process performance management, performance indicators are vital for assessing the operational performance of processes and estimating the effects of improvement projects (Leyer et al., 2015). In line with the conceptualization of process performance as a multidimensional construct, process performance indicators are typically grouped according to various performance dimensions (Linhart et al., 2015). A popular framework for grouping performance indicators is the Devil's Quadrangle, which comprises the performance dimensions of time, cost, quality, and flexibility (Reijers & Liman Mansar, 2005). In the Devil's Quadrangle, improving one dimension weakens at least one other, disclosing conflicts among performance dimensions and highlighting the trade-offs to be resolved. To cover not only dimensions with respect to operational process performance, the Devil's Quadrangle can be extended to incorporate further, often less easily quantifiable dimensions such as risk or ecological and social sustainability (Seidel, Recker, & Vom Brocke, 2013; Suriadi et al., 2014; Vom Brocke & Sonnenberg, 2015).

To enable an integrated view on process performance and account for trade-offs among performance dimensions, some approaches use integrated performance measures (Bolsinger, 2015). An increasing number of these approaches adopt value-based BPM, which has evolved into an accepted paradigm of process and BPM decision-making (Vom Brocke & Sonnenberg, 2015; Buhl, Röglinger, Stöckl, & Braunwarth, 2011). Value-based BPM strives to make process

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and BPM decisions in line with their contribution to the organization's long-term firm value, accounting for cash flow effects, the time value of money, and the decision-makers' risk attitude. Owing to its long-term orientation, value-based BPM complies with the more general stakeholder value approach and with other multidimensional approaches to process performance management (Buhl et al., 2011; Danielson, Heck, & Shaffer, 2008; Vom Brocke & Sonnenberg, 2015).

3. Structuring the Field of Process Project Portfolio Management

We now structure the field of process project portfolio management using BPM, project portfolio management, and performance management as theoretical lenses. In line with our study's interdisciplinary focus, Figure 2 includes three layers, i.e., a BPM, a project portfolio management, and a performance management layer. The BPM layer and the performance management layer refer to temporal snapshots of the organization or the organizational entity in focus. That is, they reflect the status quo or potential target states. The project portfolio management layer covers the transformation from the status quo to potential target states through the implementation of project roadmaps. Project roadmaps include a selection of process improvement and BPM projects scheduled over multiple periods, accounting for interactions and constraints. Thus, each roadmap reflects a distinct way of developing the organization's BPM capability and improving individual processes, leading to distinct target states. To identify the most desirable target state and compile the corresponding project roadmap, process project portfolio management must account for multiple business objects (e.g., processes, BPM capability areas, projects, performance dimensions) and for interactions among these objects (e.g., interactions among processes, interactions among projects, or interactions among BPM capability areas and processes). Many research questions are to be answered before process project portfolio management can be put into practice. Before discussing these questions, we provide information about the relevant business objects and their interactions structured along the three layers.

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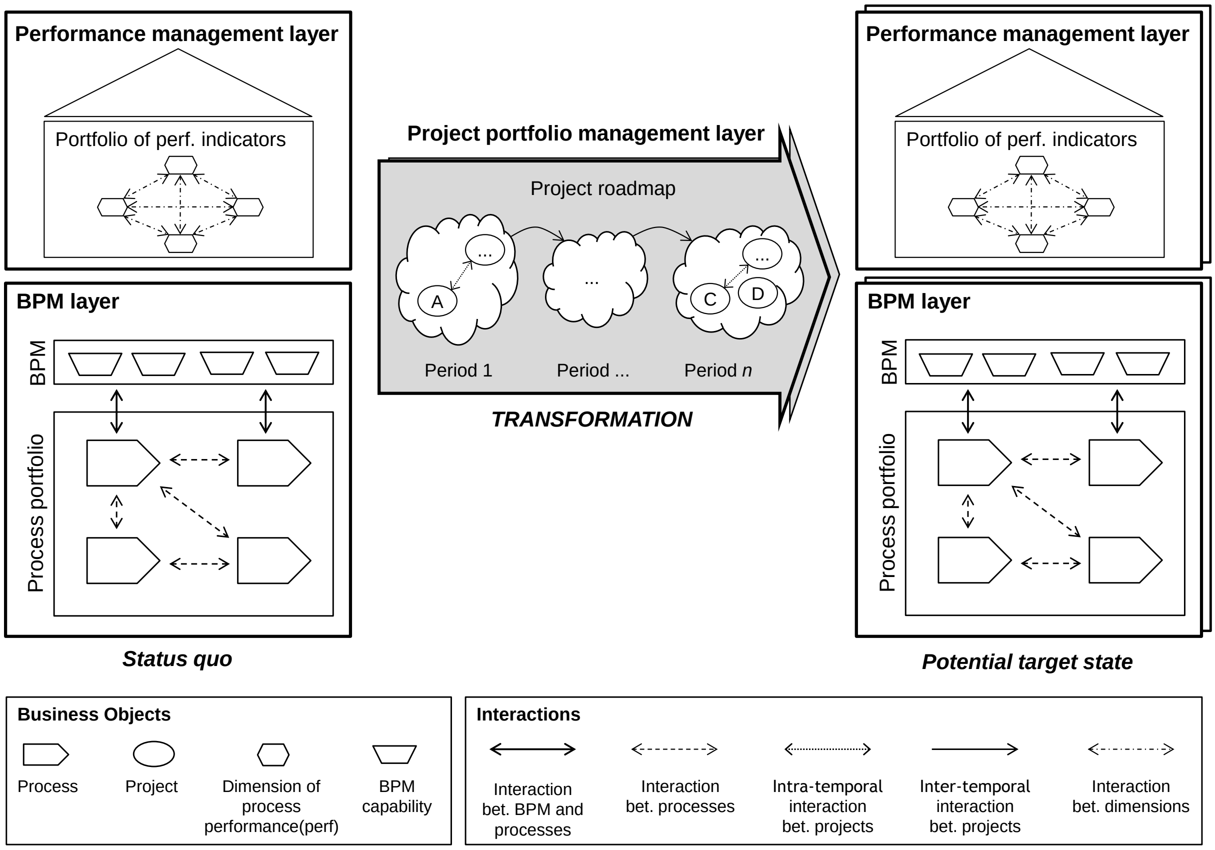

Figure 2. Structuring the field of process project portfolio management

The BPM layer includes the organization's process portfolio as well as relevant areas of the organization's BPM capability. The process portfolio encompasses core and support processes as well as the interactions among them, as processes may require the output of other processes to continue their execution or may just trigger the execution of other processes (Dijkman et al., 2016). The BPM layer also includes interactions among distinct areas of the organization's BPM capability as well as the processes from the process portfolio. With BPM serving as an infrastructure for efficient and effective work as well as for improving existing processes more easily, there is an interaction between how an organization's BPM capability is developed and how processes are performed (Niehaves et al., 2014). The development of the BPM capability relates to the deliberate implementation and institutionalization of selected capability areas of a BPM capability framework (see the framework proposed by Rosemann and Vom Brocke (2015) for a representative example). For instance, strengthening the capability area "process design and modeling" helps redesign processes more easily in the future, whereas "process-related standards" contribute to establishing and complying with process standards across the organization. Moreover, the capability area "process measures" enables process performance measurement as well as goal-oriented redesign.

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The project portfolio management layer deals with the transformation of the status quo into potential target states. It includes the projects available to improve individual processes (i.e., process improvement projects) and to develop the organization's BPM capability (i.e., BPM projects). Process improvement projects (e.g., adoption of a workflow management system) help develop the organization's operational capabilities by improving particular processes (Winter, 2003). BPM projects aim to develop BPM as a dynamic capability (Pöppelbuß et al., 2015). As such, they can facilitate the improvement of processes in the future (e.g., training on process modeling or redesign methods) or make the execution of existing processes more cost-efficient starting from the next period (e.g., implementation of process performance indicators). To compile process improvement and BPM projects into project roadmaps, projects must be selected from a list of predefined project candidates that meets the organization's stated objectives in a desirable manner (Archer & Ghasemzadeh, 1999). Therefore, all project candidates are checked in a pre-screening stage for their strategic fit. Project roadmaps cannot be compiled arbitrarily based on the project candidates. 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 for different processes). Project interactions and constraints determine which project roadmaps and thereby which potential target states are admissible (Liu & Wang, 2011; Müller, Meier, Kundisch, & Zimmermann, 2015). Considering these interactions and constraints, project roadmaps can be valued in line with how they affect the performance of the process portfolio.

The performance management layer focuses on monitoring the performance of processes and estimating the effects of process improvement and BPM projects. This layer includes relevant performance dimensions that help conceptualize process performance as a multidimensional construct (Leyer et al., 2015). These performance dimensions have to be operationalized by adopting performance indicators (Dumas et al., 2013). This layer also accounts for the interactions among the performance dimensions that may be complementary or conflicting (Franco-Santos et al., 2012). To assess and compare the effects of project roadmaps, process performance must be integrated across performance dimensions and aggregated across all processes from the process portfolio. One option for doing so is to calculate the value contribution of process portfolios as well as changes in the value contribution due to the implementation of project roadmaps in line with value-based BPM (Buhl et al., 2011; Vom Brocke & Sonnenberg, 2015).

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In sum, the integrated planning of business process improvement and BPM capability development takes a multi-process, multi-project, and multi-period perspective that requires accounting for multiple business objects as well as for various interactions among these objects. Integrated planning also requires combining knowledge from BPM, project portfolio management, and performance management. As BPM and process improvement projects have direct and indirect effects on process performance as well as, in the case of BPM projects, on other projects, project roadmaps lead to different target states. Thereby, process project portfolio management takes the organization’s strategy as given when compiling project roadmaps. However, project roadmaps have a strategic impact on the organization as business process improvement and BPM capability development support the attainment of potential target states to meet the organization’s strategic goals. In fact, all projects included in any project roadmap have been checked for strategic fit. After the optimal project port-folio has been determined, it should also be checked whether this portfolio as a whole is complies with the organization’s corporate strategy. Thus, determining the most desirable target state and respective roadmap for process improvement and BPM projects is an essential challenge of process project portfolio management.

4. Research Agenda

We now outline exemplary research questions that, from our viewpoint, need to be answered when aiming at an integrated planning of business process improvement and BPM capability development. As our study takes an interdisciplinary perspective, these research questions relate to the intersection areas (4) to (7) and to the organizational context (8) in Figure 1. For each intersection area, we provide a brief introduction and discuss related questions as well as available justificatory knowledge and potential research methods. We acknowledge that in the areas (1) to (3) in Figure 1, many unanswered research questions remain, which have been discussed in other studies and thus are outside the scope of our study. As only few researchers have thus far addressed the intersection of business process improvement and BPM capability development, our research questions differ in terms of granularity, point of view, and suitable methods. For example, the questions cover topics ranging from single processes to process portfolios and from single projects to project portfolios. For increased understandability, we sort the questions from a stand-alone to a portfolio perspective. We also classify them according to whether they relate to descriptive (d) or prescriptive (p) knowledge (Gregor & Hevner, 2013). We already provided an initial answer to some of the proposed research questions in our prior research (e.g., Lehnert et al., 2016). Table 1 provides an overview.

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Table 1. Exemplary research questions

Intersection of BPM and project portfolio management (Area 4)	
- How to classify process improvement and BPM projects?	(d)
- How to classify the interactions among process improvement and BPM projects?	(d)
- How to classify the boundary conditions relevant for process project portfolio management?	(d)
Intersection of BPM and performance management (Area 5)	
- How to classify the interactions among individual processes?	(d)
- How to measure the performance of individual processes?	(d)
- How to measure the performance of process portfolios?	(d)
- How to predict the future performance of individual processes and process portfolios?	(p)
- How to prioritize individual processes within a process portfolio?	(p)
Intersection of project portfolio management and performance management (Area 6)	
- How to measure the effects of process improvement and BPM projects on process performance?	(d)
- How to measure the effects of process improvement and BPM projects on other project effects?	(d)
- How to measure the strategic fit of process improvement or BPM projects?	(d)
- How to measure the effects of project portfolios on the performance of process portfolios?	(d)
Intersection of BPM, project portfolio management, and performance management (Area 7)	
- How to compile process improvement and BPM projects into project roadmaps?	(p)
- How to consider the effects of already completed projects in selection and scheduling decisions?	(p)
- How to assess the robustness of project roadmaps?	(p)
- How to adapt once-planned project roadmaps?	(p)
Organizational context (Area 8)	
- Which context factors influence process project portfolio management?	(d)
- How to establish a knowledge base for project, process, and performance data?	(p)
- How to integrate process project portfolio management into corporate portfolio management activities?	(p)

4.1. Intersection of BPM and Project Portfolio Management

The intersection of BPM and project portfolio management refers to all interactions, effects, and constraints among processes and projects as well as among process portfolios and project portfolios, respectively. The key challenge is to identify and structure the huge amount of

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studies and real-world examples that already partially cover the interactions among processes and projects. Above, we simplifyingly referred to two project types, namely BPM projects and process improvement projects (Lehnert et al., 2016). Research should extend this high-level classification, compiling a framework of project types, their effects on the BPM capability and on individual processes, and the interactions among these project types. Vanwersch et al. (2016), for example, propose a framework for generating process improvement ideas. A next step would be to transform these ideas into project types. Further, the interaction types and boundary conditions relevant to project portfolio selection and scheduling in the context of process project portfolio management should be explored and classified (Kundisch & Meier, 2011; Liu & Wang, 2011).

Overall, more descriptive knowledge is required at the intersection of BPM and project portfolio management to enable the integrated planning of business process improvement and BPM capability development. Related research methods must help identify, structure, and classify project types, interaction types, and boundary conditions. We recommend using research methods such as structured literature reviews (Vom Brocke et al., 2015), taxonomy building (Nickerson, Varshney, & Muntermann, 2013), explorative multi-case studies (Yin, 2013), and grounded theory (Corbin & Strauss, 2014). We also recommend using quantitative empirical methods (e.g., survey research) as far as possible for validation purposes. Relying on deductive and inductive research methods is crucial to cover both the existing knowledge from the literature and the vast amount of real-world examples.

4.2. Intersection of BPM and Performance Management

The major challenge at the intersection of BPM and performance management is how to measure, aggregate, and compare the performance of processes and process portfolios. The performance of individual processes must be conceptualized as a multidimensional construct comprising many performance dimensions, each of which is operationalized by using process performance indicators (Reijers & Liman Mansar, 2005). Traditionally, performance dimensions relate to operational process performance (e.g., cost, quality, time, and flexibility). However, novel dimensions such as risk as well as ecological and social sustainability must be included, as they also influence the value-added of processes and BPM (Seidel et al., 2013; Suriadi et al., 2014). In addition, also the future performance of individual processes and process portfolios needs to be considered when striving for well-founded process decision-making. Research should identify and catalog performance dimensions and respective indicators. To avoid hard-to-quantify performance dimensions suffering a crowding out effect,

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research must also develop respective measurement scales and indicators. On this foundation, research should investigate how to determine the performance of process portfolios by exploring the interactions among individual processes based on knowledge about business process architectures (Dijkman et al., 2016; Malinova et al., 2014). Research should also analyze how different interaction types affect the cascading and aggregation of performance effects throughout a business process architecture (Lehnert et al., 2015). The knowledge on how to measure performance can serve as a foundation for predicting the future performance of individual processes and process portfolios and prioritizing the processes within business process architectures, accounting for interactions among processes.

In sum, the intersection of BPM and performance measurement requires building descriptive knowledge on performance measurement as well as prescriptive knowledge on performance prediction and process prioritization. To build descriptive knowledge, the same research methods can be used as outlined in Section 4.1. Furthermore, approaches from performance management (e.g., balanced scorecards (Kaplan & Norton, 1995) and value-driver trees), multi-criteria decision analysis (e.g., analytical hierarchy process (Saaty, 2004)), scale development (DeVellis, 2012), and analytical modeling (Meredith, Raturi, Amoako-Gyampah, & Kaplan, 1989) can be used. These approaches also help avoid the crowding out effect for hard-to-quantify performance dimensions. As for prescriptive knowledge, business process architectures can be interpreted as process networks, namely as sets of interacting processes. This allows for reverting to the vast body of knowledge on network analysis (e.g., centrality measures) when prioritizing business processes (Newman, 2010). Moreover, knowledge on stochastic processes as well as portfolio theory, which are commonly used in mathematical finance, help predict the performance of processes and process portfolios (Manderscheid, Reißner, & Röglinger, 2015; Markowitz, 1952; Stewart, 2009).

4.3. Intersection of Project Portfolio Management and Performance Management

The intersection of project portfolio management and performance management focuses on measuring the effects of process improvement and BPM projects on process performance as well as, in the case of BPM projects, on other projects. Decisions on project implementation are often made based on an insufficient analysis of project benefits and risks, nor do organizations systematically evaluate project effects based on performance indicators (Braun, Mohan, & Ahlemann, 2010; Pavlou, Housel, Rodgers, & Jansen, 2005). In addition to quantitative performance indicators, organizations also are advised to consider soft factors such

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as the project's strategic fit. While this is quite realizable for single process improvement projects, it is more challenging for projects that affect BPM as a dynamic capability and thus only indirectly influence process performance. Moreover, a comprehensive overview of short- and long-term effects on process performance is missing. To understand how process improvement and BPM projects affect process performance, the characteristics of these effects must be investigated (e.g., the distinction between absolute and relative effects or between stochastic and deterministic effects). Further, BPM projects can also have a moderating influence on the effects of other projects. In other words, path dependencies between process improvement and BPM projects occur if previous projects influence future projects and their effects (Cohen & Levinthal, 1994). All these questions on determining project effects become even more complex by adding a portfolio view instead of a single process or a single project view. For instance, improving a process can also influence processes that are not in the primary of that project owing to the interconnectedness of the processes.

At the intersection of project portfolio management and performance management, the focus is on developing descriptive knowledge on how to measure the effects of process improvement and BPM projects. First of all, the effects of process improvement and BPM projects must be classified. Again, the taxonomy development method as per Nickerson et al. (2013) provides useful guidance. In addition, existing taxonomies like Kundisch and Meier (2011) can serve as starting point for a more in-depth classification of process improvement and BPM projects effects. Second, the classified effects of process improvement and BPM projects must be modelled analytically as well as equipped with measurement scales and aggregation functions. As for non-deterministic project effects, statistical methods, probability theory (Feller, 2008), or fuzzy logic (Klir & Yuan, 1995) offer valuable guidance. Further, approaches related to multi-criteria decision analysis (Meredith et al., 1989; Saaty, 2004) as well as managerial finance help operationalize the effects of and define aggregation functions for individual projects and for project portfolios (Ittner & Larcker, 2001; Koller, Goedhart & Wessels, 2010).

4.4. Intersection of BPM, Project Portfolio Management, and Performance Management

As for the intersection of BPM, project portfolio management, and performance management, it is necessary to build on the results of the intersection areas (4) to (6) in Figure 1 and to compile these insights into an overarching concept for process project portfolio management to define project roadmaps for the organization in focus. The main challenge is the selection and scheduling of process improvement and BPM projects while considering multiple

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interconnected business objects (Figure 2) to enable an integrated planning of business process improvement and BPM capability development in light of various interactions. Deciding the most suitable roadmap calls for a multi-process, multi-project, multi-performance, and multi-period perspective and requires to account for effects from already completed, currently realized, and planned projects. As many of the input parameters of process project portfolio management are hard to estimate (e.g., the effects of a distinct BPM capability area on process performance), research should also investigate means of analyzing the robustness of project roadmaps. Such a robustness analysis should avoid situations where minor deviations have a major impact on a desirable project roadmap. Another challenging problem is the adaptation of once-developed project roadmap as the organizational context changes over time. We further elaborate on the importance of understanding the organizational context of process project portfolio management in Section 4.5.

To compile admissible project roadmaps and to determine the most suitable roadmap, particularly prescriptive knowledge is needed. In this regard, normative analytical modeling helps capture the essentials of this decision problem in terms of closed-form mathematical representations (Meredith et al., 1989). In particular, multi-criteria decision analysis assists with structuring complex decision problems by incorporating multiple criteria, e.g., performance dimensions of the Devil's Quadrangle (Reijers & Liman Mansar, 2005), resolving conflicts among these criteria, and appraising value judgments to support a deliberate and justifiable choice among alternatives (Keeney & Raiffa, 1993). To perform project selection and scheduling, quantitative approaches help resolve these conflicts among relevant criteria and to plan project roadmaps (Carazo et al., 2010; Perez & Gomez, 2014). Hereby, methods from operations research, such as heuristic and mathematical programming as already proposed by vom Brocke et al. (2011), offer appropriate guidance. Qualitative approaches to project portfolio selection and scheduling propose reference processes as well as enable the integration of soft factors (Archer & Ghasemzadeh, 1999; Jeffery & Leliveld, 2004). If a closed-form mathematical representation is impossible due to the complexity of the decision problem, normative analytical modeling can be replaced by simulation-based approaches (Kelton & Law, 2000). Process project portfolio management must also learn from other disciplines that already draw from the project portfolio management body of knowledge (e.g., managing portfolios of product development projects under resource constraints) (Browning & Yassine, 2016). When prescriptive knowledge has been built, it must be evaluated rigorously and iteratively in order to provide valid decision support for process project portfolio management (Sein, Henfridsson, Purao, Rossi, & Lindgren, 2011; Sonnenberg & Vom Brocke, 2012).

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4.5. Organizational Context

In addition to the intersections of BPM, project portfolio management, and performance management, the organizational context is crucial for process project portfolio management. When exploring how the organizational context influences process project portfolio management, the BPM context framework provides valuable orientation (Vom Brocke, Zelt & Schmiedel, 2016). Two important questions are which organizational context factors are required to apply process project portfolio management and which factors influence the application of process project portfolio management. For example, it must be clarified whether distinct areas of the BPM capability (e.g., process measures, process architecture) must be developed to a certain extent before process project portfolio management can be applied. Based on the BPM context framework, it must also be analyzed how factors such as the repetitiveness, knowledge intensity, and variability of processes as well as the scope, industry, size, culture, and competitiveness of an organization influence process project portfolio management. Research about context-aware BPM (e.g., Reichert & Weber, 2012; Rosemann, Recker, & Flender, 2008) can be a starting point to answer these questions. Research should also analyze whether different variants of process project portfolio management are required to deal with different contexts. In fact, as the characteristics of how corporate work is performed are subject to change (e.g., blurring boundaries between process and project work), process project portfolio management must be able to cope with an evolving conceptualization of BPM (Kerpedzhiev et al., 2016). Such an evolving conceptualization of BPM requires incorporating new performance dimensions or project types. To ensure that activities related to process project portfolio management align with other corporate portfolio management activities (e.g., IT portfolio management, customer and supplier portfolio management, technology portfolio management), further research is needed as well.

Another challenge is to transform the developed research results on process project portfolio management into useful decision support tools for corporate decision-makers, i.e., those individuals who cater for corporate process and BPM decisions (Roy, 1993). Thereby, the developed models and concepts must face the real systems, real users, and real tasks. That is, the research results re-quire an extensive evaluation to ensure their applicability, real-world fidelity, understandability, and the acceptance of model- and data-based decision support tools by individual decision-makers (Sonnenberg & Vom Brocke, 2012). Finally, for efficient and effective process project portfolio management, research and practice should join forces to

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establish a knowledge base as well as de-sign data collection routines for project, process, and performance data.

As far as the organizational context of process project portfolio management is concerned, prescriptive and descriptive research is needed. As process project portfolio management cannot be applied independently of the organizational context, we recommend conducting multiple-case studies as well as following an iterative research approach in close collaboration with subject matter experts from industry. This helps identify relevant context factors and best practices. The conception of a knowledge base requires design-oriented methods such as data modeling, software engineering, and prototyping (Gregor & Hevner, 2013). As IT artifacts are shaped by the organizational context during their development and use, we also recommend following the action design research paradigm (Sein et al., 2011). This technique fosters multiple cycles of analysis, action, and evaluation to interweave development, organizational context, and evaluation. Further, process project portfolio management can learn from existing knowledge on project portfolio management and other corporate portfolio management activities. Hereby, we recommend focusing on ex-post naturalistic evaluation methods and conducting acceptance tests of the developed models and constructs (Sonnenberg & Vom Brocke, 2012).

5. Conclusion

In this study, we made the case for research located at the intersection of business process improvement and BPM capability development. Despite the obvious connection between both research streams, they have thus far been treated in isolation. To explore the intersection of business process improvement and BPM capability development, we drew from knowledge on BPM, project portfolio management, and portfolio management. We focused on the integrated planning of business process improvement and BPM capability development as, in line with our industry experience and prior research, this is where both streams have the closest interaction. For this reason, we refer to the research field located at the intersection of business process improvement and BPM capability development as process project portfolio management. In this study, we structured the field of process project portfolio management and proposed a research agenda, including exemplary research questions and potential research methods.

This study's main limitation is that it reflects the authors' individual viewpoints based on their experiences of several industry projects and prior research. Although the proposed structure for process project portfolio management as well as the research questions are based on extant

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knowledge, we admit that both may suffer from subjective influences. Other theoretical lenses for structuring the intersection of business process improvement and BPM capability development might be possible as well. Moreover, we do not claim that the compiled research questions and potential research methods are exhaustive. These questions and methods serve as starting points for exploring the intersection of both research streams. We posit that this limitation is inevitable, as we do not make a final statement about the intersection of business process improvement and BPM capability development, but aim to present opportunities and challenges regarding a neglected research field. Despite this limitation, we hope that our study opens up avenues for interdisciplinary BPM research and contributes a novel perspective to the ongoing discussion about the future of BPM. We would be happy if fellow researchers and practitioners took our arguments up and continued the discussion about how to best explore the intersection of process improvement and BPM capability development. We also hope that our results find their way into organizations' decision-making routines as well as into discussions about their strategic development.

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III. Value-based Process Project Portfolio Management

Research Paper 2: 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 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's (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 section 2, we provide relevant justificatory knowledge and derive design objectives (*objectives of a solution*). In section 3, we outline the research method and evaluation strategy. In section 4, we introduce the planning model's design specification (*design and development*). Section 5 reports on our evaluation activities (*evaluation*). We conclude in section 6 by pointing to limitations and future research possibilities.

2. Theoretical Background and Design Objectives

2.1. Business Process Management and Capability Development

BPM 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).

BPM 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 thirty BPM-related capability areas grouped into six 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 Liman 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 (a) the effects of individual projects on process performance, (b) interactions among projects, and (c) 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 (a) cash flow effects and (b) the time value of money. Moreover, (c) 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 (section 4.1). We then formulate the planning model's objective function to determine the value contribution of different project roadmaps (section 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 (sections 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 (section 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's (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 section 5.1. Activity EVAL3 strives for validated artifact instantiations. We thus implemented the planning model as a software prototype, which we present in section 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 section 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 (Figure 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 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 an improved status quo candidate with the highest value contribution.

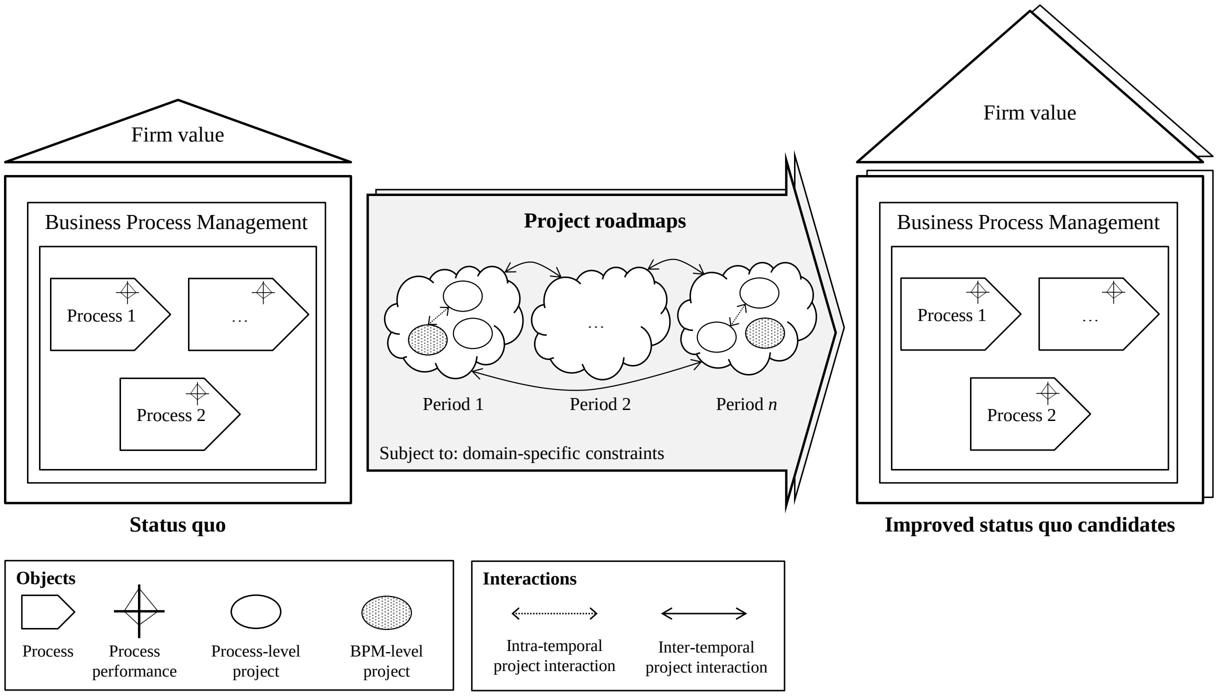

Figure 1. Conceptual architecture of the planning model's design specification

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.

$$r = (\{1,4\}, \{1,5,7\}, \{\ \}, \{2\}, \{2,3,6\}, \{\ \}) \qquad \text{(Eq. 1)}$$

Below, we specify the planning model's objective function that values alternative project roadmaps (section 4.2). We then introduce BPM- and process-level projects with a focus on their performance effect (section 4.3), before showing how to integrate these effects into the planning model's objective function (section 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 (section 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.

$$r^* = \underset{r \in R}{\operatorname{argmax}} \, NPV_r =$$

$$= \underset{r \in R}{\operatorname{argmax}} \sum_{y=0}^{Y} \left[-\frac{O_y^{\text{inv}}}{(1+z)^y} - \frac{O_y^{\text{fix}}}{(1+z)^y} + \sum_{i \in I} \left[-\frac{O_{i,y}^{\text{fix}}}{(1+z)^y} + \frac{n_i(q_{i,y}, t_{i,y}) \cdot \left[I_i^{\text{op}} - O_{i,y}^{\text{op}} \right]}{(1+z)^{y+1}} \right] \right] \quad \text{(Eq. 2)}$$

where

$r \in R$	a distinct project roadmap from the set of admissible project roadmaps R
NPV_r	NPV of project roadmap r
$y \leq Y \in \mathbb{N}$	period within planning horizon Y
$z \in \mathbb{R}_0^+$	risk-adjusted interest rate
$O_y^{\text{inv}} \in \mathbb{R}_0^+$	investment outflows in period y
$O_y^{\text{fix}} \in \mathbb{R}_0^+$	overarching BPM-related fixed outflows in period y
$i \in I$	distinct process from the set of processes I

$O_{i,y}^{\text{fix}} \in \mathbb{R}_0^+$	process-specific fixed outflows of process i in period y
$n_i(q_{i,y}, t_{i,y}) \in \mathbb{R}_0^+$	expected number of instances of process i in period y
$q_{i,y} \in \mathbb{R}_0^+$	quality performance of process i in period y
$t_{i,y} \in \mathbb{R}_0^+$	time performance of process i in period y
$I_i^{\text{op}} \in \mathbb{R}_0^+$	internal or external price for executing process i once
$O_{i,y}^{\text{op}} \in \mathbb{R}_0^+$	process-specific operating outflows of process i in period y

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 minutes) 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 Figure 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.

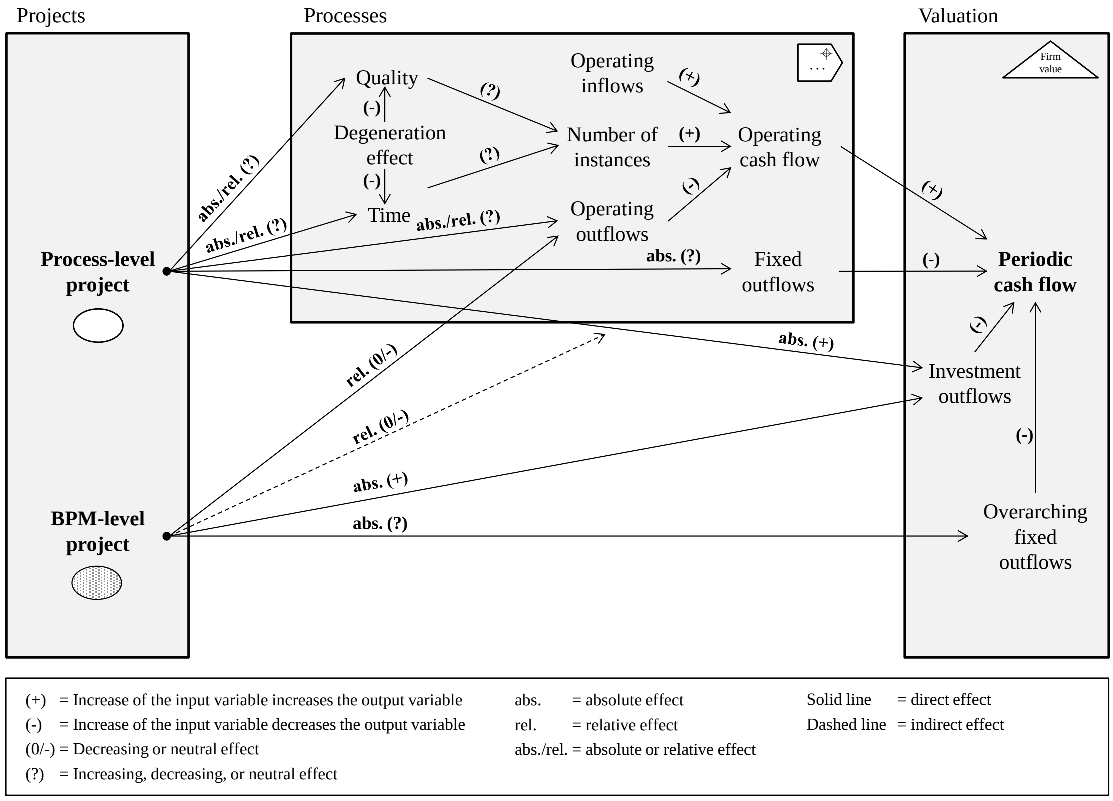

Figure 2. Performance effects of process- and BPM-level projects (for a single period and process)

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 Liman 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 Figure 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 (section 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.

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

where

$\alpha_{i,y-1}^{\text{abs.}} \in \mathbb{R}$	Absolute effect on quality, equals $\alpha_s^{\text{abs.}}$ 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.
$\alpha_{i,y-1}^{\text{rel.}} \in]0;\infty[$	Relative effect on quality, equals $\alpha_s^{\text{rel.}}$ 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 η_i.
$\eta_i \in]0;1]$	Process-specific quality degeneration effect
$q_i^{\max} \in \mathbb{R}^+$	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.

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

where

$\beta^{\text{abs.}}_{i,y-1} \in \mathbb{R}$ 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.

$\beta^{\text{rel.}}_{i,y-1} \in]0;\infty[$ 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 θ_i.

$\theta_i \in [1;\infty[$ 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.

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

where

$\gamma^{\text{abs.}}_{i,y-1} \in \mathbb{R}$ 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.

$\gamma^{\text{rel.}}_{i,y-1} \in]0;\infty[$ 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.

$\varepsilon_j \in]0;1]$ 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).

$$O_{i,y}^{\text{fix}} = \begin{cases} O_{i,0}^{\text{fix}}, \text{if } y = 0 \\ \max\left(O_{i,y-1}^{\text{fix}} + \delta_{i,y-1}; 0\right), \text{else} \end{cases} \quad \text{(Eq. 6)}$$

where

$\delta_{i,y-1} \in \mathbb{R}$ Absolute effect on the process-specific fixed outflows, equal to δ_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.

$$O_{y}^{\text{fix}} = \begin{cases} O_{0}^{\text{fix}}, \text{if } y = 0 \\ \max\left(O_{y-1}^{\text{fix}} + \sum_{j \,\in\, BPM_{y-1}^{\text{fin\_in}}} \epsilon_j \,;\, 0\right), \text{else} \end{cases} \quad \text{(Eq. 7)}$$

where

$\epsilon_j \in \mathbb{R}$ Absolute effect of project $j \in BPM_{y-1}^{\text{fin\_in}}$ 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.

$$O_{y}^{\text{inv}} = \sum_{j \,\in\, BPM_{y}^{\text{run}}} O_j^{\text{inv}} + \sum_{j \,\in\, PLP_{y}^{\text{run}}} O_j^{\text{inv}} \cdot \prod_{j \,\in\, BPM_{y-1}^{\text{fin\_upto}}} \zeta_j \quad \text{(Eq. 8)}$$

where

$O_j^{\text{inv}} \in \mathbb{R}^+$ 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.

$\zeta_j \in]0; 1]$ Relative effect of project $j \in BPM_{y-1}^{\text{fin\_upto}}$ on the investment outflows of process-level projects

BPM_y^{run} Set of BPM-level projects currently running in period y

PLP_y^{run} Set of process-level projects across all processes currently running in period y

$BPM_{y-1}^{\text{fin\_upto}}$ 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.

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).

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 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.

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.
(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 on individual processes. Projects are not considered.
(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's (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.

(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.
(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 modelled 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 modelled implicitly.	No domain-specific constraints are considered.	No domain-specific constraints are considered.
(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.	The process selection matrix builds on strategic business drivers and a service gap perception. No cash flows or other monetary performance indicators are included.	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 not considered.	Long-term effects are not considered.	Long-term effects are not considered.
(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.

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 two hours 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 section 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 3,000 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 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 section 5.3.2.

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. ▪ Process quality was consistently measured in terms of maturity levels.	▪ The number of instances of most processes is driven by quality and time. Some processes are only driven by quality, others only by time. ▪ 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. ▪ The implementation of a project takes between three months and one year. ▪ Process-level projects and BPM-level projects are often implemented simultaneously (e.g., process modeling training and process analysis projects).	▪ 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 either one or two periods according 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. ▪ 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 many regulatory projects per period. These projects must be finished in a predetermined period at the latest. ▪ 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.

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 (Figure 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 (Figure 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 Figure 4.

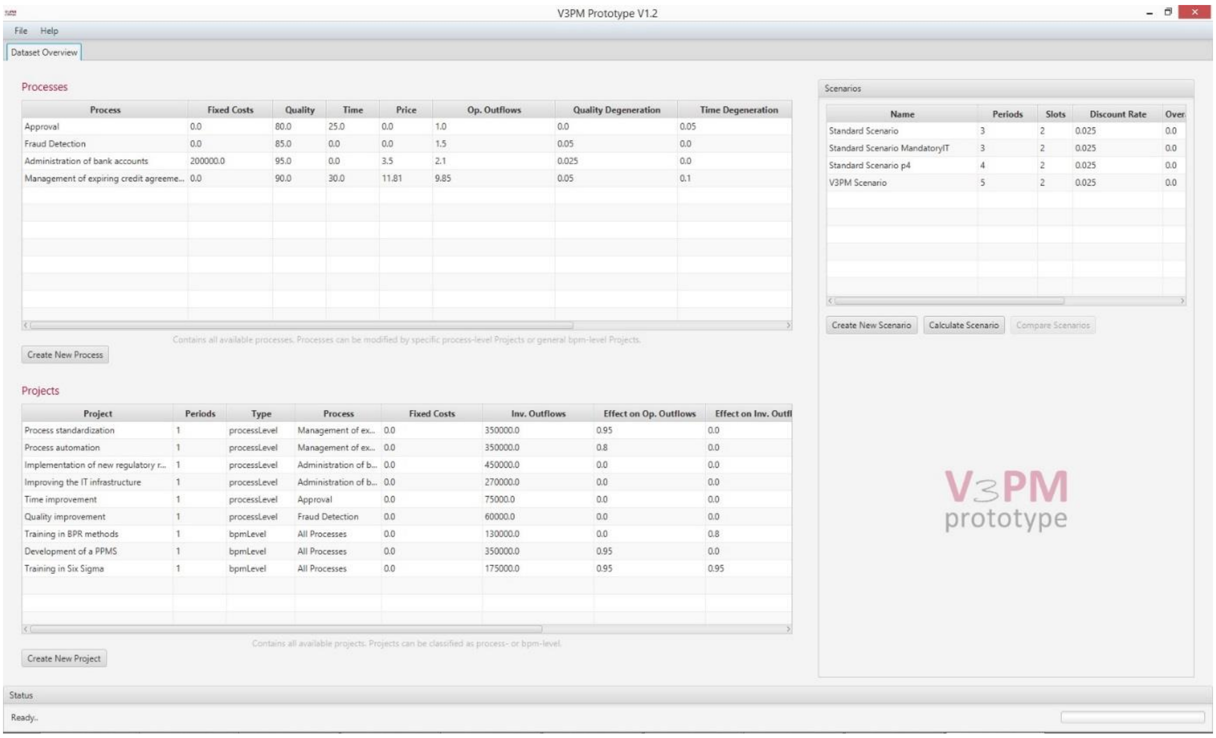

Figure 3. Software prototype – Input data section

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 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 projects 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 (Figure 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.

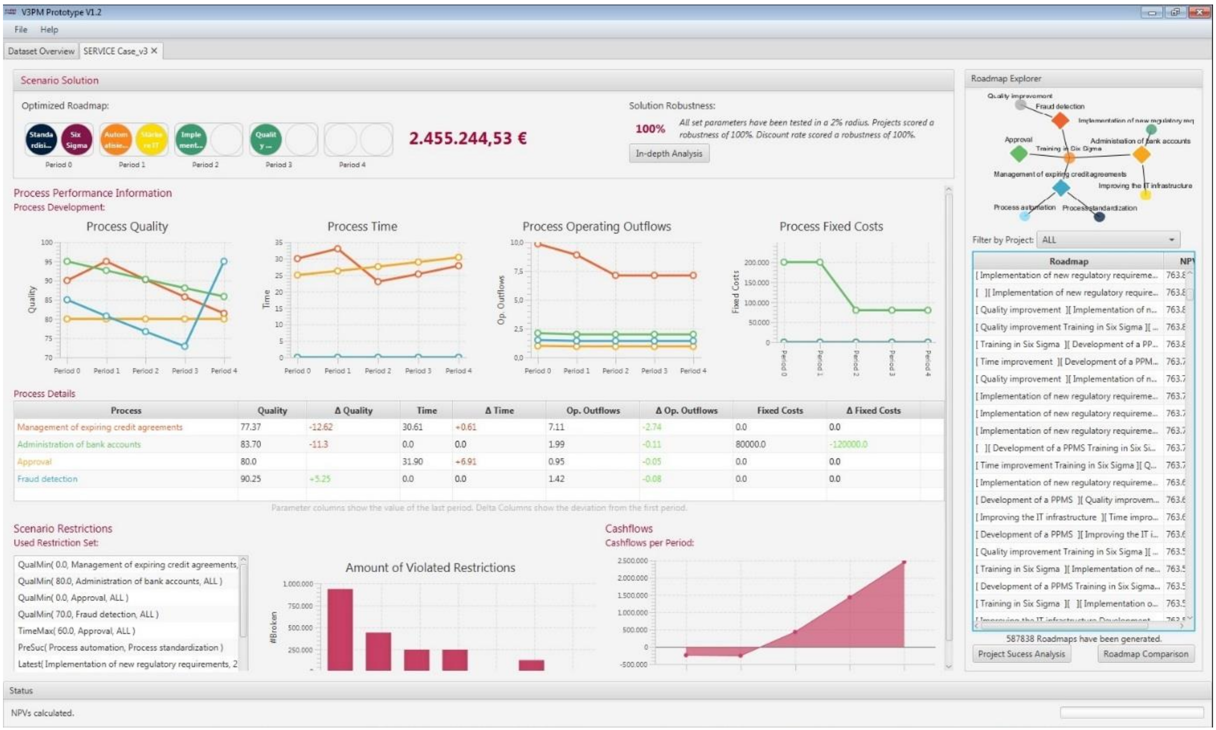

Figure 4. Software prototype - Scenario analysis section

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 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 six 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 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.

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.* Increases quality and reduces operating outflows.	(I)	$PreSuc(s_1, s_2)$
(2)	*Process automation.* Reduces time, increases quality, and reduces operating outflows.	(I)	$PreSuc(s_1, s_2)$
(3)	*Implementation of new regulatory requirements.* No effects on process performance.	(II)	$Latest(s_3, 3)$, $Mandatory(s_3)$
(4)	*Improving the IT infrastructure.* Reduces fixed outflows.	(II)	-
(5)	*Time improvement.* Reduces time.	(III)	-
(6)	*Quality improvement.* Increases quality.	(IV)	-

Table 6. BPM-level projects considered in the case

Project	Description / Effects	Interactions / Constraints
(7)	*Training in BPR methods.* 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.* Direct effects on operational capabilities reduce operating outflows of all processes under investigation.	$LocMutEx(s_7, s_8)$
(9)	*Training in Six Sigma.* Combination of direct and indirect effects. Indirect effects affect future process-level projects, direct effects reduce operating outflows of all processes.	-

Consider the optimistic scenario of case (A): The optimal project roadmap $(\{1, 9\}, \{2, 4\}, \{3\}, \{6\}, \{\ \})$, which is also shown in Figure 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 Figure 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 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.

Table 7. Optimal project roadmaps from the scenario analysis

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

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.

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 section 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 be collected also in non-automated environments. In order to cope with estimations inaccuracies, which are inevitable in naturalistic settings, the software prototype implements robustness check and analysis functionality, as discussed in section 5.2. Applying the planning model

	should not be a 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.
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 of 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 section 5.3.1 required 26 seconds to determine admissible project roadmaps and to calculate the corresponding value contributions. The robustness check of the optimal project roadmap took about 3 minutes, 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 known constraints in the prototype, as these considerably reduce the amount of admissible project roadmaps.

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's (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.

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Research Paper 3: V3PM: A Decision Support Tool for Value-based Process Project Portfolio Management

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Abstract: In the context of Business Process Management (BPM), organizations strive to develop their BPM capability and to improve their individual business processes in an integrated manner. Planning models assist in selecting and ordering implementable BPM- and process-level projects maximizing the firm value, catering for the projects' effects on process performance and for interactions among projects. To facilitate process managers for calculating scenarios of non-trivial complexity, the Value-Based Process Project Portfolio Management (V3PM) tool has been developed. The V3PM tool is a stand-alone program that effectively and efficiently selects one project portfolio for which the net present value takes the highest value. It is designed to fulfil a twofold objective: the scientific perspective in terms of an adequate evaluation for existing design science research artifacts as well as the user's point of view in terms of a first step towards a full-featured version for decision support in daily business operations. In this paper, we describe the application's architecture focusing on the data management, the roadmap engine and the graphical user interface. Deeper insights into the functionality for creating and analyzing persistent problem sets highlight the strengths of the V3PM tool as well as its usefulness and practical applicability for decision support.

Keywords: Business Process Improvement, Process-Decision Making, Project Portfolio Management, Business Process Management

1. Introduction

1.1. Status Quo of Decision Support for Process Improvement

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, for instance, support process improvement (van der Aalst, 2013; Zellner, 2011). However, only few approaches give guidance on how to put process improvement into practice (Bandara et al., 2015; Shrestha et al., 2015; Ohlsson et al., 2014) mostly sharing a single process as unit of analysis and consequently neglecting interactions among multiple processes. 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 (de Bruin and Rosemann, 2005; Poeppelbuss et al., 2015). Research mainly focuses on identifying and grouping the constituents of BPM and developing related capability frameworks (de Bruin and Rosemann, 2007; Rosemann and vom Brocke, 2015; van Looy et al., 2012). Few guidance on how to develop an organization's BPM capability from a theoretical, prescriptive perspective is available (Niehaves et al., 2014; Poeppelbuss et al., 2015). Consequently, there is a lack of approaches that assist organizations in selecting and ordering projects that improve multiple processes and organization's BPM capability in an integrated manner to maximize the firm value, while catering for the projects' effects on process performance and for interactions among projects.

Against this background, we developed two planning models answering differing aspects with our prior research (Lehnert et al., 2014; Lehnert et al., 2016; Linhart et al., 2015). They help valuating so-called BPM roadmaps in line with the principles of project portfolio selection and value-based management. We define a BPM roadmap as a scheduled portfolio of projects an organization should implement. To identify the BPM roadmap that maximizes the company's value, we calculate the BPM roadmaps' net present value (NPV). The BPM roadmap with the highest NPV is the roadmap to be implemented. In Lehnert et al. (2014; 2016), we focus on improvement projects for process improvement and BPM capability development in an integrated manner. The planning model takes a multi-process, multi-project, and multi-period perspective while catering for the projects' effects as well as for interactions among projects and processes. Due to the multi-process and multi-project focus, we analyze single processes only in terms of their performance indicators and exclude more detailed process characteristics. In Linhart et al. (2015), we examine how organizations should improve a distinct process via improvement projects with a particular focus on the characteristics of that process. We consider characteristics that capture how work is performed and organized. To restrict the set of admissible BPM roadmaps, this planning model introduces the specification of project-specific (e.g., earliest beginning), process-specific (e.g., critical boundaries for performance indicators), and period-specific constraints (e.g., available budget) that BPM roadmaps must not violate. Due to the single-process perspective, interactions among processes are excluded.

1.2. Need for new Prototype / Design Objectives

Multi-process, multi-project, and multi-period perspectives on process improvement lead to non-trivial complexity and call for a useful and easy-to-use decision support tool. Thus, we developed the Value-based Process Project Portfolio Management (V3PM) tool enhancing the prototypes that resulted from our prior research on process improvement and project portfolio selection (Lehnert et al., 2014; Lehnert et al., 2016; Linhart et al., 2015). When developing the tool, we primarily focused on scientific rigour and practical applicability. Following design science research (DSR), our prior work resulted in planning models that comprise the identification of and motivation for the research problem, objectives of a solution, design, and development (cf. Peffers et al., 2007). However, to complete the DSR process, an adequate evaluation of the DSR artifacts that solve the observed problem (e.g., constructs, models, methods, and instantiations; see Hevner et al., 2004) is necessary (cf. March and Storey, 2008; Sonnenberg and vom Brocke, 2012). As result, the design objectives of the V3PM tool focus on the ex post evaluation activities according to the evaluation framework of Sonnenberg and vom Brocke (2012). The V3PM tool is used both for incorporating a proof of concept (EVAL3) and for preparing an application in naturalistic settings to validate its usefulness (EVAL4). Thus, we need an adequate user interface and have to overcome various shortcomings of the existing prototypes. Since no external requirements exist, we focus on internal quality and quality in use as specified in the evaluation criteria of DSR artifacts (Sonnenberg and vom Brocke, 2012) and the quality requirements of systems and software quality (ISO/IEC 25010). Further, we intended to merge the scientific insights of our distinct research streams in one single application. The V3PM tool at its current stage should only be a first step towards a full-featured decision support tool applicable in daily business operations (e.g. from production or service industry).

The V3PM tool was designed as executable program that effectively and efficiently generates all admissible BPM roadmaps, applies the objective function to each admissible roadmap to calculate the NPV, and selects the roadmap which the highest NPV. The V3PM tool was designed to consider the multi-process perspective as well as all improvement effects of Lehnert et al. (2014; 2016) in combination with multi-period projects and the integration of constraints as shown in Linhart et al. (2015). Further, an almost unlimited number of projects and processes should be feasible. In view of the necessary performance, we decided for a new software architecture, e.g. persistent and fast data management, as well as for new algorithms, e.g. for a more efficient roadmap generation minimizing existing bottlenecks and providing modularity according to the maintainability. In order to improve usability and satisfaction, a graphical user interface (GUI) just as analysis and visualization functionalities were integrated. We introduced the concept of scenarios to allow the examination of different persistent problem sets based on the combinations of projects and processes. They were designed to simplify data in- and output and to prevent errors. A focussed provision of information as well as in-depth insights in terms of sensitivity analyses improve the decision support.

1.3. The Architecture

The V3PM tool is an executable program mainly relying on Java. Its implementation follows a typical 3-tier architecture dividing presentation, business logic and data storage into independent modules due to the modularity and maintainability requirements (Fowler, 2002). Figure 1 shows the different components: the data collection, the roadmap generation, the roadmap calculation, and the analysis functionalities. The data collection and the analysis functionalities belong to the presentation tier as front-end that consists of multiple GUI components. Therefore, we used the toolkit JavaFX and the related open source project ControlsFX as well as the third party library GraphStream that provide a lot of visualization features needed for the analysis functionalities, particularly for charts and dynamic graphs. The roadmap generation and calculation are part of the business logic. The business logic and the data storage tier represent the back-end of the application. They implement the insights of the decision model as well as database connections for reading and writing data to a persistent storage. The communication across the different layers is performed via defined interfaces. Despite the typical representation of a 3-tier architecture, we first outline the business logic tier (section 2) as it is the implementation of our planning models and the core of the V3PM tool. We then introduce the presentation layer (section 3) to highlight the extension of the roadmap calculation in terms of analysis and visualization functionalities.

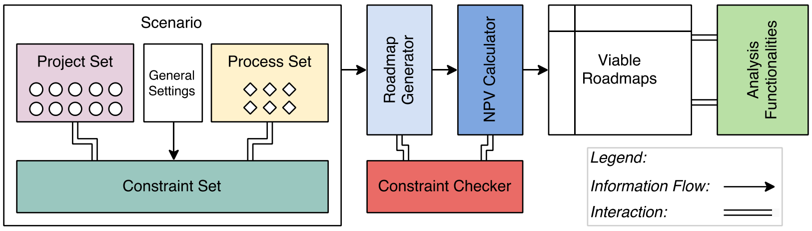

Figure 1. The components of the business logic

2. The Business Logic and the Back-end Side

The business logic tier contains multiple algorithms for the generation, calculation, and analysis of BPM roadmaps considering the projects' effects on process performance and for interactions among projects. The data collection provides the input data in terms of distinct scenarios. Each scenario consists of multiple projects and processes. Each project has specific performance effects that influence one or more processes from the process set. Further a constraint set (e.g., for interactions among projects) and general settings (e.g., the risk-adjusted interest rate) are part of a scenario. For each scenario, the roadmap generator evaluates the potential process and project combinations. The NPV calculator applies the objective function to them resulting in the NPV and additional variables for further in-depth analyses, e.g. scenario analyses, provided by the analysis functionalities. The constraint checker ensures considering only admissible BPM roadmaps during the generation and calculation.

The parts of the business logic that happen before the roadmap calculation demonstrate the most significant differences and improvements compared to the existing prototypes at the back-end side. In the following, we focus on the algorithms of the roadmap generator with particular regard to the performance features and present the prototype's data management functionalities. The scenario component is part of the data management as well as the GUI components in the front-end section.

2.1. Constraint-based Roadmap Generation

The roadmap generation based on the user-defined project sets mainly generates lexicographical permutations (Knuth, 2011) in a broader sense. Difficulties arise from the multi-period perspective and the opportunity not to implement any project within distinct periods. Both are not captured by existing java libraries (e.g., `org.paukov.combinatoricslib`, `com.google.common.collect.Collections2`). Thus, we designed a special form of the algorithm. We use containers based on `ArrayList` to record all periods considered for the implementation of a project as well as combinations of these to form the entire roadmaps. Figure 2 illustrates the roadmap generation including restriction handling in general and exemplifies the roadmap generation considering three potential process improvement projects and a planning horizon of three periods without restrictions. The implementation of project 1 would take one period, for project 2 it would take two periods and for project 3 it would take three periods. The available capacity within the organization allows for two project implementations in parallel.

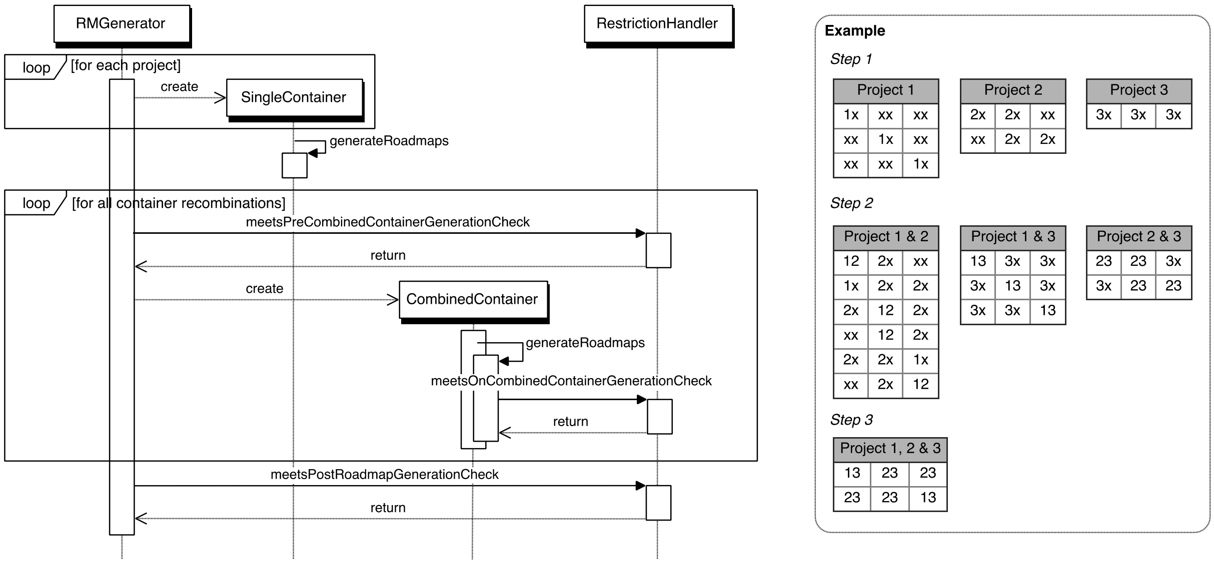

Figure 2. Roadmap Generation and Restriction Handling

First, the algorithm generates the containers for each single project of the project set. A container includes all possible project schedules due to project duration and planning horizon. In our example, we get three containers. These are the basis for the following combinations. Each cycle forms further containers as Cartesian product of two containers generated beforehand. Finally, recombination leads to $\sum_{k=1}^{n}\binom{n}{k}$ containers (with n = number of projects) and an even larger amount of roadmaps. A tracking mechanism hinders double combinations of containers.

However, not all generated unique roadmaps are admissible due to given constraints, e.g. for organizational, content-related, or regulatory reasons (Linhart et al., 2015). This can be assured by incorporating a constraint check at multiple stages. Project-specific constraints, e.g. earliest beginning or latest completion, can be checked during the generation of the creation. Interactions among projects, e.g. predecessor-successor-relationship, have to be examined afterwards. Unfortunately, the stepwise design of roadmap generation hinders the allocation of some constraints to earlier stages and gives room for further improvements. Nonetheless, the container design allows for fast constraint checks as the distinct included projects are known. Additionally, there is a further check for process- and period-specific constraints, e.g. quality boundaries or budget limits, included in the NPV calculation (see Figure 3).

Nonetheless, the generation and calculation algorithms have to cope nearly an infinite number of BPM roadmaps. A naturalistic setting including four processes, nine projects, and a planning horizon of five periods that we derived from expert interviews led to 2,7 million potential and, at least, approximately 250,000 admissible roadmaps. To facilitate the needed high throughput in terms of performance as intended in the design objectives, we incorporated a concurrency concept based on the `javafx.concurrent` package. Following this, multiple threads are performed asynchronously or in parallel while updating the user interface, generating roadmaps and calculating the NPVs.

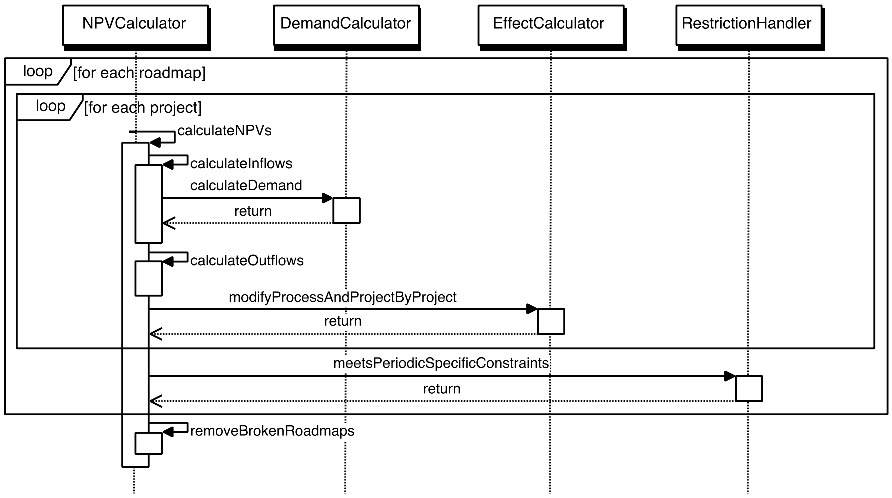

Figure 3. Roadmap Calculation

2.2. The Data Management

The design decisions towards the data management are in line with the performance and usability requirements. We use the database management system (DBMS) SQLite that is often used as the on-disk file format for desktop applications such as financial analysis tools. The DBMS offers high performance, reliability, and security in terms of ISO/IEC 25010 including efficient data access and data integrity (Ramakrishnan and Gehrke, 2003). Due to the sophisticated techniques to store and retrieve the (intermediate) results efficiently, the essential part of computing time remains content-related depending on the planning model, e.g. roadmap generation or NPV calculation, and less affected by the technical environment. Further, based on the DBMS, we were able to introduce a relational data model that provides more usability and flexibility via reuse of data. Once processes and projects have been created, they can be combined in any way for new scenarios whereas constraints are specific for each scenario. Further, the scenario component allows to store different problem instances which can be re-opened, copied, and modified for determining the effect of slight changes on distinct scenarios at any point in time. As data does not have to be entered every time, we expect that the user experience increases.

3. Front-end and Functionality of the V3PM Tool

While the concept of the back-end side aims at the product quality, the concept of the front-end side has a strong focus on quality in use (ISO/IEC 25010). A well-structured GUI (Figure 4) just as selected analysis functionalities assure quality by usability and satisfaction.

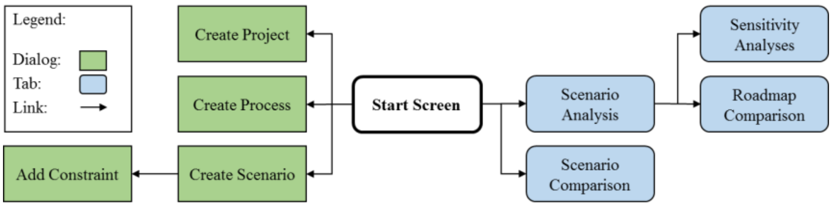

Figure 4. GUI Navigation Model

3.1. The Graphical User Interface (GUI)

The GUI gives a very compact and clean design. The start screen (Figure 5) as the center of the application provides an overview of the projects, processes, and scenarios. From here, all functions of the V3PM tool can be reached. As shown in Figure 4, the navigation model follows two approaches that differ optically as well as technically.

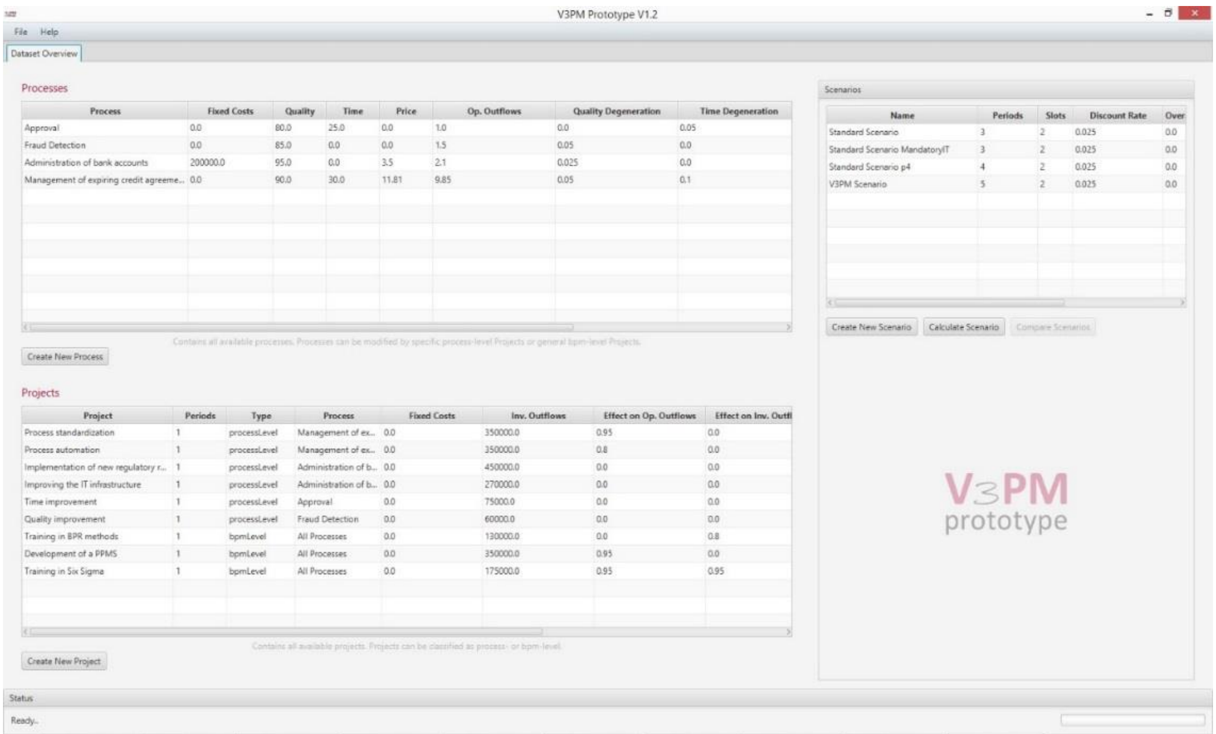

Figure 5. Start Screen as Overview

Dialogs that open in a new window enable the gathering of further input data (Figure 6). The provided data entry fields change dynamically due to the selected project type. In case of scenarios, the input is a combination of projects and processes in addition to the information about the interactions and constraints to be considered as well as the general settings (e.g., risk-adjusted interest rate, number of periods in the planning horizon). Here, the GUI also provides usability features in terms of product quality. As it uses referential integrity for error protection, the mapping of projects and processes is only possible for those that have already been created. For the results of the NPV calculation, additional tabs show detailed scenario information. Whereas the dialogs are only visible for a certain time until the input is finished, the tabs remain open for analysis purposes until the user finishes.

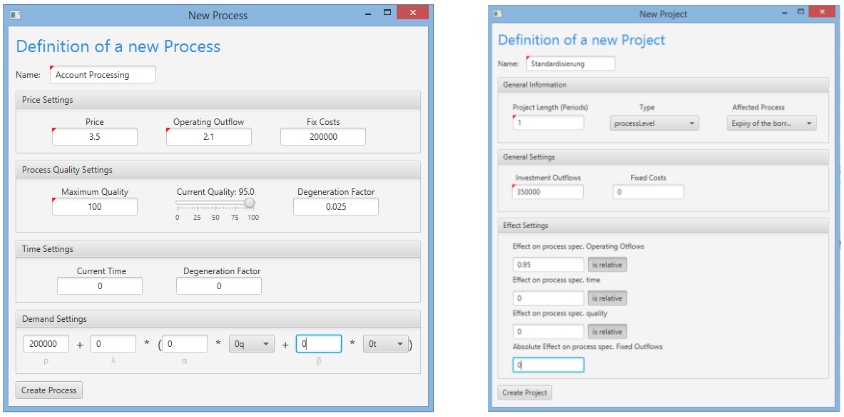

Figure 6. Definition of new processes or projects

3.2. Analysis functionality

Once calculated, the V3PM tool provides detailed information about a scenario. While the back-end design and the GUI mainly support the practical use of the planning model, the analysis section goes beyond the model's intention of determining the optimal BPM roadmap. Beside the visualization of the NPV calculation it enables to gain in-depth insights into the BPM roadmaps associated with a distinct scenario. According to the DSR evaluation criteria (Sonnenberg and vom Brocke, 2012) and with regard to well-informed decisions, this section extends our prior research providing comparisons between roadmaps and scenarios as well as sensitivity analyses to test the robustness of the calculated results.

For each scenario analysis, the results of the respective optimal BPM roadmap are the starting point (Figure 7). An overview shows information about the scheduled project selection, the processes' performance, the considered interactions and constraints as well as occurred violations while roadmap generation, just as the cash flow development. For better understanding, we choose different presentation forms and chart types. For example, the temporal development of the processes' performance in terms of time, quality, operating outflows, and fixed outflows due to the implementation of projects is presented with line charts. The amount of restriction violations, in turn, is better reflected by a bar chart. Further, the overview includes a project-to-process relationship graph. It captures all interdependencies among processes and projects visually and can be examined interactively by the tool user. Concerning any other admissible roadmap, a list sorted by NPV in descending order allows access to the presented information. In addition, the scenario analysis is the entry for the comparison and sensitivity features.

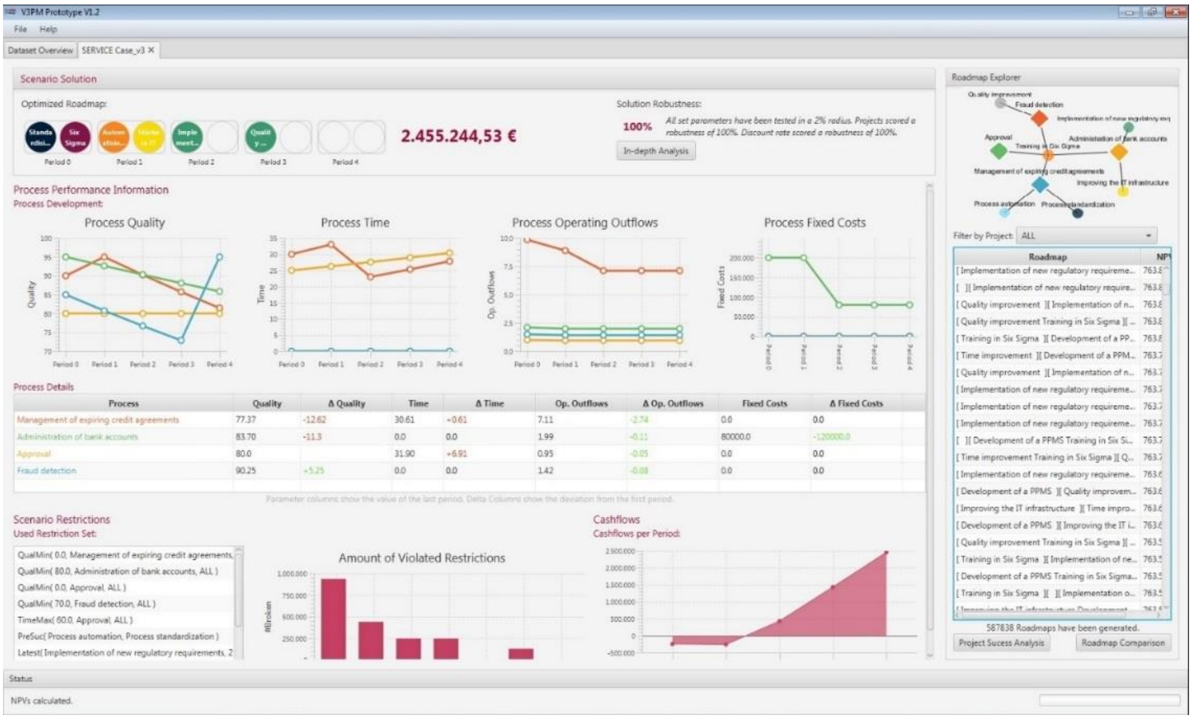

Figure 7. Scenario analysis section

The comparison section contains information about roadmaps themselves in terms of the selected projects and their order, about the performance parameters as well as the cash flow development. It represents the differences using selected graphic representations, as well. Comparisons are possible both between roadmaps and scenarios. For roadmaps, the user can compare any of the calculated admissible roadmaps. The scenario comparison considers the best roadmaps of the two selected scenarios and allows for variations in the process, project, and constraint sets. Therefore, it also provides information about the differences regarding the constraint violations. As the project selection just as the effects on time, quality, costs, and cash flows are visible, the comparison section helps to easily detect the impacts of various planning foundations (e.g., a change of a project's position or varying budget targets) on the probable results in terms of intentional variations.

The sensitivity analyses examine the consequences of random, unintentional variations in terms of estimation errors, as the planning model at hand is very complex. The model's robustness should avoid a situation where minor deviations would have major impact on the dominant BPM roadmap. Therefore, we integrated a robustness check to test how strongly the value contribution of the selected roadmap is affected by such variations. For the maximum 50,000 best BPM roadmaps, we vary all project-related input parameters ceteris paribus in a range of ±2% by steps of 1% and determine the percentage of cases in which the optimal BPM roadmap remains dominant compared to the other BPM roadmaps. Following the demonstration examples relying on discussions with our industry partners from the financial service industry (e.g., as described in Linhart et al., 2015), the robustness check confirmed that the calculated optimal BPM roadmap is robust in regard to estimation errors.

Furthermore, the tool user may also refer to a project's input parameter in all or any input parameter whether or not it depends to a process, a project, or the general setting to test the model's robustness. He or she can define a finite interval as variation scope as well as the step width. Allowing for individual and flexible analyses, the user can specify relative or absolute adjustments and decide for positive, negative, or positive and negative interval boundaries in addition. For example, a step width of 5% and a positive boundary of 10% would result in two calculations, while in the first iteration the input value of the selected parameter is increased by 5% and in the second iteration by 10%. With this more detailed sensitivity analysis, the V3PM tool provides further insights to the major factors of influence from two perspectives. The user can investigate the role of a distinct project or the role of a project's specific input parameter in relation to the NPV of an entire roadmap.

4. V3PM Evaluation & Discussion

We introduced the V3PM tool to facilitate process managers for calculating scenarios of non-trivial complexity in a multi-project, multi-process and multi-period perspective on process improvement as well as on BPM capability development. We aimed to design a useful and easy-to-use decision support tool that effectively and efficiently calculates the NPV of quite a lot of BPM roadmaps derived from different scenarios. Besides the identification of the optimal BPM roadmap, we intended to use the tool and the results for analysis purposes. This could be realized by a 3-tier architecture with focus on a dynamic, information-rich GUI, appropriate back-end algorithms, and the use of a DBMS.

First performance tests on regular work stations using artificial as well as real-world data already indicate the applicability of the tool in business environments. For example, the roadmap generation and NPV calculation of a case with four processes, nine projects and a planning horizon of five periods requires about half a minute. The robustness check takes about 3 minutes. Complexity drivers are the planning horizon and the amount of available projects. As planning horizons usually are rather small (i.e., between 2 and 8 according to our experiences) and only a limited selection of projects comply with organizational goals (Archer and Ghasemzadeh, 1999), both factors are uncritical. However, more information has to be gathered by real world application. For this, the GUI concept and the analysis functionalities were relevant and necessary steps as well as for the evaluation of our DSR artifact (EVAL3, EVAL4) in the sense of Sonnenberg and vom Brocke (2012).

Besides the limitations grounded in the planning models (Lehnert et al., 2014; Lehnert et al., 2016; Linhart et al., 2015) as conceptual basis of the V3PM tool (e.g. projects that already started in an organization are excluded), there are still shortcomings towards the software quality (ISO/IEC 25010). We will consider further requirements of ISO/IEC 25010 (e.g. introducing a user concept for security reasons) when extending the functionalities to integrate additional aspect from our prior research. However, the V3PM tool was designed for evaluation purposes. Although we already discussed our results with organizations and could derive real world data as input, the V3PM tool is not yet operational in organizations. For instance, we have not yet tested the user interface with intended users. Thus, the V3PM tool needs further development to mature to a full-featured version for decision support in daily business operations. In addition, a comprehensive user documentation and a web-based, platform-independent tool are in preparation.

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IV. Integration of Process Interdependencies in Process Prioritization Decisions

Research Paper 4:
ProcessPageRank - A Network-based Approach to Process Prioritization Decisions

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Abstract: Deciding which business processes to improve first is a challenge most corporate decision-makers face. The literature offers many approaches, techniques, and tools that support such process prioritization decisions. Despite the broad knowledge about measuring the performance of individual processes and determining related need for improvement, the interconnectedness of processes has not been considered in process prioritization decisions yet. So far, the interconnectedness of business processes is captured for descriptive purposes only, for example in business process architectures. This drawback systematically biases process prioritization decisions. As a first step to address this gap, we propose the ProcessPageRank (PPR), an algorithm based on the Google PageRank that ranks processes according to their network-adjusted need for improvement. The PPR is grounded in the literature related to process improvement, process performance measurement, and network analysis. For demonstration purposes, we created a software prototype and applied the PPR to five process network archetypes to illustrate how the interconnectedness of business processes affects process prioritization decisions.

Keywords: Business Process Decision-Making, Business Process Architecture, Decision Support, PageRank, Business Process Improvement, Business Process Prioritization

1. Introduction

Process orientation is a recognized paradigm of organizational design and a source of corporate performance (Dumas et al., 2013; Kohlbacher and Reijers, 2013). Business process management (BPM) in general and process decision-making in particular receive continued attention from practitioners and researchers (Buhl et al., 2011; vom Brocke et al., 2011). Fundamental to BPM is process improvement, a task that also requires prioritizing which processes to improve (Bandara et al., 2015; van der Aalst, 2013). Process prioritization requires to focus on processes that are of strategic importance or that show significant need for improvement (Bandara et al., 2015; Burlton 2015; Ohlsson et al., 2014). Most approaches to process prioritization neglect that processes are interconnected, a drawback that biases prioritization decisions and must be addressed in further research.

So far, the interconnectedness of processes is only captured for descriptive purposes, for example in process model repositories and business process architectures (BPA) (Dijkman et al., 2014; Malinova et al., 2014). While process model repositories organize large collections of process models to facilitate process modeling, composition, and execution, BPAs identify and visualize relations among processes (La Rosa et al., 2011; Malinova et al., 2013). As for process prioritization, Bandara et al. (2015) state that available methods are "either of very high level and hence not of much assistance […], or, on the contrary, are so detailed that it can take a significant effort to simply identify the critical processes". However, improving a process according to one or several performance dimensions such as time, quality, or cost largely influences the performance of connected processes – and thus the overall performance of a company's processes (Leyer et al. 2015). Neglecting interconnections among processes also entails operational risks such as a change-related downtime of interconnected processes or disruptions and delays due to a change in process demand (Setzer et al., 2010). What is missing are approaches that provide concrete decision support on process prioritization integrating the need for improvement of single processes with their interconnectedness. Therefore, our research question is as follows: *How can process prioritization decisions be made in line with how processes are interconnected?*

As a first step to answer the research question, we interpret BPAs as networks with processes as interconnected nodes, combining network analysis and BPM research. In this analytical paper, we propose the ProcessPageRank (PPR), an adaptation of the Google PageRank that ranks processes according to their network-adjusted need for improvement and helps prioritize processes for improvement purposes.

The paper is organized as follows: In section 2, we sketch the foundations of BPM and network analysis, and derive high-level requirements. In section 3, we show how to transform BPAs into process networks, concretize the high-level requirements in terms of rationality postulates, and propose the PPR algorithm. In section 4, we apply the PPR to five process network archetypes and compare the results in a cross-case analysis. In section 5, we sum up key results and point to limitations as well as to future research.

2. Theoretical Background and Requirements

2.1. Business Process Management

Business Process Management (BPM) combines knowledge from information technology and management sciences, and applies this to corporate processes (van der Aalst, 2013). Processes split into core, support, and management processes (Harmon, 2010). Core processes are collections of events, activities, and decision points that involve actors and objects, collectively leading to valuable outcomes (Dumas et al., 2013). Support processes ensure that core processes continue to function, whereas management processes plan, organize, communicate, monitor, and control the activities within an organization (Harmon, 2010). In this paper, we focus on core and support processes and refer to both as processes.

Within the BPM lifecycle, process improvement is a fundamental activity (Zellner, 2011). The BPM literature offers numerous approaches to process improvement (Sidorova and Isik, 2010; Zellner, 2011). Many of these approaches focus on quantifying the performance and the need for improvement of single processes in terms of performance measures (Bolsinger, 2014; Dumas et al., 2013; Levina and Hillmann, 2012). Though relying on performance measures from different domains such as investment theory or social network analysis, these approaches share the individual process as unit of analysis. Few process improvement approaches take on a multi-process perspective. Lehnert et al. (2014), for example, propose a decision model to determine which projects an organization should implement in which sequence to balance the improvement of individual processes with the development of BPM capabilities. Ohlsson et al. (2014) propose a method for prioritizing process improvement initiatives. Thawesaengskulthai and Tannock (2008) compare popular quality management and continuous improvement initiatives to support the selection of process improvement projects. All these approaches do not cater for interconnections among processes.

Process performance and the effect of improvement projects are measured in terms of performance indicators (Leyer et al. 2015). Among others, performance indicators refer to the dimensions of the Devil's Quadrangle, i.e., time, cost, quality, or flexibility (Reijers and Liman

Mansar, 2005). Some approaches also resolve the partly conflicting nature of these performance dimensions by means of integrated performance measures (Bolsinger, 2014). This leads to our first high-level requirement:

(R.1) *Performance of individual processes*: When prioritizing processes, the individual performance of the processes in focus must be measured in terms of one or more performance indicators and considered in the resulting ranking.

The processes of an organization and their relations are typically modelled as BPAs. A BPA is an organized overview of an organization’s processes and their relations, potentially accompanied by guidelines that determine how to organize these processes (Dijkman et al., 2014). The topmost level of a BPA is also referred to as process map or landscape (Malinova and Mendling, 2013). There are four kinds of relations occurring in a BPA, i.e., specialisation, decomposition, use, and trigger (Dijkman et al., 2014). The specialisation expresses that one process is a specialised version of another process. The decomposition expresses that a process is decomposed into multiple sub-processes. Use relations model situations where a process needs the output of another process to continue or complete its execution (synchronous communication). That is, the performance of the using process partly depends on the performance of the used process – not vice versa (Malone and Crowston, 1994). Trigger relations express that one process triggers the execution of another process without having to wait for the other process’ output (asynchronous communication). The performance of the triggering and triggered process are independent. This leads to our second high-level requirement:

(R.2) *Relations among multiple processes*: When prioritizing processes, the relations among the processes in focus such as those captured in a BPA must be considered in the resulting ranking.

2.2. Network Analysis

Approaches to identifying important nodes in networks have been applied in fields like IT landscape management, biology, or power grids (Özgür et al., 2008; Simon and Fischbach, 2013; Wang et al., 2010). With the rise of online social networks (OSN), researchers from social network analysis found centrality measures to be very useful. Due to extensive research during the last years, the knowledge base regarding centrality measures can be considered quite mature (Probst et al., 2013).

In the OSN context, there are three especially popular approaches to measure the centrality of a distinct node, i.e., degree centrality (measures the amount of direct neighbours), closeness centrality (measures the shortest path to each node in the network), and betweenness centrality (measures the amount of shortest paths between every two nodes in the network that contain the node in focus) (Freeman, 1977). The drawback of these measures is that local patterns can have a disproportionally high influence on the centrality of a single node (Hanneman and Riddle, 2005). Another centrality measure that accounts for this problem and explicitly acknowledges that connections to influential nodes add more importance to a node than connections to less influential nodes, is the eigenvector centrality (Newman, 2003). The eigenvector centrality extends the concepts of degree and closeness centrality to a node's interconnectedness in the entire network (Hanneman and Riddle, 2005). A popular algorithm, based on the eigenvector of a network's adjacency matrix, is the Google PageRank.

Even though developed for determining the relative importance of a web page compared to all other web pages based on its link structure (Brin and Page, 1998), the PageRank has proven suitable for many other applications like key user identification, word sense disambiguation, or journal ranking (Chen and Chen, 2011; Heidemann et al., 2010; Mihalcea et al., 2004). The original PageRank algorithm as published by Brin and Page (1998) is shown in Formula (1).

$$PR(i) = c \cdot \sum_{j \in I_i} \frac{PR(j)}{|O_j|} \tag{1}$$

The PageRank rises with the number of links that point to node i. The higher the value of $PR(i)$ compared to the PageRank of all other nodes, the more central node i is in the network. The variable c is a constant used for normalization such that the sum of the ranks of all web pages is constant. The set I_i represents the links pointing to node i, and $|O_j|$ represents the number of outgoing links from node j. The PageRank of node i can be interpreted as follows: For each incoming link, node i receives a share of the PageRank from the respective source node j. The share of its PageRank that node j gives to node i depends on how many links leave node j in total. As the PageRank has a recursive form, Brin and Page introduced the concept of the random surfer to solve the underlying eigenvector problem, where each node receives an initial PageRank of $1/n$ (Brin and Page, 1998). The idea is that a surfer travels through the network using the link structure. Each time the random surfer reaches a node, he randomly chooses one of the outgoing links with an equal probability and follows that link to the next node. Those nodes that the random surfer reaches more often are more central in the network. One drawback of the random surfer model is the problem of isolated networks, i.e., the random surfer cannot reach all nodes if the network consists of isolated sub-networks. Moreover, the random surfer can get stuck in nodes that only have incoming links. To address both drawbacks, the random surfer, at certain times, chooses not to follow the link structure, but to teleport to a random node in the network (Langville and Meyer, 2011). As for teleportation, the probability of reaching a node is equal, i.e., $1/n$, for all nodes independent from their interconnectedness. The question that remains is when the random surfer chooses to follow the link structure as opposed to teleporting. As a solution, the event of following the link structure gets assigned the probability d, whereas the probability of the teleportation is $(1-d)$. So, the teleportation factor $(1-d)\cdot 1/n$ represents the weight of each node without considering the link structure and no node can have a PageRank lower than this value. The probability d indicates which fraction of the PageRank stems from the link structure. When d converges to 1, PageRanks become very volatile to changes in the network structure. High values of d also increase the risk of rank sinks, i.e., nodes without outgoing links concentrate the weight whereas other nodes are ranked disproportionally low. By application on web pages, a d value of 0.85 has been identified as reasonable for addressing the trade-off of either not considering the interconnectedness enough or ending with a very volatile result (Langville and Meyer, 2011). These adjustments lead to the PageRank shown in Formula (2).

$$PR(i) = (1-d)\cdot\frac{1}{n} + d\cdot\sum_{j\in I_i}\frac{PR(j)}{|O_j|} \tag{2}$$

As mentioned, node i receives weight from node j if node j points to node i. The transferred weight depends on how many nodes leave node j, assigning an equal weight to each link. One can easily imagine that weighting all outgoing links equally is not always appropriate. In the case of web pages, for instance, the probability of a surfer following a distinct link depends on the anchor text of the link or on how prominent the link is placed. For that reason, an early adjustments to the PageRank was to give links individual weights (Langville and Meyer, 2011). The weight of the link that points from node j to node i is w_{ji}. Moreover, the probability of reaching an arbitrary node in the event of teleportation was previously described to be the same for each node in the network. However, in one of their early publications, Brin and Page (1998) already mention the possibility of customizing this probability. The only restriction is that each weight is from the interval [0; 1] and that the weights sum up to 1, since they are supposed to be probabilities. Therefore, each node can get assigned an individual weight k_i proportional to the weights of all nodes in the network (Langville and Meyer, 2011). The consideration of individual weights for nodes and links leads to Formula (3), which also serves as foundation of our PPR algorithm.

$$PR(i) = (1-d)\cdot\frac{k_i}{\sum_{p=1}^{n} k_p} + d\cdot\sum_{j\in I_i}\frac{PR(j)\cdot w_{ji}}{\sum_{k\in O_j} w_{jk}} \tag{3}$$

3. The ProcessPageRank

3.1. Translating Business Process Architectures into Process Networks

Building on the Google PageRank, the PPR algorithm requires a network with nodes and edges as input. Such a network can be derived from a BPA. Below, we address all components of a BPA, translate them into elements of a process network, specify their notation, and indicate which additional information is needed to apply the PPR algorithm Figure 1 shows a collection of interconnected processes as they are depicted in a BPA following the ArchiMate notation and how they are represented as a process network (Dijkman et al., 2014).

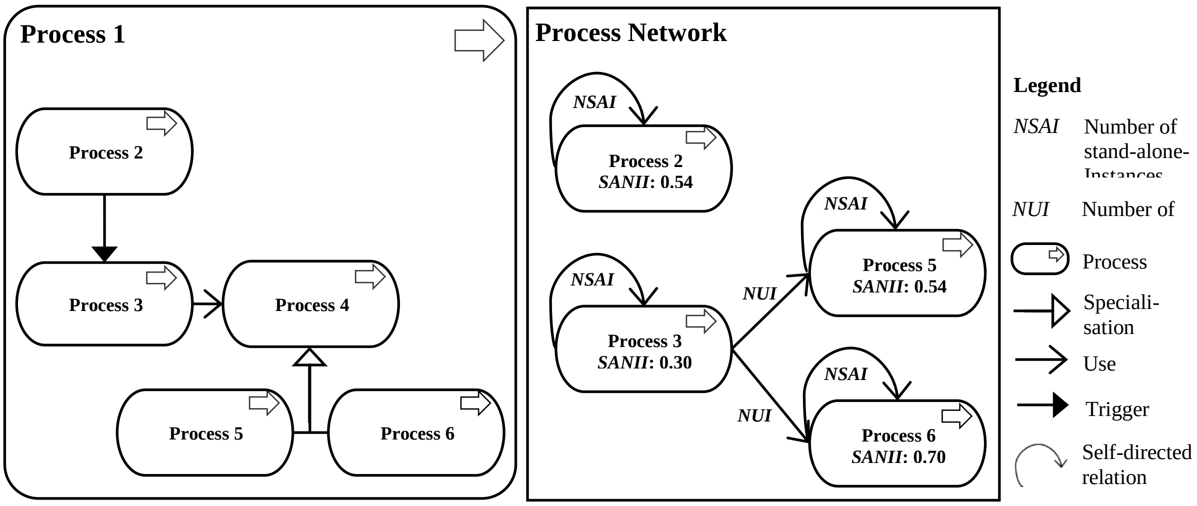


Figure 1. Example of a BPA (left) and a corresponding process network (right)

As a first step, we define each process of the BPA as a node in the process network. For a better understanding, we refer to each node in the process network as process. All processes from the BPA must be included in the process network. We assume that each process is measured in terms of its stand-alone need for improvement, e.g., according to the dimensions of the Devil's Quadrangle (Reijers and Liman Mansar, 2005). Each process has a stand-alone need for improvement index ($SANII$). The $SANII$ can take values from the interval [0; 1], where 0 indicates that the process does not need to be improved and 1 represents the highest possible stand-alone need for improvement. We refrain from further elaborating on how to build such an index and assume that the $SANII$ condenses information related to typical dimensions of process performance. Other important indicators are economic benefits and the contribution to a company's market position or innovation potential. One possible technique for building such an index is the Analytical Hierarchy Process, which has already been used for process redesign (Liman Mansar et al., 2009). Other methods from multi-criteria decision analysis include Techniques for Order Preference Similarity to Ideal Solution (Hwang and Yoon, 1981) or

Multiple Attribute Utility Theory (Dyer, 2005). Furthermore, the $SANII$ must reflect the number of instances of a process in order to be able to differentiate between processes that perform equally well, but one is executed more often than the other. We assume that the $SANII$ of all processes can be compared.

As a second step, the relations among the processes as modelled in the BPA must be transferred to the process network. As for decomposition relations, either the decomposed process is modelled as a single process or all its component processes are modelled in the process network, depending on the intended level of granularity. In case of specialisation relations, we assume that all relations regarding the super-process hold true for each sub-process, which is why we only include sub-processes in the process network. Since the decomposition and specialisation relations from the BPA are more of a structural nature, we do not consider them explicitly in the process network (Figure 1). Use relations among the processes from the BPA are directly transferred to the process network. Each use relation is modelled in terms of a directed edge originating from the using process pointing to the used process. Because a process may use another process several times within a single instance, each use relation is assigned a weight that represents the number of instances a process is used by the other one. We refer to this weight as the number of use instances (NUI). Due to their asynchronous communication property, the trigger relations from the BPA need not be directly transferred to the process network. Instead, all ingoing trigger relations of a distinct process are mapped to a self-directed relation of that process in the process network. The self-directed relation is assigned a weight that represents the number of all instances where the process is executed without using any other processes, i.e., where the process runs without its output being relevant for any other process instance, also including the number of related triggered instances. We refer to this weight as the number of stand-alone instances ($NSAI$). As one process may use different processes several times in the same instance, the weight of the self-directed edge does not necessarily equal the difference between the number of all instances and the weights of all outgoing use relations.

3.2. Rationality Postulates

To ensure that process prioritization decisions based on the PPR algorithm are rational, we define rationality postulates that the algorithm must not violate. Each rationality postulate is a concrete prioritization rule derived from the PageRank characteristics and the high-level requirements from above.

The first rationality postulate takes on the process perspective. In line with high-level requirement (R.1), process prioritization decisions must account for the individual performance of the processes under investigation. A process that ceteris paribus performs worse than another process must be ranked higher in a need for improvement ranking. Figuratively speaking, if two processes have the same interconnectedness, i.e., the same relations to the same processes with the same weights and their self-directed relations have the same weights, but one process performs worse, the process with the worse performance must be ranked higher. With the performance of a single process from the process network being reflected by the $SANII$, we postulate:

1. For any two processes from the process network one of which, ceteris paribus, has a higher $SANII$, the network-adjusted need for improvement of this process must exceed the network-adjusted need for improvement of the process with the lower $SANII$.

In line with high-level requirement (R.2), the relations among the processes from the process network must be considered when prioritizing processes. If a process uses another process from the process network, the used process must be ranked higher because it is responsible for its own output and that of the using process. As a result, the using process also benefits from an improvement of the used process. In contrast, if a process depends on the output of another process, its improvement does not affect the used process. Therefore, it is rational that the using process loses an amount of its importance considering the number and intensity of use relations to other processes within the process network. We postulate:

2. For any two processes from the process network one of which, ceteris paribus, …
   I. …is used by an additional process or has a higher NUI for at least one of the ingoing use relations, the network-adjusted need for improvement of this process must exceed the network-adjusted need for improvement of the other process.
   II. …uses an additional process or has a higher NUI for at least one of the outgoing use relations, the network-adjusted need for improvement of this process must be smaller than the network-adjusted need for improvement of the other process.

If the $SANII$ of two processes are equal, rationality postulate (P.II) assures that the PPR algorithm considers the interconnectedness of the processes from the process network. The more frequently a distinct process is used by other processes, the higher is its ranking because more processes depend on the output of this process. Postulate (P.II) also holds true for transitive use relations as the effects of improving a used process cascades to each directly and transitively using process. A simple example is an improvement project that decreases the cycle time of a process and the stand-alone need for improvement of this process. The reduced time of the improved process decreases the time a using process has to wait for the output of the improved process, which in turn most certainly positively affects the cycle time of any process that uses this intermediate process. Therefore, we postulate:

3. For any two processes from the process network, which are both used by other (different) processes, the network-adjusted need for improvement of the process that is used by the process with the higher network-adjusted need for improvement must ceteris paribus exceed the network-adjusted need for improvement of the other process

3.3. Adjustments to the Google PageRank

The high-level requirements introduced above regarding process prioritization decisions set the scope of the PPR algorithm. Therefore, the algorithm must integrate the stand-alone need for improvement of the processes under consideration with their interconnectedness from the process network. The Google PageRank seemed to be applicable to this problem as it integrates node weights and edge weights into a single index. Before it can be applied to process networks, the Google PageRank must be adjusted.

In section 2.1, we introduced the weighted PageRank algorithm, which can deal with individual weights of the edges between any two nodes in the network. Another extension of the PageRank enables using individual node weights (Brin and Page, 1998). The process network introduced in section 3.1 contains individual parameters for the processes as nodes as well as for the use and self-directed relations as directed edges. To take all parameters of the process network into account, we base the PPR algorithm on the most sophisticated version of the PageRank.

As described in the rationality postulates, a process should receive the more weight, the more it is used by other processes. Thus, the NUI and the $NSAI$ must be included in the algorithm. The first parameter we adjust is the edge weight in the PageRank formula w_{ji} to include the NUI as well as the $NSAI$. As previously described, the weight w_{ji} is used to control the relative importance of edges in the network. In line with the random surfer concept, it determines the relative probability for using a distinct outgoing edge of a distinct node in the event that the random surfer uses the network structure. Consequently, if an edge has a higher weight w_{ji}, more weight is transferred via that edge than via an edge with a lower w_{ji} coming from the same node. In our process network, the weight of a relation can represent the amount of use instances if the relation points from one process to another process. Otherwise, in case of a self-directed relation, the weights represent the amount of instances where the process does not use any other process. Using the weight of the use and self-directed relation as w_{ji} in the PageRank formula ensures two things: First, if a process uses two other processes, but one of them more often than the other, it transfers more weight to the process it uses more often since the weight of the use relation is higher. Second, the process does not transfer weight at times when it is executed without using other processes. Since the weight of the self-directed relation represents the number of instances where a process is executed without using another process and the relation points to the process from which it originated, no weight is transferred to another process. Figuratively speaking, if the random surfer chose the self-directed relation while traveling through the process network, he would end up at the same process where he started. Therefore, he does not take any weight to another process in case of choosing the self-directed relation.

Up to this point, a process transfers weight to other processes only according to the use relations. This circumstance implies that processes, which are used by the same process equally often, receive the same weight. As described in our rationality postulates above, the positive effect of improving a distinct used process on a distinct using process also depends on how high the stand-alone need for improvement of the used process was before. This is based on the following idea: Consider process i uses another process j. The higher the $SANII$ of process j, the higher the effect on process i and, therefore, the higher the network-adjusted need for improvement of process j. For example, if process i uses process j and the cycle time is the only indicator condensed in the $SANII$, the network-adjusted need for improvement of process j rises with a rising cycle time of process j, because i has to wait for j to finish. Hence, the higher the $SANII$ of the used process j, the more important it is for process i that process j is improved first. To be improved first, process j needs to rise in the ranking. Since this is in the interest of process i, it should consequently transfer the more weight to process j, the higher the $SANII$ of process j. Therefore, for the calculation of w_{ji}, the $SANII$ of process j must be included.

To integrate both effects just described into the weight w_{ji}, we multiply the NUI and the $NSAI$ with the $SANII$ of the node a relation points to. We refer to the $SANII$ of a process i as $SANII_i$ and to the NUI of a relation from process j to process i as NUI_{ji}. For better legibility, we refer to the $NSAI$ of a process i as NUI_{ji} with $i = j$. These adjustments result in Formula (4).

$$PPR(i) = \frac{1}{n} \cdot (1 - d) + d \cdot \sum_{j \in I_i} PPR(j) \cdot \frac{NUI_{ji} \cdot SANII_i}{\sum_{k \in O_j} NUI_{jk} \cdot SANII_k} \tag{4}$$

The second adjustment addresses the teleportation factor. As previously stated, this factor assigns each node an initial teleportation probability according to the random surfer model. It is equal for all nodes in the original model, but the extended model allows individual node weights. If one used the original form of the PageRank formula, where each node gets assigned the same node weight, isolated nodes without any ingoing or outgoing edges from or to other nodes end up being ranked equally. Moreover, it significantly influences the amount of weight that can be transferred away from the node (remember the recursiveness of the PageRank algorithm). To overcome this issue, we use the relative $SANII$ of a process as individual node weight. To do so, we scale the $SANII$ of a distinct process by the sum of the $SANII$ of all processes in the network to meet the requirements of the PageRank algorithm. This way, isolated processes get ranked according to their $SANII$ values and processes with a high $SANII$ value can transfer more weight to other processes. Integrating the relative $SANII$ as individual node weight into Formula (4) results in the final PPR algorithm, which is shown in Formula (5).

$$PPR(i) = \frac{SANII_i}{\sum_{j=1}^{n} SANII_j} \cdot (1-d) + d \cdot \sum_{j \in I_i} PPR(j) \cdot \frac{NUI_{ji} \cdot SANII_i}{\sum_{k \in O_j} NUI_{jk} \cdot SANII_k} \quad (5)$$

Note that in addition to the adjustments to the formula, one also has to choose an appropriate value for the parameter d from the interval $[0; 1]$. As previously stated, d is set to 0.85 when ranking web pages (Langville and Meyer, 2004). The interpretation in the random surfer model is that the surfer uses a link from the current web page to get to the next web page with a probability of 0.85 as opposed to the case in which he teleports to a random web page within the network with a probability of 0.15. In case of the PPR, the parameter d balances the effects of a process' $SANII$ and the network structure on the ranking. Thus, d must be chosen carefully. If d is set to 0, the process network structure is not taken into account at all and the processes are ordered according to their $SANII$ values. If d is chosen very high, the network structure is considered to a great extent compared to the $SANII$. This would imply that the interconnectedness of a process has a much larger influence on its performance as the stand-alone criteria. To better understand the effect of a concrete d value, we analyse this parameter in detail in section 4.

4. Demonstration

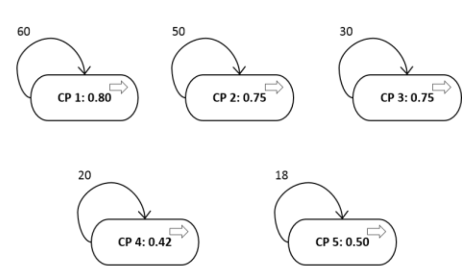
For the demonstration, we implemented a software prototype that can handle arbitrary process networks. We then applied the prototype to five archetypical cases and interpreted the PPR results for each case. Finally, we conducted a cross-case analysis to highlight differences among the single cases and to discuss the PPR algorithm against the high-level requirements and rationality postulates from above.

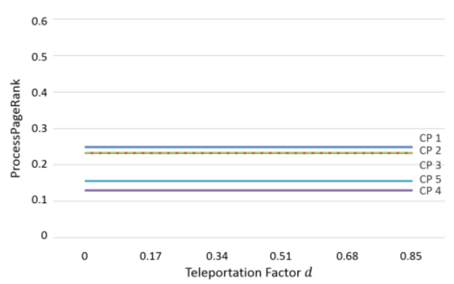
4.1. Single-Case Analysis

In the single case analysis, we apply the PPR to five cases each of which covers a distinct process network archetype. When choosing these cases, we had to consider four parameters, i.e., the stand-alone need for improvement as well as the ingoing, outgoing, and self-directed use relations of each process. The cases below cover changes in all these parameters. We deliberately constructed the cases presented here as small as possible to make the results more comprehensible. However, the prototype can also handle very large process networks. We simulated cases with up to 100,000 processes and up to 100,000 use relations per process.

Each case starts by briefly describing an exemplary situation where the case may occur in the real world. For illustrative purposes, we distinguish core processes (CP) and support processes (SP). We investigate how the PPR results change when the weighting between the $SANII$ and the process network is changed. We therefore analyse the PPR results subject to different d values from the interval [0.0000; 0.8500]. The PPR results are then interpreted for 0.3750 as an exemplary d value. This value appeared appropriate, as it assigns more weight to the stand-alone need for improvement, while still considering interconnectedness. Identifying a generally valid d is not the objective of this paper (see section 4.2 for a detailed discussion). For each case, we provide a table that shows the process network, a diagram of the PPR results as a function of d as well as the PPR results and the robustness interval for d = 0.3750. The robustness interval is the asymmetric interval around a chosen d value in which ranking not change.

4.1.1. Isolated Core Processes





Ranking for d=0.3750:

1.	CP 1	0.2485
2.	CP 2	0.2329
2.	CP 3	0.2329
4.	CP 5	0.1553
5.	CP 4	0.1304

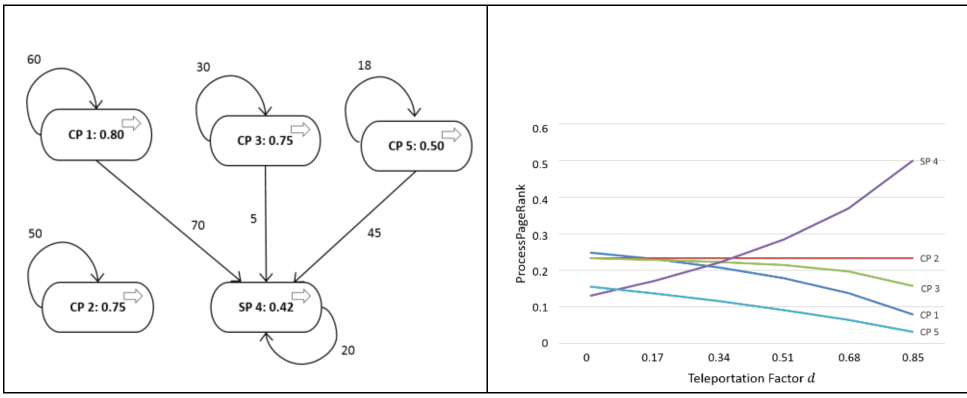
Robust interval for d:

$d \in$ [0.0000; 0.8500]

Table 1. Isolated Core Processes (Case 1)

In this case, we consider isolated core processes without use relations. An example would be a facility manager who performs tasks like mowing the lawn, clearing snow, or repairing something in the house. In the related process network, all processes only have a self-directed edge. As there are no use relations, the PPR results are independent of d. Consequently, the ranking only depends on the $SANII$ of the processes. The ranking therefore is perfectly robust in a trivial sense. As this case leads to the same PPR results as any other case where existing relations are ignored, it can serve as a benchmark for all following cases. We therefore use the same $SANII$ values in all cases.

4.1.2. Isolated Core Processes use one Support Process



Ranking for d=0.3750:

1.	SP 4	0.2329
2.	CP 2	0.2328
3.	CP 3	0.2216
4.	CP 1	0.2023
5.	CP 5	0.1104

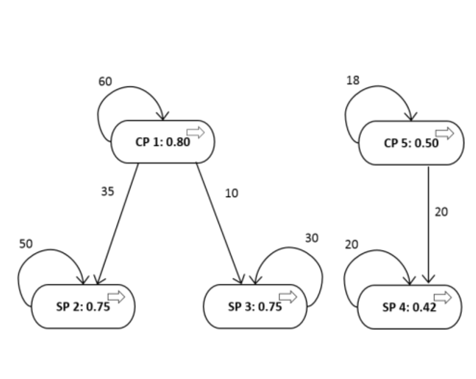
Robust interval for d:

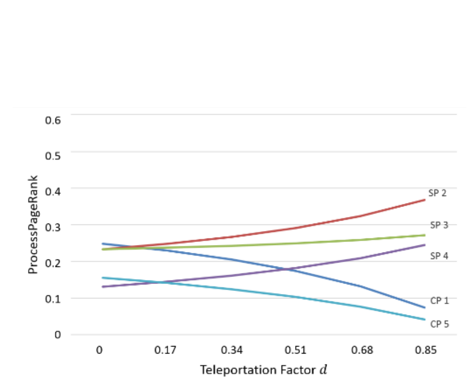
$d \in [0.3457; 0.3755]$

Table 2. Isolated Core Processes use one Support Process (Case 2)

In this case, we consider one support process used by many core processes. This setting can occur in a bank where core processes like opening an account or granting a loan use a support process that checks the client's credit history. The PPR value of the support process rises steeply with an increasing d as it receives weight from almost all core processes, while the PPR results of the using core processes drop. The PPR value of CP 2 is independent from d as it is not related to any other process. Comparing the core processes CP 2 and CP 3 shows that, even though both processes have the same $SANII$, the rank of CP 3 drops below the rank of CP 2 with a rising d as it uses the support process and therefore transfers weight to it. Moreover, comparing the core processes CP 3 and CP 1 reveals that, even though CP 1 has a higher $SANII$ and both use the support process, their ranks develop differently and even switch at $d = 0.1881$. The reason is that the proportion of the instances where CP 1 uses the support process as opposed to being executed stand-alone is far greater than the corresponding proportion of CP 3. Therefore, CP 1 gives a higher proportion of its weight to the support processes than CP 3. The support process is already ranked first for a d value of 0.3750 because it receives weight of three other processes. For a d value of 0.3750, the robustness interval is [0.3457; 0.3755]. This interval is rather small and suggests that a decision-maker should take great care when choosing his teleportation factor (see section 4.2 for details).

4.1.3. Isolated Core Processes use Isolated Support Processes





Ranking for d=0.3750:

1.	SP 2	0.2713
2.	SP 3	0.2439
3.	CP 1	0.1991
4.	SP 4	0.1653
5.	CP 5	0.1204

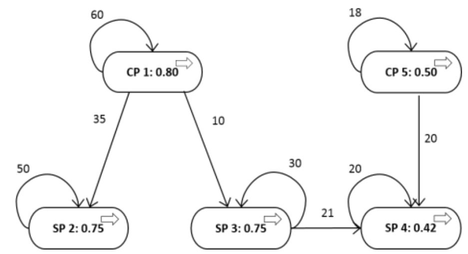
Robust interval for d:

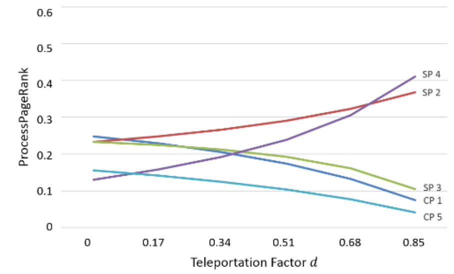
$d \in [0.1527; 0.4849]$

Table 3. Isolated Core Processes use Isolated Support Processes (Case 3)

In this case, the process network consists of isolated sub-networks where each core process uses one or more support processes. This process network may occur in a post-merger situation where the processes of the merged companies have not been integrated yet. Both companies virtually run stand-alone, which is why their core and support processes are not connected. What is interesting in this case is the development of the PPR results of the support processes SP 2 and SP 3. Even though both processes have the same $SANII$ and an ingoing use relation from the core process CP 1, the PPR value of SP 2 rises faster than that of SP 3. The reason is that SP 2 is used much more often by CP 1 than SP 3. CP 1 thus transfers more weight to SP 2 than to SP 3. This case also illustrates the ability of the PPR algorithm to rank processes even if they are located in isolated sub-networks (enabled by the teleportation actions of the random surfer). For d = 0.3750, support process SP 2 is ranked first as it has a fairly high $SANII$ and receives additional weight from CP 1. Moreover, support process SP 4 is ranked higher than core process CP 5 because the weight transferred from CP 5 to SP 4 overcompensates for the lower $SANII$ of SP 4. The ranking is robust in the interval [0.1527; 0.4849], which can be considered to be very high.

4.1.4. *Isolated Core Processes use unidirectionally interacting Support Processes*





Ranking for d=0.3750:

1.	SP 2	0.2713
2.	SP 3	0.2086
3.	CP 4	0.2006
4.	SP 1	0.1991
5.	CP 5	0.1240

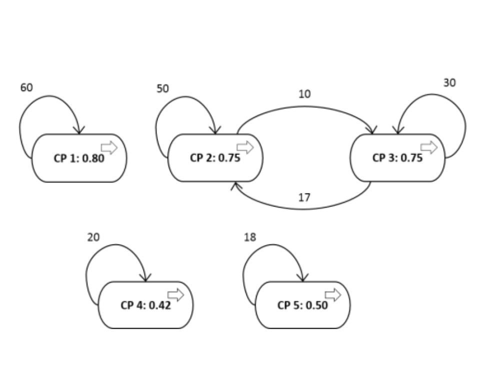
Robust interval for d:

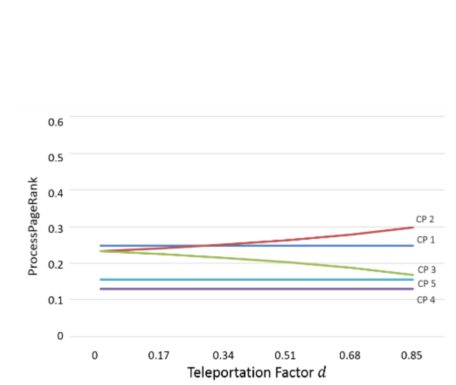
$d \in [0.3717; 0.3979]$

Table 4. Isolated Core Processes use unidirectionally interacting Support Processes (Case 4)

This case is very close to the previous one. The only difference is that two of the support processes that were previously located in isolated sub-networks are now unidirectionally connected via an use relation. We still consider a company in a post-merger situation. This time, the company has already integrated one support process from one subsidiary into the BPA of the other subsidiary (i.e., a shared accounting support process). In this case, the PPR value of support process SP 4 rises very fast as it is used by two processes, i.e., SP 3 and CP 5, of which one has a pretty high $SANII$. Moreover, SP 3 is in turn used by core process CP 1. Even though SP 3 has an ingoing use relation, its PPR value drops. The reason is that SP 3 has both an ingoing and an outgoing use relation. Since the weight of the outgoing use relation is higher than that of the ingoing use relation, SP 3 transfers more weight to SP 4 than it receives from CP 1. For d = 0.3750, the support process SP 2 is ranked first even though SP 4 is used by two other processes of which one is also used by another process. However, the fact that SP 4 is used more often than SP 2 cannot overcompensate for the fact that the $SANII$ of SP 2 is almost twice as high as that of SP 4. The PPR results are volatile for small d values and robust in the interval [0.3717; 0.3979] for a chosen d of 0.3750. The reason is that the ranking of SP 4, the process with the lowest $SANII$, rises while the PPR results of the processes CP 1, SP 3, and CP 5 decrease. When d increases, SP 4 switches ranks with the other processes. After this calibration, the only change in the PPR results comes from SP 4. Since the PPR value of SP 2 grows with a raising d, it takes very high d values for the rank of SP 4 to excel that of SP 2.

4.1.5. Bidirectionally interacting Core Processes





Ranking for d=0.3750:

1.	CP 2	0.2536
2.	CP 1	0.2485
3.	CP 3	0.2122
4.	CP 5	0.1553
5.	CP 4	0.1304

Robust interval for d:

$d \in [0.2944; 0.8500]$

Table 5. Bidirectionally interacting Core Processes (Case 5)

In this case, core processes CP 2 and CP 3 use one another. All other processes operate stand-alone. The process network may represent a cross-selling situation, which could again turn up in a bank. Imagine a customer wants to open an account. The employee may suggest also opening a share deposit account. In such cases, process i, generally speaking, cannot use process j, while process j uses process i in the same instance. This implies for each process i, with an outgoing and an ingoing use relation to and from process j, that the number of instances where process i is executed without being used by process j must at least equal the amount of instances in which process i uses process j. The PPR value of CP 2 rises, while that of CP 3 decreases, even though both processes seem to have similar use relations. This circumstance is rooted in the different weights of the relations. Since the relative amount of instances in which CP 2 uses CP 3 as opposed to being executed without using another process is much smaller than that of CP 3, CP 2 transfers much less weight than CP 3. A changing d has no influence on the other processes since they have no relations with one another. For a d value of 0.3750, CP 2 is already ranked first. CP 1 is ranked second as it has a very high $SANII$ and does not give away any weight. All other processes stay on the same rank because the only other process that reacts to a rising d is CP 3. As there is only one change in the ranking, it is fairly robust. The ranking does not change beyond a d of 0.2944.

4.2. **Cross-Case Analysis**

In the single-case analysis, we discussed five process network archetypes to show how the PPR algorithm works in different situations. We now consider the effects of all cases and discuss them against the rationality postulates derived from the high-level requirements above.

Rationality postulate 1 requires processes to be ranked according to their $SANII$ if they only differ in their $SANII$. This particularly applies to isolated processes such as in the first case.

There, all processes only have a self-directed relation and, independent of d, are ranked according to their descending $SANII$. Another example is the fifth case where the processes CP 1, CP 4, and CP 5 have the same PPR results independent of d. However, their rankings change because the PPR values of the other processes change. This behaviour can also be found in the second case for process CP 2. This shows that, even in case of isolated processes, the ranking must consider the interconnectedness of all processes.

As stated in rationality postulate (P.II), the interconnectedness of a process is decisive for its ranking. Regarding ingoing use relations (P.II.0 the positive effect on the network-adjusted need for improvement becomes particularly apparent by comparing process SP 4 in the second and third case. In the second case, SP 4 has a higher NUI for the ingoing use relation it shares with SP 4 from the third case, and it has more ingoing use relations. As a result, the network-adjusted need for improvement rises much faster in the second case than in the third case. This effect can also be seen for processes SP 2 and SP 3 in the third case. Even though SP 2 and SP 3 have the same $SANII$ and have one ingoing use relation coming from the same process, the PPR value of SP 2 rises faster. This behaviour is justified by the higher NUI for the ingoing use relation of SP 2. As stated in rationality postulate (P.II.0, outgoing use relations negatively affect the network-adjusted need for improvement. Regarding the second case, one can see that the PPR value of process CP 3 stays constant while that of process CP 2 drops, even though both processes have the same $SANII$. The reason is that CP 3 has an outgoing use relation while CP 2 is isolated. The negative effect of outgoing relations is even stronger for processes CP 1 and CP 3. Even though CP 1 has the higher $SANII$, its network-adjusted need for improvement is lower for d values greater than 0.5740 since it transfers more weight to SP 4. In the fourth case, the support process SP 3 brings together the effects of rationality postulate (P.II.a) and (P.II.b), having both an ingoing and an outgoing use relation. As the weight given to SP 4 through the outgoing use relation overcompensates for the weight received through the ingoing use relation from CP 1, the PPR value of SP 3 drops with an increasing d. Regarding rationality postulate (P.II), decision-makers must be aware that not only the relations among processes must be carefully modelled, but also the weights of these relations as they can heavily influence the PPR results and thus the process prioritization decisions.

Rationality postulate (P.III) states that if a process uses another process, the transferred weight does not only depend on the stand-alone need for improvement of the using process but on the network-adjusted need for improvement. This effect is particularly evident in the fourth case where the PPR value of process SP 4 rises much faster than in the third case. The reason is that

SP 4 has an additional ingoing use relation from SP 3. Whereas, in the fourth case, the PPR value of process SP 3 drops, it rises in the third case due to the ingoing use relation from CP 1. This shows that the fast rise of SP 4's PPR value in the fourth case also depends on the use relation from CP 1 to SP 3. The importance of the network-adjusted need for improvement of a process for the PPR results of related processes shows that not only direct, but also transitive relations are important. Another example for this behaviour are processes CP 2 and CP 3 in the fifth case. Even though both processes have the same $SANII$, the PPR value of CP 2 rises, while that of CP 3 drops. As a result, decision-makers must not prioritize processes based only on parts of a BPA, as such decisions are usually biased.

As seen in the single-case analysis, the interconnectedness of processes heavily affects process prioritization decisions. In the preceding cross-case analysis, we discussed that these effects may largely differ depending on the characteristics of the interconnectedness without violating the rationality postulates. As an additional factor, we evaluate the parameter d whose choice is particularly important in two situations. First, if a process that features both a low $SANII$ and either very many ingoing use relations or at least one ingoing use relation with a high NUI (such as process SP 4 in the second and forth case), the PPR value of that process rises very steeply for a rising d and therefore causes many changes in the ranking. Second, if there is a process that features a high $SANII$ and either very many outgoing use relations or at least one outgoing use relation with a high NUI (such as process CP 1 in the second, third, and fourth case), the PPR value of this process drops very steeply for rising values for d and therefore causes many changes in the ranking. In sum, if the process network contains at least one such process the previously defined robustness interval for d will most likely be rather small, implying that the ranking might change significantly for small changes in d. Therefore, when the results show a small robustness interval for the chosen d value, decision-makers are advised to invest in identifying a more robust d value that still balances the stand-alone need for improvement and the effect of the process network in an appropriate manner. The diagrams included in the tables above assist in identifying such d values. Note that, as already mentioned above, identifying a generally valid d is not the objective of this paper. However, applying the PPR algorithm to a process network helps identify major problems rather easily. The results also show which processes should be improved to leverage the effect on other processes. These processes can then undergo an in-depth analysis using methods with a single-process perspective.

5. Conclusion

In this paper, we investigated the question how processes can be prioritized considering both their individual need for improvement and interconnectedness. Building on the seminal work of Brin and Page (1998), we proposed the PPR algorithm that ranks processes according to their network-adjusted need for improvement. The PPR algorithm requires a process network and some individual performance indicators as inputs. The process network can be derived from a business process architecture (BPA) while dealing with common relation types, i.e., trigger, use, specialisation, and decomposition. The performance indicators include the stand-alone need for improvement, the number of instances where the process is executed without using any other process, and the number of instances where the process uses other processes. On this foundation, we derived rationality postulates for process prioritization decisions and adapted the original PageRank algorithm accordingly. For demonstration purposes, we implemented a software prototype and applied the PPR algorithm to five process network archetypes. We showed that process prioritization decisions require the processes' stand-alone need for improvement, their interconnectedness, and the intensity of the relations among one another to be considered.

The PPR algorithm is beset with limitations that should be addressed in future research. First, we assumed that the stand-alone need for improvement index is a single performance indicator, neglecting that process performance is a multi-dimensional construct. Future research should analyse how to build a stand-alone need for improvement index that reflects multiple dimensions of process performance. The index should also account for economic benefits to be more helpful for practitioners (Buhl et al. 2011). Second, the PPR algorithm, as developed so far, only focuses on the need for improvement and blinds out the effects of improvement projects. Such projects, however, may change the ranking. Besides the effects on single processes, it would be interesting to analyse how strongly improvement projects impact other processes and cascade through the process network. Third, the PPR algorithm would benefit from considering an economic perspective to process improvement. In real-world settings, improvement projects typically are differently expensive and have different effects on the processes' need for improvement. Hence, we encourage future research to investigate how an economic perspective can be integrated. Fourth, in line with the analytical nature of this paper, we illustrated the properties of the PPR algorithm by means of five process network archetypes and a cross-case analysis. Nevertheless, it would further benefit from real-world case studies.

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Research Paper 5: Prioritization of Interconnected Processes – A PageRank-based Approach

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Abstract: Deciding which business processes to improve is a challenge of all organizations. The literature on business process management (BPM) offers several approaches that support process prioritization. Sharing the individual process as unit of analysis, these approaches determine the processes' need for improvement mostly based on performance indicators, but neglect how processes are interconnected. So far, the interconnectedness of processes is only captured for descriptive purposes in process model repositories and business process architectures. Prioritizing processes without catering for their interconnectedness, however, biases process prioritization decisions and causes a misallocation of corporate funds. What is missing are process prioritization approaches that consider both the processes' individual need for improvement and interconnectedness. To address this research problem, we propose the *ProcessPageRank* (*PPR*) as our main contribution. The *PPR* prioritizes processes of a given business process architecture by ranking them according to their network-adjusted need for improvement. The *PPR* builds on knowledge from process performance management, business process architectures, and network analysis – particularly the Google PageRank. As for evaluation, we validated the *PPR*'s design specification against empirically validated and theory-backed design propositions. We also instantiated the *PPR*'s design specification as a software prototype and applied the prototype to a real-world business process architecture.

Keywords: Business Process Management, Network Analysis, PageRank, Process Architecture, Process Interconnectedness, Process Network, Process Prioritization

1. Introduction

Process orientation is an acknowledged paradigm of organizational design and a source of corporate performance (Dumas et al. 2013; Kohlbacher and Reijers 2013). Business Process Management (BPM) thus receives continued interest from industry and academia, supporting organizations to achieve operational excellence and capitalize on improvement opportunities (Rosemann and vom Brocke 2015; van der Aalst 2013; vom Brocke et al. 2011). Process improvement has been a top priority of process decision-makers for over a decade (Harmon and Wolf 2014). Despite the efforts put into process improvement, about 60% of related projects are reported to fail (Chakravorty 2010; Ohlsson et al. 2014). One key reason of this failure rate is ineffective process prioritization (Olding and Rosser 2007).

The BPM literature offers several approaches that support process prioritization. Extant approaches are split in two groups, i.e., performance-based and non-performance-based approaches. Performance-based approaches quantify the actual and target performance of processes, derive the related need for improvement, and rank processes based on their need for improvement (Bandara et al. 2015; Dumas et al. 2013; Leyer et al. 2015). A process' need for improvement is typically quantified via performance indicators (e.g., time, cost, flexibility, or quality), whose realizations are eventually merged into integrated performance indicators (e.g., net present value or stakeholder service gap perception) (Bolsinger 2014; Hanafizadeh et al. 2008; Reijers and Liman Mansar 2005; Shrestha et al. 2015). Non-performance-based approaches rely on criteria such as urgency, strategic importance, process dysfunctionality, difficulty of improvement, or perceived degree of change (Davenport 1993; Hammer and Champy 1993; Hanafizadeh and Osouli 2011). The link between both groups is that the need for improvement operationalizes process dysfunctionality.

Existing process prioritization approaches are subject to criticism. They have been characterized either as too high-level to be useful or as such detailed that the mere identification of critical processes requires significant effort (Bandara et al. 2015). Moreover, all approaches share the individual process as unit of analysis. They neglect whether and how processes are interconnected. Process interconnectedness has so far only been considered for descriptive purposes, e.g., in process model repositories and business process architectures (BPA) (Dijkman et al. 2016; La Rosa et al. 2011; Malinova et al. 2014). It is vital, however, to also account for process interconnectedness for prescriptive purposes, such as process prioritization (Manderscheid et al. 2015). This is for several reasons: First, improving a process affects the performance of other processes if these processes rely on other process' outcome (Leyer et al.

2015). It may be reasonable to prioritize processes with a low stand-alone need for improvement if their outcome is used by many other processes. If process interconnectedness is ignored, prioritization decisions are biased and corporate funds may be allocated inefficiently. Second, neglecting process interconnectedness may entail risks such as downtimes or delayed executions in case of excess demand (Setzer et al. 2010). Beyond BPM-specific reasons, the need for considering interconnectedness as well as for identifying central nodes in networks has been recognized and addressed in many disciplines (e.g., project portfolio management, network analysis, enterprises architecture management) (Landherr et al. 2010; Probst et al. 2013; Winter and Fischer 2007). What is missing are process prioritization approaches that do not only consider the need for improvement of individual processes, but also their interconnectedness. Thus, we analyze the following research question: *How can processes be prioritized based on their individual need for improvement and interconnectedness?*

To address this question, we adopted the design science research (DSR) paradigm (Gregor and Hevner 2013). Our artefact is the *ProcessPageRank* (*PPR*). Belonging to the group of performance-based approaches, the *PPR* assists organizations with prioritizing their processes by ranking them based on their network-adjusted need for improvement. The *PPR* shows characteristics of a model and method (Gregor and Hevner 2013; March and Smith 1995). On the one hand, it includes constructs and relations, capturing the problem of interconnectedness-aware process prioritization (e.g., process networks, dependence intensity). On the other, the *PPR* specifies how process prioritization activities should be performed in a goal-oriented manner. The *PPR* builds on descriptive knowledge from process performance management and BPA to conceptualize process performance and interconnectedness. To provide decision support, the *PPR* draws from prescriptive knowledge on network analysis. The *PPR* interprets processes as connected nodes and extends the Google PageRank as a popular centrality measure to identify central nodes in process networks. The *PPR* substantially extends our research on process prioritization by further specifying the need for improvement of individual processes considering multiple performance dimensions, substantiating process interconnectedness via dependence intensities, and advancing the evaluation (Lehnert et al., 2015).

This study follows the DSR methodology as per Peffers et al. (2007): In Sect. 2, we provide justificatory knowledge and derive design objectives. Sect. 3 outlines the research method and evaluation strategy. In Sect. 4, we present the *PPR*, including the transformation of BPAs into process networks, the specification of input variables, and the *PPR* algorithm. In Sect. 5, we report on the results of different evaluation activities, before highlighting limitations and opportunities for future research in Sect. 6.

2. Theoretical Background and Design Objectives

2.1. Process Performance Management and Business Process Architectures

BPM is the art and science of overseeing how work is performed to ensure consistent outcomes and take advantage of improvement opportunities (Dumas et al. 2013). It combines knowledge from information technology (IT) and management sciences (Van der Aalst, 2013). From a lifecycle perspective, BPM involves activities such as the identification, definition, modeling, implementation and execution, monitoring, control, and improvement of processes (Recker and Mendling 2016). Dealing with all processes of an organization, BPM offers an infrastructure for effective and efficient work (Harmon 2014). Processes, as BPM's unit of analysis, split into core, support, and management processes (Armistead et al. 1999). Core processes are collections of events, activities, and decision points involving actors and objects leading to valuable outcomes (Dumas et al. 2013). Support processes ensure that core processes continue to function, while management processes plan, organize, monitor, and control corporate activities (Harmon 2014). We focus on core and support processes, referring to both as processes.

To assess processes performance and to estimate the effects of improvement projects, performance indicators are an essential tool (Leyer et al. 2015). In process performance management, the realizations of performance indicators are regularly compared with target values and admissible value ranges (Leyer et al. 2015). Complying with the predominating conceptualization of process performance as a multidimensional construct, performance indicators are grouped according to performance dimensions (Linhart et al. 2015). A popular framework is the Devil's Quadrangle that comprises flexibility, time, cost, and quality as dimensions (Reijers and Liman Mansar 2005). The Devil's Quadrangle is so-named as improving one dimension weakens at least one other, disclosing trade-offs among performance dimensions to be resolved. To prioritize processes, process performance dimensions must be integrated in a way that accounts for trade-offs (Bolsinger 2015; Limam Mansar et al. 2009). Thereby, the related multi-criteria decision problem is reduced to a single-criterion problem, a necessary task in normative analytical modeling and multi-criteria decision analysis (Cohon 2004; Meredith et al. 1989). The result is an integrated performance indicator. Examples for integrated indicators are the value contribution of a process (Buhl et al. 2011), the return on process transformation (vom Brocke and Sonnenberg 2015), the aggregated cash flow deviation from a predefined threshold (Manderscheid et al. 2015), the stakeholder service gap perception by (Shrestha et al. 2015), and the business value score (Bandara et al. 2015).

Processes and their relations are typically modeled as BPA. BPA are structured overviews of an organization's processes and relations, potentially accompanied by guidelines that determine how to organize these processes (Dijkman et al. 2016). The topmost level of a BPA is also known as process map (Malinova et al. 2014). The four most frequent relation types in a BPA are specialization, decomposition, use, and trigger (Dijkman et al. 2016). Specialization relations express that a process is a specialized version of another process, inheriting all characteristics of the super-process. A decomposition expresses that a process is decomposed into multiple sub-processes. Use relations indicate that a process requires the output of another process to continue or complete its execution. That is, the performance of the using process depends, at least in parts, on the performance of the used process (Malone and Crowston 1994). Finally, trigger relations express that a process triggers the execution of another process without having to wait for the output of that process. In contrast to use relations, the performance of the triggering and the triggered processes are independent.

2.2. Network Analysis

In network analysis, centrality measures help determine central nodes in networks. If processes are interpreted as connected nodes, centrality measures help identify central nodes in process networks. With the *PPR* building on an extended Google PageRank, this section introduces the foundations of the PageRank. To better illustrate the PageRank's components, we also outline the eigenvector centrality, which is an immediate conceptual predecessor of the PageRank.

We chose the extended Google PageRank as it is the only centrality measure that integrates all components of process networks, which we introduce in Sect. 4, and that suits the purpose of process prioritization. Neither the simple degree nor the eigenvector centrality cope with node and edge weights. Further, they primarily apply to undirected networks. As process networks are directed networks containing both node and edge weights, only the Katz centrality and the PageRank apply to process prioritization. In the Katz centrality, the weight transferred from one node to another via an outgoing edge does not depend on other outgoing edges of that node. Applying such a reasoning to process networks, processes would always assign the same weight to a used process irrespective of how many other processes it uses. However, if a using process transfers weight to a used process, it is very relevant to consider the characteristics of other use relations of the using process. In addition, the Katz centrality does not allow for adjusting the balance between a process' individual importance and its interconnectedness.

The eigenvector central extends the degree centrality concept, which accounts for a node's direct neighbors, in order to resolve weaknesses of simple centrality measures (Hanneman and

Riddle 2005; Newman 2003). Instead of assigning equal weights for direct neighbors, the eigenvector centrality takes the connectedness of direct neighbors into account. A node ranks higher if it has well-connected, as opposed to sparsely connected, neighbors (Newman 2003). If we define x_i as the eigenvector centrality of a node i, it is higher when the centrality x_j of all nodes j that are direct neighbors is higher. We define $\boldsymbol{A}$ as the adjacency matrix, where a_{ij} is 1, if node i is a direct neighbor of j, and 0 otherwise. Moreover, we define λ as the largest eigenvalue of the adjacency matrix. Based on this, the eigenvector centrality as proposed by Bonacich (1987) is computed as shown in Eq. (1).

$$x_i = \frac{1}{\lambda} \cdot \sum_j (a_{ij} \cdot x_j) \tag{1}$$

The eigenvector centrality serves as foundation for Brin and Page‘s (1998) PageRank. It works well for undirected networks, but has weaknesses when applied to directed networks, including the eigenvector centrality of nodes being 0 in certain constellations. Adding a constant term to a node’s centrality irrespective of its connectedness prevents its centrality from becoming 0 and spreading that value through the network. To balance the constant and the network term, the factor $1/\lambda$ is replaced by the dampening factor d, weighting the network structure and constant terms with d and $(1-d)$, respectively. Another drawback of the eigenvector centrality is that if a node i has an ingoing edge from a node j, the weight that node i receives is the same irrespective of how many outgoing edges j has. Nevertheless, there are many applications where node i’s centrality increases less strongly if node j has more outgoing edges (Brin and Page 1998). Adjusting the effect of one node on other nodes based on the number of outgoing edges can be accomplished by dividing x_j by the number of j’s outgoing edges $|O_j|$. We refer to the set of outgoing edges of a node i as O_i, and to the set of ingoing edges as I_i. These adjustments lead to the PageRank as presented in Eq. (2) (Brin and Page 1998).

$$PR(i) = (1-d)\frac{1}{n} + d \cdot \sum_j \left(a_{ij} \cdot \frac{PR(j)}{|O_j|} \right) = (1-d)\frac{1}{n} + d \cdot \sum_{j \in I_i} \frac{PR(j)}{|O_j|} \tag{2}$$

The PageRank, as shown in Eq. (2), is interpreted as follows: for each ingoing edge, node i receives a share of the PageRank of the respective source node j, which, in turn, depends on how many outgoing edges node j has. The dampening factor d balances the weight between the constant and network terms. With these adjustments, one can prove mathematically that the upper boundary of the interval containing d always equals 1 in case of an undirected network and, even though the mathematical proof does not hold in case of directed networks, in practice it will roughly be of order 1 (Newman 2003). Therefore, d should generally be chosen from interval $[0; 1]$. However, if d converges to 1, PageRank values become highly susceptible to changes in the network structure. High d values increase the risk of rank sinks, i.e., nodes without outgoing edges have higher weight, while other nodes rank disproportionally low. When applying the PageRank to web pages, a d value of 0.85 is deemed reasonable to address this trade-off (Langville and Meyer 2011).

As mentioned, node i receives weight from node j if node j points to node i. This weight is determined based on node j's number of outgoing edges, assigning equal weight to each edge. However, weighting all outgoing edges equally is not always appropriate. In the case of websites, the importance of a distinct edge also depends on the anchor text of the link or on how prominently the link is located. Thus, an early adjustment to the PageRank was to allow individually weighted edges (Langville and Meyer 2011). The weight of an edge that points from node i to node j is denoted as w_{ij}. Moreover, in the initial PageRank, the constant term is initialized with $1/n$. Each node (or webpage respectively) has the same initial weight. However, some nodes are more important than others, irrespective of their connectedness. Thus, Brin and Page (1998) expanded the concept of the constant term by allowing individual constant terms for each node. The only restriction is that each weight is from $[0; 1]$ and that the weights sum up to 1. This expansion is implemented by introducing an individual node weight k_i, which is proportional to the weights of all nodes in the network (Langville and Meyer 2011). The consideration of individual weights for nodes and edges leads to Eq. (3).

$$PR(i) = (1-d) \cdot \frac{k_i}{\sum_{t=1}^{n} k_t} + d \cdot \sum_{j \in I_i} \frac{PR(j) \cdot w_{ji}}{\sum_{k \in O_j} w_{jk}} \tag{3}$$

We rely on the extended PageRank, as shown in Eq. (3), as justificatory knowledge to derive the *PPR* algorithm in sect. 4.3, enabling process prioritization that integrates the processes' individual need for improvement and interconnectedness.

3. Research Method and Evaluation Strategy

To design the *PPR*, we adopted the DSR paradigm by Gregor and Hevner (2013) and followed the DSR methodology as per Peffers et al. (2007). The DSR methodology includes six phases, i.e., problem identification, definition of design objectives, design and development, demonstration, evaluation, and communication. Complying with the *design-evaluate-construct-evaluate* pattern advocated by Sonnenberg and vom Brocke (2012), we did not traverse these phases strictly sequentially, but switched between the design and develop as well as the demonstration and evaluation phases.

As for problem identification, we justified the need for considering the interconnectedness of processes in process prioritization decisions as a valid DSR problem in Sect. 1. We also defined two design objectives drawing from extant knowledge related to process performance and BPA (Sect. 2.1). Both objectives provided guidance in the design and development phase as we operationalized them in terms of design propositions based on prescriptive knowledge on network analysis (Sect. 2.2). The design objectives and related design propositions also helped validate the *PPR*'s design specification in the demonstration and evaluation phase. The design objectives are specified as follows:

(DO.1) *Performance of individual processes*: When prioritizing processes for improvement purposes, the individual performance of these processes must be measured via performance indicators and considered in the resulting ranking.

(DO.2) *Relations among multiple processes*: When prioritizing processes for improvement purposes, the relations among these processes must be considered in the resulting ranking.

In the design and development phase, we conceived the *PPR*'s design specification, building on normative analytical modeling and multi-criteria decision analysis (Cohon 2004; Meredith et al. 1989). We illustrate how to transform BPA into process networks as well as which performance and interconnectedness data must be added to apply the *PPR* (Sect. 4.1). We then show how to determine relevant input parameters, i.e., the process need for improvement index and dependence intensity (Sect. 4.1). We finally derive the *PPR* algorithm as an extension of the Google PageRank in line with theory-backed and empirically validated design propositions (Sect. 4.3).

To demonstrate and evaluate the *PPR*, we adopted the evaluation framework by Sonnenberg and vom Brocke (2012). The framework comprises four activities (EVAL1–EVAL4) to cover the ex-ante/ex-post and the artificial/naturalistic evaluation dimensions (Venable et al. 2012). EVAL1 ensures the identified problem's meaningfulness from an academic and practical viewpoint. With EVAL1 strongly resembling the first phases of Peffers et al.'s (2007) DSR methodology, we do not provide further information here. EVAL2 aims to validate design specifications regarding their alignment with the research problem, real-world fidelity, and understandability. From a naturalistic perspective, we report on an in-depth interview with an expert from a global online retailer. From an artificial perspective, we validated the *PPR*'s design specification by discussing it against design propositions. With the *PPR* being a complex recursive algorithm, we present this discussion in the course of EVAL3. This is where it becomes evident that the *PPR* implements the design propositions. In contrast to other studies, we also validated our design propositions empirically with industrial and academic BPM experts. Regarding EVAL3, which strives for validated instantiations, we implemented the *PPR* as a software prototype. In a previous study, we already applied a prior version of the prototype in a scenario analysis (Lehnert et al. 2015). In the study at hand, we use the prototype to show the *PPR* in action based on a real-world BPA together with an efficiency and a robustness analysis. EVAL4 strives for validating the applicability and usefulness of an artefact's instantiation in naturalistic settings. Although our demonstration builds on a real BPA and draws from our industry experience, it is not a full-fledged real-world case study. The reason is that the *PPR* is very data-intensive, a feature that causes considerable data collection effort in many organizations. In line with the uptake of process-aware information systems and the availability of process logs, we are confident that many organizations will be able to gather high-quality data with reasonable effort in the near future. We get back to this limitation in the conclusion.

4. The ProcessPageRank

4.1. Transformation of Business Process Architectures into Process Networks

The *PPR* prioritizes processes while accounting for their individual need for improvement and interconnectedness. To do so, the *PPR* thus ranks the processes from in a given BPA in line with their network-adjusted proce ss improvement index ($NPNI$). As a prerequisite for the *PPR*'s application, we first transform all components of the given BPA into a process network and enrich the network with additional information (e.g., how often a process uses other processes). Figure on the left shows connected processes as captured in a BPA using the ArchiMate notation (Dijkman et al. 2016). On the right, Figure illustrates the corresponding process network, which is used as input of the *PPR*.

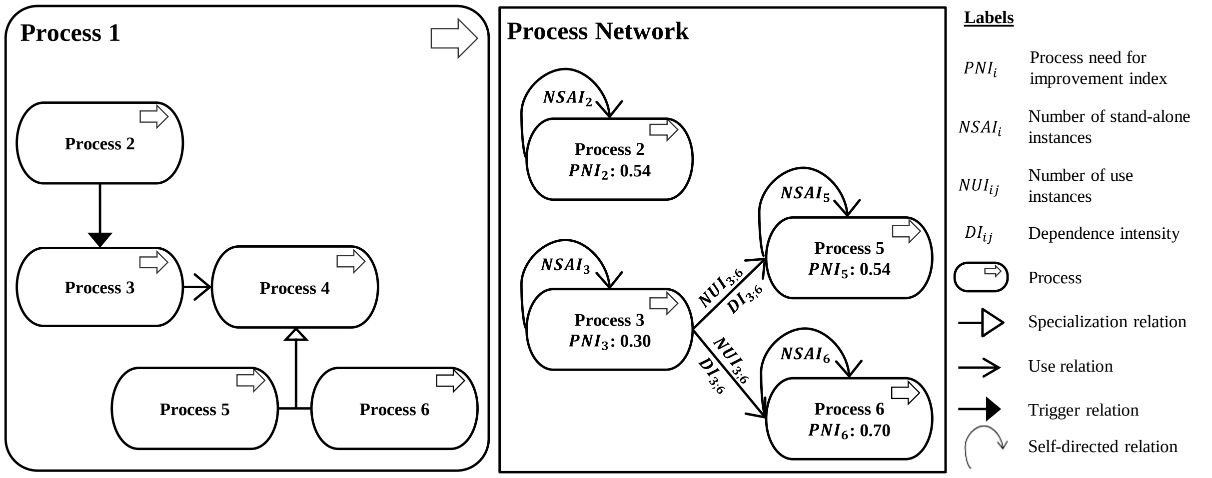


Figure 1. Example of a BPA (left) and the corresponding process network (right)

To transform a BPA into a process network, we first define each process included in the BPA as a node in the process network. From a stand-alone perspective, we assume that each process has a process need for improvement index (PNI) that will be adjusted by the PPR in line with its interconnectedness. Thus, each process i features a PNI_i, which takes values from [0;1], where 0 and 1 indicate no or substantial need for improvement, respectively. The PNI operationalizes the process dysfunctionality used in earlier approaches to process prioritization. We provide more information about the PNI in Sect. 4.2.2. . As a second step, we transfer the relations included in the BPA to the process network as follows:

- Decomposition: A composed process is either modeled as a single process or all its component processes are modeled, depending on the intended level of granularity. In Figure, processes 2 to 6 are modeled as a components of process 1. The network only contains the component processes.

- Specialization: Based on the idea that all relations of a super-process hold for its sub-processes, we only include sub-processes in the process network (Dijkman et al. 2016). In case a sub-process has additional relations with other processes, these relations must be transferred to the process network as well and treated as trigger or use relations, respectively. In Figure, processes 5 and 6 specialize process 4. Hence, process 4 is not included in the process network. Processes 5 and 6 inherit the use relation between processes 3 and 4.

- Use: Use relations are directly transferred to the process network. Each use relation is modeled as an edge from a using to a used process. As processes may use other processes several times per instance and period, each use relation has a weight representing the number of instances a process uses another process. We refer to this weight as the number of use instances NUI_{ij} between the processes i and j. Use relations capture dependencies among processes whose intensity may vary from process to process (Malone and Crowston 1994). Each use relation is therefore assigned a second weight, i.e., the dependence intensity DI_{ij} between the processes i and j. The DI indicates how strongly the performance of the using process depends on the used process. We formally introduce the DI in Sect. 4.2.

- Trigger: In line with the asynchronous communication property of trigger relations, the performance of triggering processes is independent from that of triggered processes. Triggering processes have “no interest” in triggered processes being improved. Thus, trigger relations need not be directly transferred to the process network. However, they influence the number of instances that a process is executed without using other processes. We model this number of stand-alone instances $NSAI$ as weights of self-directed edges in the process network. In the PPR logic, self-directed edges and their weights prevent a process’ PNI from being cascaded throughout the process network for those instances that do not use other processes. As processes may use other processes several times during the same instance within a distinct period, the $NSAI$ does not necessarily equal the difference between the number of all instances and the number of all use instances.

4.2. Input Parameters of the *ProcessPageRank*

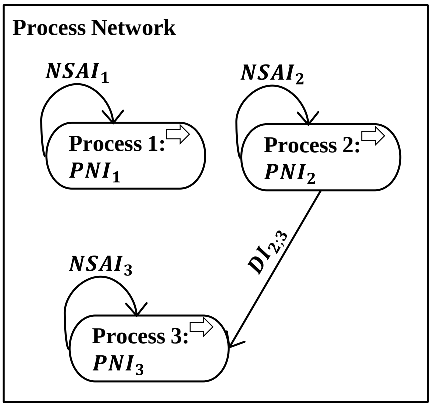
Processes are valuated via performance indicators, which are typically structured along the dimensions of the Devil’s Quadrangle (i.e., time, cost, quality, and flexibility). The PPR considers the cost, time, and quality dimensions, as flexibility can be covered via other dimensions such as time (Ray and Jewkes 2004). As these performance dimensions must be treated differently in process networks, we first model the dimension-specific PNI and DI individually, and aggregate them in a second step building on ideas from multi-criteria decision analysis (Cohon 2004). Figure 2 shows an exemplary calculation of the PNI and the DI that illustrates the equations below. Please find an overview of all variables in the Appendix.

4.2.1. Process Need for Improvement Index

The dimension-specific process need for improvement index PNI_i^p reflects the urgency of process i to be improved regarding performance dimension $p \in \{\text{Cost}, \text{Time}, \text{Quality}\}$. To quantify the PNI, we compare the target state TS_i^p of a performance dimension with its actual state AS_i^p. This is sensible because, in process performance management, the realizations of performance indicators are typically compared with desired target values (Leyer et al. 2015). In the PPR, target and actual states are quantified via a single performance indicator per dimension. In the cost dimension, we choose the *process costs per execution*, covering the costs of the process itself as well as the costs of used processes. As for time, we choose the *lead-time*, covering the total time for the completion of a process instance end-to-end. As for quality, we use the *error rate* because it has the same polarity as process costs and lead-time. We assume that each performance indicator covers the performance in the respective dimension and that the target state is never worse than the actual state. The PPR can also be extended to build on other indicators.

The PNI_i^p builds on the difference between the target and actual performance. The higher the difference, the higher the PNI. If processes A and B have the same difference between their actual and target states, but process A is executed more often, then process A should be improved first. Thus, the PNI of process A must be higher than that of process B. We thus multiply the difference between the actual and target states with the amount of executions AE_i. This makes the dimension-specific PNI comparable across all processes included in the process network. For the same reason, the dimension-specific PNI is normalized to the interval [0;1] against the highest dimension-specific PNI across all processes. As a result, we define the PNI for each performance dimension according to Eq. (4). If a process performs such badly that it cannot be used by other processes and does not deliver any useful output, it may be reasonable to improve this process first. To achieve this, the actual state can be set to an extremely high value, an intervention ensuring that the process is ranked first. Such a manual intervention, however, should be an exception as it bypasses the PPR's prioritization logic.

$$PNI_i^p = \frac{\left(AS_i^p - TS_i^p\right) \cdot AE_i}{\max_j \left[\left(AS_j^p - TS_j^p\right) \cdot AE_j\right]} \tag{4}$$



Processes		Process 1	Process 2	Process 3	Relations	$DI_{2;3}$
Cost	AS	45	80	90	$BDI_{2;3}^{\text{Time}}$	10
	TS	25	60	75		
Time	AS	50	75	55		
	TS	40	70	40		
Quality	AS	70	90	80	$MDI_{2;3}^{\text{Quality}}$	0.5
	TS	65	80	70		
AE_i		1,500	1,000	2,000		
$\boldsymbol{PNI_i}$		…	**0.444**	…	$\boldsymbol{DI_{2;3}}$	**1.694**

$\rho^{\text{C}} = 0.25;\ \rho^{\text{T}} = 0.50;\ \rho^{\text{Q}} = 0.25$

Exemplary calculation of PNI_2

$$PNI_2^{\text{C}} = \frac{(80-60)\cdot 1{,}000}{\max(30{,}000;\ 20{,}000;\ 30{,}000)} = 0.667$$

$$PNI_2^{\text{T}} = \frac{(75-70)\cdot 1{,}000}{\max(15{,}000;\ 5{,}000;\ 30{,}000)} = 0.167$$

$$PNI_2^{\text{Q}} = \frac{(90-80)\cdot 1{,}000}{\max(10{,}000;\ 20{,}000;\ 7{,}500)} = 0.500$$

$$PNI_2 = \frac{(0.667\cdot 30{,}000\cdot 0.25)+(0.167\cdot 30{,}000\cdot 0.50)+(0.500\cdot 20{,}000\cdot 0.25)}{(30{,}000\cdot 0.25)+(30{,}000\cdot 0.5)+(20{,}000\cdot 0.25)}$$

$$= 0.444$$

Exemplary calculation of $DI_{2;3}$

$$DI_{2;3}^{\text{C}} = \frac{90-75}{80-60} = 0.750$$

$$DI_{2;3}^{\text{T}} = \frac{\min(10;55-40)}{75-70} = 2.000$$

$$DI_{2;3}^{\text{Q}} = \frac{0.5\cdot(80-70)}{90-80} = 0.500$$

$$DI_{2;3} = \frac{(0.750\cdot 30{,}000\cdot 0.25)+(2.000\cdot 30{,}000\cdot 0.50)+(0.500\cdot 20{,}000\cdot 0.25)}{(30{,}000\cdot 0.25)+(30{,}000\cdot 0.5)+(20{,}000\cdot 0.25)}$$

$$= 1.694$$

Figure 2. Exemplary calculation of the PNI and DI in a sample process network

4.2.2. Dependence Intensity

The dependence intensity DI of a use relation indicates how strongly the performance of a using process depends on the performance of a used process. Figuratively, if a using process performs badly only due to the performance of a used process, the PNI of the using process depends highly on the used process' PNI. This phenomenon is captured in terms of a high DI between the using and used processes. Thus, the DI depends on the PNI of both the using and the used processes. The concrete modeling of the DI also depends on which performance dimension is analyzed.

Dependence Intensity in the Cost Dimension

The dependence intensity DI can vary for different use relations. Consider a process B that has a significant difference between its actual and target performance (i.e., it performs poorly) but is executed infrequently. This leads to a moderately high PNI_{B}. Now consider a process C that has a small difference between its actual and target state (i.e., it performs far better than process B) but is executed frequently. This results in a moderately high PNI_{C}, equal to PNI_{B}. Finally, consider a process A that uses processes B and C equally often. Even though PNI_{B} and PNI_{C} are equal, from process A's perspective, improving process B is more desirable than improving process C, since the performance per instance of process B is worse and both processes are used equally often.

The DI captures this property as shown in Eq. (5). The worse the performance per instance of process j, the larger the impact of improving that process on a using process i. Thus, the larger the difference between the actual and the target performance of the used process j (i.e., the need for improvement), the larger the impact of improving process j on process i. Vice versa, the larger the difference between the actual and the target performance of the using process i, the smaller the impact of improving process j on the using process i. Consider process A performing poorly itself, it is more important to improve process A (from the perspective of process A) than to improve any used process. In contrast to the other performance dimensions, this effect always cascades through the process network in the cost dimension and it is independent of the specific design of the involved processes.

$$DI_{ij}^{\text{Cost}} = \frac{AS_j^{\text{Cost}} - TS_j^{\text{Cost}}}{AS_i^{\text{Cost}} - TS_i^{\text{Cost}}} \tag{5}$$

Dependence Intensity in the Time Dimension

The dependence intensity DI of the time dimension is an adjusted version of the cost-specific DI. Consider two processes A and B where A uses B. In general, an improvement in process B's lead-time will improve process A's lead-time as well. Now consider process A running two parallel streams I and II and process B being used in stream I. If both streams run equally fast, improving process B's lead-time only improves the lead-time of stream I, but not that of process A. This is as stream I then has to wait for stream II to finish. Process A's lead-time is thus not affected by improving process B. The same holds true if stream I is already faster than stream II before improving process B. Consider the lead-time for stream I being 10 minutes higher than for stream II. Improving process B's lead-time by 15 minutes results in stream I being 5 minutes faster than stream II. Process A as a whole, however, is only 10 minutes faster than before improving process B. Thus, the effect of improving process B's lead-time only partly influences process A.

Hence, even though a used process may seem to have high need for improvement due to a large difference between the actual and target lead-time, improving this process does not necessarily affect the using process to the same extent. Therefore, we define an upper boundary BDI_{ij}^{Time} for the DI associated with the time dimension as shown in Eq. (6). This boundary represents the maximum improvement of the used process j that can cascade to the using process i.

$$DI_{ij}^{\text{Time}} = \frac{\min\left(BDI_{ij}^{\text{Time}}; AS_j^{\text{Time}} - TS_j^{\text{Time}}\right)}{AS_i^{\text{Time}} - TS_i^{\text{Time}}} \tag{6}$$

Dependence Intensity in the Quality Dimension

To calculate the dependence intensity DI associated with the quality dimension, it is necessary to consider the following property: if process A uses process B and process B creates defective output, the output of process A is likely to be faulty, too. Reducing process B's error rate, however, does not necessarily reduce process A's error rate to the same extent. For instance, if errors occur in process A and if we eliminate errors in process B, the errors in process A may still occur, and process A's error rate remains unchanged. In order to model this property, the quality-specific DI includes a moderator variable $MDI_{ij}^{\text{Quality}}$ as shown in Eq. (7). The variable can be interpreted as the conditional probability of good quality in the using process i if the quality of the used process j is good after an improvement. Thus, it takes values from the interval [0;1]. The quality-specific DI has no fixed upper boundary.

$$DI_{ij}^{\text{Quality}} = \frac{MDI_{ij}^{\text{Quality}} \cdot \left(AS_j^{\text{Quality}} - TS_j^{\text{Quality}}\right)}{AS_i^{\text{Quality}} - TS_i^{\text{Quality}}} \tag{7}$$

4.2.3. Integration of the Dimension-specific Input Parameters

We now integrate the dimension-specific process need for improvement indexes and dependence intensities into a single index to enable a prioritization across all performance dimensions and all processes included in the process network. Such an integration of multiple criteria into a single-criterion problem is a necessary step in multi-criteria decision analysis to provide decision support (Cohon 2004).

As an integrated indicator, the overall PNI must cater for trade-offs and the importance of the included performance dimensions. With all chosen performance indicators featuring the same polarity (i.e., low values are desirable), the overall PNI needs not resolve trade-offs. The dimension-specific PNI can be summed up, which is possible as they share the same measurement dimension (i.e., they are non-dimensional due to the normalization of the dimension-specific PNI). To capture that performance dimensions can be differently important, we use custom weights ρ^p that take values from the interval [0;1] and sum up to 1 (Keeney and Raiffa 1993). Like the dimension-specific PNI, the overall PNI must be normalized to be comparable across all processes. The overall PNI is shown in Eq. (7).

When aggregating the dimension-specific PNI, one must consider that they need not necessarily be included in the overall PNI as equally important, even if the they are equal for two performance dimensions. The reason is that the dimension-specific PNI are relative measures, normalized using the highest dimension-specific value across all processes from the process network. Consider a process A that performs well regarding all performance dimensions. Further, consider the highest difference between the actual and the target cost value within the process network to be very high, while the highest difference in time is rather low. This makes process A's cost-specific need for improvement index rather low and the time-specific index rather high. Aggregating both indices with equal weight into process A's overall PNI would lead to an average value for process A, although it performs well in both performance dimensions. To prevent such a bias, we also consider the highest dimension-specific PNI values across all processes when aggregating the dimension-specific PNI. The higher the maximum PNI in a distinct dimension, the worse the performance of the processes in that dimension. Thus, the higher the PNI in one performance dimension, the higher its importance for the overall PNI.

$$PNI_i = \frac{\sum_p \left(PNI_i^p \cdot \max_j \left[\left(AS_j^p - TS_j^p \right) \cdot AE_j \right] \cdot \rho^p \right)}{\sum_p \left(\max_j \left[\left(AS_j^p - TS_j^p \right) \cdot AE_j \right] \cdot \rho^p \right)} \tag{8}$$

The same rationale holds for the aggregation of the dimension-specific dependence intensities. Their aggregation is analogous to that of the PNI as shown in Eq. (9).

$$DI_{ij} = \frac{\sum_p \left(DI_{ij}^p \cdot \max_j \left[\left(AS_j^p - TS_j^p \right) \cdot AE_j \right] \cdot \rho^p \right)}{\sum_p \left(\max_j \left[\left(AS_j^p - TS_j^p \right) \cdot AE_j \right] \cdot \rho^p \right)} \tag{9}$$

4.3. The *ProcessPageRank* Algorithm

In order to prioritize processes in line with their network-adjusted need for improvement index, the PPR further develops the extended PageRank from Eq. (3) by integrating the domain-specific input parameters introduced above. The extended PageRank encompasses two summands, weighted by the dampening factor. The first summand assigns each node a stand-alone weight. The second summand adjusts the stand-alone weight in line with the node's interconnectedness. The dampening factor indicates how strongly the interconnectedness adjusts the stand-alone weight. Following this structure, we first integrate the process need for improvement index PNI into the extended PageRank and, then, the number of use instances NUI, the number of stand-alone instances $NSAI$, and the dependence intensity DI. The integration of our input parameters is guided by the design objectives, we derived from the BPM literature. We operationalized the design objectives in terms of design propositions from a network analysis perspective and validated them with a group of BPM experts (Sect. 5.1).

4.3.1. Integration of the Process Need for Improvement Index

According to design objective 0, process prioritization must consider the involved processes' individual performance. The PPR accounts for individual process performance via the PNI. To integrate the requirements of 0 into the PPR, we formulated the following design proposition:

(P.1) *For any two processes* i *and* j *from the process network: If, ceteris paribus, process* i *has a higher process need for improvement index than process* j*, then the network-adjusted need for improvement index of process* i *must exceed that of process* j.

Figuratively, if two processes have the same interconnectedness (i.e., same relations with the same processes, same weights, and same self-directed relations) and the only difference is that one process performs worse, then the process with the worse performance must be ranked higher. Eq. (10) shows how the PNI is integrated is integrated into the PPR. On the one hand, the PNI is of course integrated into the first summand of the PPR, which reflects the stand-alone weight of each process. On the other, the PNI needs to be integrated into the second summand as it also influences to which extent the processes' weights are adjusted in line with their interconnectedness. We provide more information about this property in the next section.

4.3.2. Integration of the Process Network Structure

In line with design objective (DO.2), process prioritization should account for the relations among the processes from the process network. If a process uses another process, improving the used process gains importance as this positively affects the performance of both the used and the using process. The more intensely the using process uses the other process, the higher the effect of process improvement. As the intensity of use relations is represented by the dependence intensity DI and the number of use instances NUI, process prioritization must account for both parameters. This leads to the following design proposition for ingoing use relations:

(P.2) *For any two processes* i *and* j *from the process network: If, ceteris paribus, process* i *is used by an additional process or has a higher number of use instances or a higher dependence intensity for at least one ingoing relation than process* j*, then the network-adjusted need for improvement index of process* i *must exceed that of process* j.

A similar logic holds for outgoing relations. The more intensely a process uses other processes, the more important it is for this process to improve the used processes, the idea being that improving the using process has no effect on the used process, while, in general, improving the used process has a positive effect on the using process. Therefore, the more a process relies on other processes, the more important it is to improve the used processes, and the less important it is to improve the using process relative to the used processes. This leads to the following design proposition for outgoing use relations:

(P.3) *For any two processes* i *and* j *from the process network: If, ceteris paribus, process* i *uses an additional process or has a higher number of use instances or a higher dependence intensity for at least one outgoing relation than process* j, *then the network-adjusted need for improvement index of process* j *must exceed that of process* i.

The design propositions (P.2) and (P.3) focus on direct use relations. Accordingly, the more intensely a process is used by other processes in terms of DI or $NSAI$, the higher it should be ranked. Consequently, the more a process uses other processes, the lower it should be ranked, relative to used processes. Design objective (DO.2) does not only hold for direct use relations, but also for transitive relations. Consider a relation where process A uses process B, which in turn uses process C. As process A uses process B, process B should be ranked higher than process A. The same holds for the use relation between process B and C. Improving process C has a positive effect on process B, which transitively affects process A. Hence, the ranking of process C should be higher based not only on its relation with process B, but also based on the relation between processes A and B. This leads to the following final design proposition:

(P.4) *For any two processes* i *and* j *from the process network that are both used by other (different) processes: If, ceteris paribus, process* i *is used by the process with the higher network-adjusted need for improvement index than process* j, *then the network-adjusted need for improvement index of process* i *must exceed that of process j.*

The extended PageRank from Eq. (3) accounts for the network structure in its second summand. This summand includes an individual edge weight w_{ij} that enables incorporating a unique relative importance for each edge in the network. Below, we operationalize the edge weights such that the PPR implements the design propositions (P.2) to (P.4).

As stated in (P.2), a process should receive higher weights, the more often it is used by other processes. In the process network, we defined NUI and $NSAI$ as weights of use relations and self-directed relations, respectively. Initializing the weight w_{ij} with the NUI and $NSAI$ ensures two properties: First, if a process uses two other processes, one more frequently than the other, it transfers more weight to the process it uses more often, since the weight of the use relation is higher (P.3). Second, the process does not transfer weight in case it does not use other processes.

As the weight of the self-directed relation represents the $NSAI$ and the relation points to the process from which it originated, no weight is transferred.

So far, a process transfers weight to other processes according to use relations only. This implies that processes that are used equally often by the same process, ceteris paribus, receive equal weights. As described above, the positive effect of improving a distinct used process on a distinct using process also depends on the used process' PNI. Consider a process A that uses process B. The higher process B's PNI, the higher the effect on process A and, thus, the higher process B's network-adjusted need for improvement index $NPNI_{\mathrm{B}}$. For example, if process A uses process B and the lead-time is the only relevant indicator: $NPNI_{\mathrm{B}}$ rises with a rising lead-time of process B, because process A must wait for B. Hence, the higher process B's PNI, the more important it is for process A to improve process B first. Thus, process B must rise in the prioritization ranking. As this is in the interest of process A, it should transfer more weight to process B, the higher process B's PNI. Therefore, PNI_{B} must be included when calculating the weight w_{AB}. We therefore update the initialization of w_{ij} and include the used processes' PNI by multiplying them with the respective number of use instances NUI, or the number of stand-alone instances $NSAI$ in the case of self-directed relations. For better legibility, we refer to the $NSAI$ of a process i as NUI_{ij} with $i = j$. Taking into account all these adjustments results in Eq. (10).

$$NPNI_i = (1-d) \cdot \frac{PNI_i}{\sum_{j=1}^{n} PNI_j} + d \cdot \sum_{k \in I_i} NPNI(k) \cdot \frac{NUI_{ki} \cdot PNI_i}{\sum_{l \in O_k} NUI_{kl} \cdot PNI_l} \tag{10}$$

In Eq. (10), weight transfers within the process network depend on the NUI of the relation between two processes and on the PNI of the used process. However, weight transfers should also depend on the using processes' PNI. Consider two processes where process A uses process B. If processes are ranked according to Eq. (10), we get distinct values for these processes' $NPNI$. If we increase process A's amount of executions AE_{A} while keeping the number of use instances NUI_{AB} constant, process A's need for improvement index PNI_{A} rises. If process A's PNI rises, the weight transferred to process B also rises as the weight transferred to a used process is relative to the using process' PNI. If more weight is transferred to the used process B, its $NPNI_{\mathrm{B}}$ also rises even though the improvement of process B did not get more important as neither the NUI_{AB} nor any other variables for process B changed. To cater for this effect, we also include the dependence intensity DI in the weights. The resulting formula for w_{ij} is $(DI_{ki} \cdot NUI_{ki} \cdot PNI_i)$. However, if DI_{ij} is less than 1, only a fraction of the original weight is transferred from the using to the used process. The remaining weight stays with the using process. To consider this for each outgoing use relation of a process, we need to add the remaining weight, which is defined as $\left((1 - DI_{ki}) \cdot NUI_{ki} \cdot PNI_i\right)$, to the self-directed relation. Applying this to Eq. (10) requires splitting the second summand into two sub-summands, which represent the weight transfers through use relations and through the self-directed relations, respectively. Integrating these changes leads to the final PPR algorithm that determines a network-adjusted need for improvement index $NPNI$ for each process in the process network. Again, for better legibility, we refer to the $NSAI$ of a process i as NUI_{ij} with $i = j$. Setting $DI_{ij} = 0$ for $i = j$ allows further simplifications. Together, this leads to Eq. (11). The complete PPR formula without the simplifications can be found in the Appendix.

$$NPNI_i = (1 - d) \cdot \frac{PNI_i}{\sum_{j=1}^{n} PNI_j} + d \cdot \left[\begin{array}{l} \sum\limits_{k \in I_i \setminus i} NPNI(k) \cdot \frac{DI_{ki} \cdot NUI_{ki} \cdot PNI_i}{\sum_{l \in O_k} NUI_{kl} \cdot PNI_l} \\ +NPNI(i) \cdot \sum\limits_{m \in O_i} \frac{(1 - DI_{im}) \cdot NUI_{im} \cdot PNI_m}{\sum_{n \in O_j} NUI_{nl} \cdot PNI_l} \end{array} \right] \quad (11)$$

5. Evaluation

5.1. Validation of the Design Propositions

Before discussing whether the PPR meets the design propositions, we validated the propositions themselves. On the one hand, the propositions align with the descriptive knowledge on process performance management and BPA as well as with the prescriptive knowledge on network analysis. One the other, we validated the design propositions via an online questionnaire with a group of ten BPM experts from industry and academia. Table 1 summarizes the experts' characteristics, where the bold numbers indicate how many experts meet a characteristic. For example, 2 experts were from academia, 6 from industry (4 from the IT domain, 2 from machine engineering, 1 from online retail, and 2 are unknown). Table 1 corroborates that the experts had great experience in BPM, i.e., about eleven years on average.

After a brief introduction of the PPR's idea, the questionnaire included four cases, each of which aimed to validate a distinct design proposition. The cases were very similar to enable the experts isolating the effects to be validated. Each case contained a process network with four processes (i.e., A to D) as well as use relations to capture the idea of the related design proposition. The cases also provided information about the process network (i.e., PNI, $NSAI$, NUI). Each case proposed a ranking and a rationale. The rationale built on the related design proposition, unknown to the experts. For each case, we asked the experts whether they agree with the ranking and rationale. The complete questionnaire can be found in the Appendix. Table 2 overviews the cases, results, and expert comments.

Table 1. Summary of characterizing data about experts in EVAL2

Industry	Academia	**2**	IT	**4**	Machine Engineering	**1**	Online Retail	**1**	Unknown	**2**
Number of Employees	1–100	**1**	101–1,000	**4**	1,001–10,000	**1**	10,000+	**3**	Unknown	**1**
Years of Experience in BPM	3–5	**3**	6–10	**2**	10–15	**4**	15+	**1**	Unknown	**0**

The four cases were set up as follows:

- In the first case, all processes had the same PNI, and each process had a self-directed relation with the same $NSAI$. There were no use relations between the processes as the case intended to validate design proposition (P.1), which requires the prioritization of processes with a higher PNI.
- The second case introduced use relations from process A to C and from process B to D, with a higher weight given to the latter use relation. This change aimed to validate design proposition (P.2), which requires the prioritization of one process over another if it is, ceteris paribus, used by an additional process, or if an existing use relation has a higher NUI or DI than another process.
- Case three introduced another use relation from process B to C to validate (P.3). This design proposition ensures that a process is prioritized over another process if it, ceteris paribus, uses less processes or if the existing use relations have a lower NUI or DI than another process. While the second case focused on a higher NUI on an existing relation, this case focuses on an additional relation.
- The last case validates design proposition (P.4), which considers transitive relations within the process network. To do so, we kept the use relations from case two between the processes A and C as well as between B and D, and we gave them equal weights. However, we changed PNI_{B} to a higher value, such that the network-adjusted index $NPNI_{\mathrm{B}}$ also rose relative to process A.

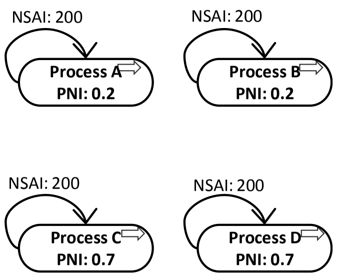
Only one expert (E02) disagreed with all proposed rankings and rationales, arguing that process prioritization depends on whether a process is a business or a support process. Our response to this comment is twofold. First, if a business process uses a support process, this will affect the performance of the business process. If the support process is, in fact, the bottleneck of the business process, improving the support process should be prioritized. Second, if decision-makers intend to focus on improving business processes as compared to support processes, they can capture this preference when instantiating the PNI. The PNI is lower if a process' target state is lower because it depends on the difference between the target and actual performance. If decision-makers have a low aspiration regarding the performance of support processes, the target state should not be as high as if the decision-maker expected excellent performance. Thus, the PNI of support processes decreases with low performance aspirations, which in turn leads to a higher ranking of business processes in general.

Experts E08 and E04 argued that some way to include a differentiation between business and support processes may be helpful. Nevertheless, they agreed with the rankings and rationales. Expert E05 suggested that more than one variable should be used to characterize processes and disagreed with the first case. However, the PNI is a variable that characterizes a process' need for improvement according to multiple performance dimensions. As the questionnaire focused on validating the design propositions, we only briefly introduced the PNI's constituents. Expert E05's suggestion to include the value of improvement projects can be captured via the PNI. The PNI depends, among others, on the target performance, which can be derived using benchmarking, project candidate evaluation, or expert estimations. If the target performance is set to the expected target performance after the implementation of an improvement project, the value of the improvement is considered in process prioritization. Two experts (E06, E08) commented that process A should be prioritized over process B in cases two and three (E06) due to a higher $NSAI$. However, this was due to an incorrect interpretation of the $NSAI$ as the amount of instances of the process, instead of the number of instances the process was executed without using other processes. For the last case, expert E06 disagreed with the statement considering (P.4) due to a lack of information given on the construction of the PNI, but confirmed the reasoning. We resolved other misinterpretations in brief bilateral interactions with the experts.

In sum, nine out of ten experts approved our design propositions fully or to great extent. This result corroborates the experts' strong consensus. Two experts explicitly commented that they very much liked the idea of considering interconnectedness when prioritizing processes.

Table 2. Results of validating the design propositions

CASE 1



Process	Rank
Process A	2
Process B	2
Process C	1
Process D	1
Agreement	**8 / 10**

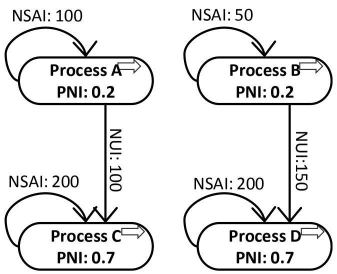
Comments:

E02 Process prioritization largely depends on whether the process is a business or support process.

E05 Suggestion to integrate additional criteria needed for process prioritization.

E08 True, if differentiation between business and support process is contained in the PNI.

CASE 2



Process	Rank
Process A	3
Process B	4
Process C	2
Process D	1
Agreement	**7 / 10**

Comments:

E02 Process prioritization largely depends on whether the process is a business or a support process.

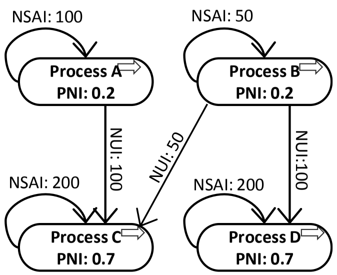
E04 To consider including differentiation between business and support processes.

E05 Value from process improvement should be taken into account.

E06 Process A should be prioritized over Process B since it is executed more often than Process B.

E08 Generally agree with prioritization, but Process A should be prioritized over Process B due to the higher NSAI.

CASE 3



Process	Rank
Process A	3
Process B	4
Process C	1
Process D	2
Agreement	**8 / 10**

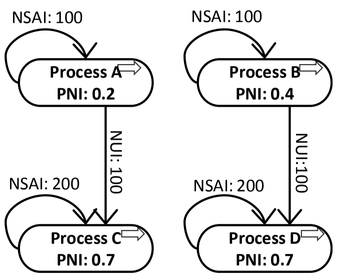
Comments:

E02 Process prioritization largely depends on whether the process is a business or a support process.

E04 To consider including differentiation between business and support processes.

E06 Process A should be prioritized over Process B since it is executed more often than Process B.

CASE 4



Process	Rank
Process A	4
Process B	3
Process C	2
Process D	1
Agreement	**8 / 10**

Comments:

E02 Process prioritization largely depends on whether the process is a business or a support process.

E06 The argument generally seems reasonable. More information on how the PNI is constructed, and how the PNI of processes are related is needed to fully support the statement.

5.2. Expert Interview at a Global Online Retailer

As a naturalistic validation of the *PPR*'s design specification, we conducted a three-hours semi-structured interview where we discussed the *PPR*'s design specification with an industry expert (IE) who also participated in the validation of the design propositions. The interview was structured along predefined evaluation criteria, i.e., real-world fidelity, understandability, expected impact on the artefact environment, and applicability (Sonnenberg and vom Brocke 2012).

The IE is working at a data-driven global online retailer that sells a wide range of products and has over 100,000 employees. That company permanently strives for new business opportunities, entailing a constant need for process redesign. It also aims for operational excellence, an objective requiring effective process prioritization. The IE has over 15 years of BPM experience and change management, and is working as a senior process manager at one of the retailer's distribution centers. The IE's main responsibility is process improvement, which makes process prioritization an integral task of his daily business. The company's strong focus on data and the IE's experience make the IE a suitable discussion partner for challenging the *PPR*. The IE expressed great interest in the idea of including process interconnectedness into process prioritization and hoped getting the opportunity to integrate the *PPR* in his company. The IE agreed with the *PPR*'s design specification, deeming the *PPR* a valid solution to the problem including process interconnectedness into process prioritization. Below, we outline the IE's subjective assessment of the evaluation criteria mentioned above.

As for real-world fidelity, the IE agreed that the *PPR* covers most constellations that occur in his company as it integrates the processes' individual need for improvement, the processes' interconnectedness, the number of use instances, and a dimension-specific dependence intensity. The IE considered the *PPR* as flexible and applicable to numerous real-world settings as it includes various possibilities for customization, e.g., the ability to adapt the target state and to weigh the included performance dimensions depending on the application context. The IE also mentioned that in a human-intensive work environment such as that of his company, he would appreciate a way to include specific staff requirements within the PNI, such as hazard potential or ease of training. However, the IE agreed that such effects would not cascade through the process network, a circumstance that makes including this additional dimension in the *PPR* rather easy. The IE also confirmed that the *PPR* is understandable for experienced experts such as typically involved in process prioritization decisions.

Regarding the *PPR*'s impact on artefact environment and users, the IE expected that already a discussion of the *PPR*'s problem statement would change the way users think about process prioritization. In the IE's opinion, using the *PPR* would facilitate a mindset shift as users tend to treat business processes as isolated entities. Further, the IE indicated that the *PPR* is likely to harmonize and promote the traceability of process prioritization decisions via clear guidelines on how to incorporate the interconnectedness. In the past, the IE tried to include process interconnectedness on his own experience, but lacked capabilities to quantify relevant constructs. According to the IE, the *PPR* solves this issue and supports users by making the integration of such effects less dependent on subjective influences. Further even if decision-makers account for relations among processes when prioritizing processes in their area of responsibility, processes from other areas of responsibility as well as the dependencies considering those processes are not included. Therefore, the *PPR* enables companies to create an integrated process prioritization across all departments.

The IE confirmed that the *PPR* would be applicable in his company as the company is highly process-oriented and collects almost all parameters via BPM tools. This is why most of the *PPR*'s input parameters can be gathered in a relatively short time span. The IE considered changing employee mindset as the key challenge associated with the *PPR*'s application. In his opinion, employees of data-driven companies are more receptive to data-driven models such as the *PPR*. However, he also assessed that companies that are not as data-driven, will have more problems with collecting all input parameters. The more data-driven a company, the more easily to apply the *PPR*.

5.3. Demonstration Example at a European Nearshoring IT Provider

5.3.1. Case Company and Business Process Architecture

To show the *PPR* in action and to demonstrate the applicability of our software prototype, we present a demonstration example based on a real BPA. This BPA was provided by a BPM expert who is working at a European nearshoring IT provider and who also participated in the design propositions' validation. To meet the requirements of an artificial ex-post evaluation (EVAL3), we transformed the BPA into a process network, applied the *PPR*, and discussed the results. In addition, we used the results to illustrate that the *PPR* implements the design propositions, as this is hard to show based on the design specification only (EVAL2).

The European nearshoring IT provider has over 1,000 employees, operating its headquarters in Romania. The provider serves customers from industries like IT, automotive, or logistics – mainly based in Europe, but also in the United States. The provider supports customers in all steps of the software development lifecycle as well as in application management. Serving major international companies makes excellent processes one of the providers' primary goals. To enhance its BPM capabilities and get an overview of its processes, the provider developed a BPA. On the top-most level, the BPA included 48 processes and 30 use relations. The BPA covered business, support, and management processes structured along four process areas, i.e., customer, workforce, human resources, and financial processes. The relations among these processes exist within and across process areas. In this BPA, processes from the upper areas use processes from the lower areas. Figure 3 shows the process network that we derived from the provider's BPA. As the BPA was under construction when we investigated the provider, detailed performance data was not available yet. This is why we had to generate data for the purposes of this demonstration example. The example, however, comes close to a real-world case study because of the included real-world processes and relations, but it is not a full-fledged one due to the lack of performance data. Please find more information about how we transformed the given BPA, how we generated suitable input data, and about which data we used in the Appendix.

With the process network containing many processes and relations, it becomes obvious that, in industry-scale settings, there generally is neither a trivial nor an intuitive answer to the question how to prioritize processes for improvement purposes. To prioritize processes in line with their individual need for improvement and interconnectedness, prescriptive knowledge as provided by the PPR is necessary. As a recursive algorithm whose complexity heavily grows with the number of processes and relations, the PPR cannot be feasibly applied without a software instantiation. We thus implemented a software prototype that efficiently handles arbitrary process networks and analyzes the robustness of prioritization results in line with the decision-makers' preferences. In fact, it took the PPR prototype less than a minute to process the network at hand on an ordinary workstation, including the robustness analysis.

5.3.2. Analysis of the Results

Table 3 shows the results of applying the PPR to the process network we derived based on the European nearshoring IT provider's BPA. From the left to the right, Table 3 includes the involved processes and their process areas (HR: human resources, WF: workforce, F: financials, C: customer). It also lists the processes' individual need for improvement index PNI, the network-adjusted need for improvement index $NPNI$, the related rankings, and rank differences. Please consider that the PNI and $NPNI$ values cannot be directly compared as each PNI stems from the interval [0;1], whereas the $NPNI$ values sum up to 1. Instead, the rankings and rank differences should be used to interpret the *PPR* results. Table 3 is sorted descending according to the *NPNI* and the resulting ranking.

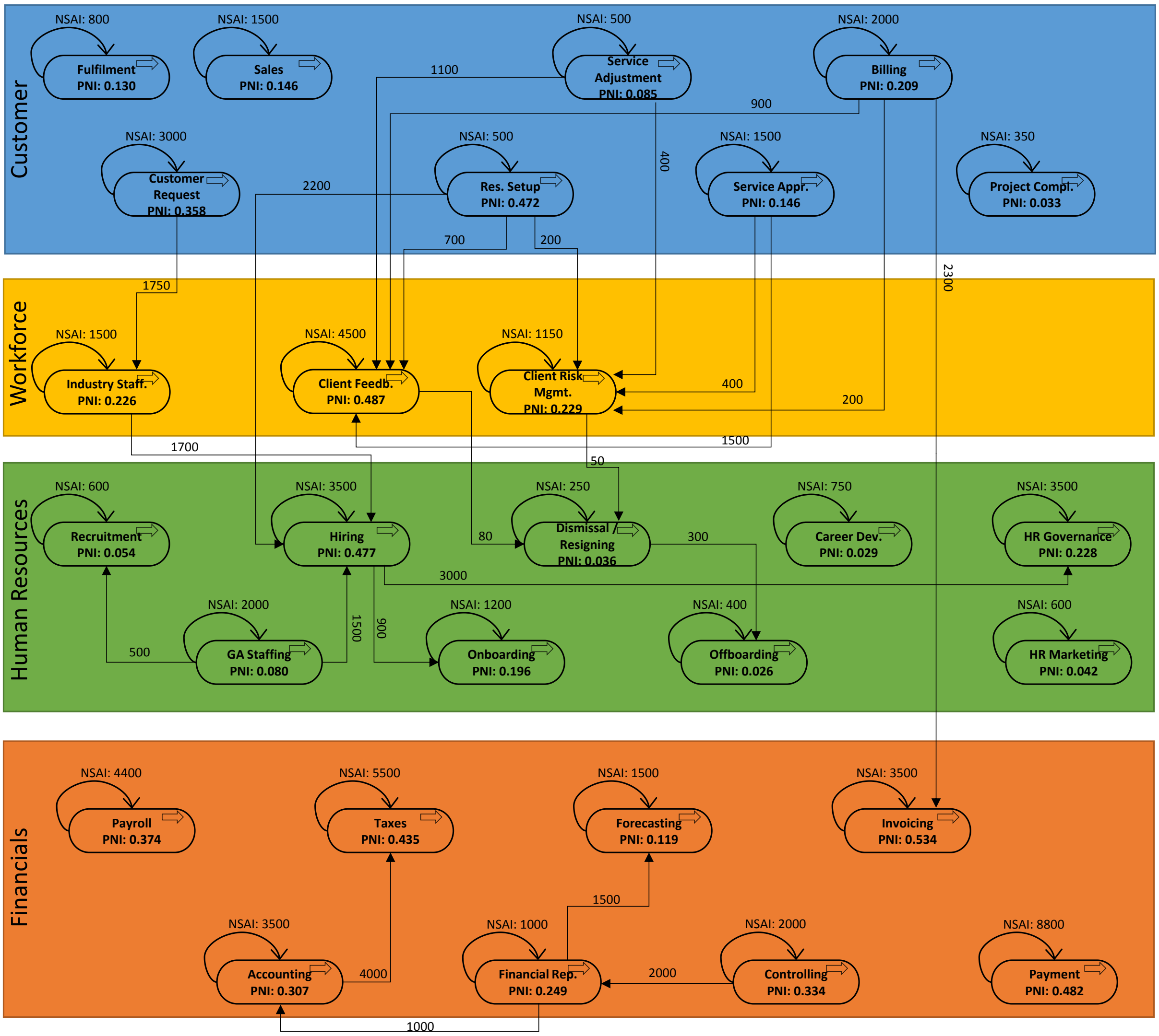


Figure 3: Process network of the European nearshoring provider

A first view on the results shows that the process network contains processes with a moderately high individual need for improvement (e.g., Client Feedback, Hiring) and processes with a very low individual need for improvement index (e.g., Project Completion, Career Development). In line with the *PPR*'s constitutive idea, we see processes whose network-adjusted rank is higher or lower than their individual rank as well as processes whose network-adjusted rank equals the individual rank. For example, the Forecasting process is ranked higher than from a stand-alone perspective. The opposite holds true for the Customer Request and Controlling processes. This is because the *PPR* adjusts the processes' individual need for improvement according their interconnectedness, with interconnectedness being measured via the number of use and stand-alone instances as well as the dependence intensity. Overall, the stand-alone and the network-adjusted ranking are positively correlated, featuring a Spearman rank correlation coefficient of 0.88. Even if some processes show greater differences regarding their individual and network-adjusted ranks, the *PPR* does not confound, but carefully adjust the individual ranking results. This is reasonable as we applied the *PPR* using a dampening factor of 0.5, meaning that the processes' individual need for improvement and interconnectedness affect the network-adjusted need for improvement in equal shares. Other values for the dampening factor would have yielded other network-adjusted rankings. A value of 0.5 is reasonable, as it is unrealistic in industry that the processes' interconnectedness receives substantially more weight than their individual need for improvement. This assessment was confirmed generally by our BPM experts and in particular by the expert working for the nearshoring provider.

Table 3. Results of applying the PPR to the provider's process network

Process	**Area***	***PNI***	***NPNI***	**Rank *PNI***	**Rank *NPNI***	**Rank difference**
Client Feedback	WF	0.487	0.097	2	1	1
Hiring	HR	0.477	0.095	4	2	2
Taxes	F	0.435	0.094	6	3	3
Invoicing	F	0.534	0.092	1	4	-3
Payment	F	0.482	0.074	3	5	-2
HR Governance	HR	0.228	0.060	13	6	7
Payroll	F	0.374	0.057	7	7	0
Client Risk Management	WF	0.229	0.044	12	8	4
Onboarding	HR	0.196	0.042	16	9	7
Forecasting	F	0.119	0.042	20	10	10
Resource Setup	C	0.472	0.041	5	11	-6
Industry Staffing	WF	0.226	0.033	14	12	2
Financial Reporting	F	0.249	0.032	11	13	-2
Accounting	F	0.307	0.028	10	14	-4
Customer Request	C	0.358	0.027	8	15	-7
Controlling	F	0.334	0.026	9	16	-7
Sales	F	0.146	0.022	17	17	0
Fulfilment	C	0.130	0.020	19	18	1
Billing	F	0.209	0.016	15	19	-4
Service Approval	C	0.146	0.011	18	20	-2
Recruitment	HR	0.054	0.008	23	21	2
Service Adjustment	C	0.085	0.007	21	22	-1
HR Marketing	HR	0.042	0.006	24	23	1
GA Staffing	HR	0.080	0.006	22	24	-2
Offboarding	HR	0.026	0.006	28	25	3
Project Completion	C	0.033	0.005	26	26	0
Career Development	HR	0.029	0.004	27	27	0
Dismissal/Resigning	HR	0.036	0.004	25	28	-3

* HR: human resources processes, F: financial processes, WF: workflow processes, C: customer processes

An in-depth analysis reveals that customer processes – except for Customer Request and Resource Setup – tend to have lower individual ranks and drop in the network-adjusted ranking. The reason is that most customer processes have a rather low PNI and many outgoing relations. No customer process is used by other process. The ranks of workforce processes, however, are rising as they are intensively used by customer processes. Changes in the ranking of human resources processes are diverse. Some processes rise (e.g., HR Governance), some drop (e.g., GA Staffing), and others remain unchanged (e.g., Career Development) in the ranking. One reason is that human resources processes feature a different interconnectedness regarding use relations. In addition, human resource processes have a very low individual need for improvement, except for Hiring. Financial processes mostly drop in the ranking, but stay in the upper half of the network-adjusted ranking. The reason is that financial processes have a comparatively high individual need for improvement. The only exception is the Forecasting process that has a rather low individual need for improvement, is directly used by Financial Reporting as well as transitively by Controlling. By trend, processes (i.e., Hiring, Client Feedback, Client Risk Management) that are often used by other processes and/or have a high individual need for improvement, raise in the network-adjusted ranking. Processes (i.e., Resource Setup, Customer Request) that use many processes and are not used by other processes drop in the network-adjusted ranking. The three best-ranked processes (i.e., Client Feedback, Hiring, Taxes) are heavily used and have a high need for improvement. Other process parameters such as the dependence intensity and the amount of executions, which are only shown in the Appendix, corroborate these results.

The demonstration example confirms that the PPR implements the design propositions derived in Sect. 4.3. As we brought forward the key arguments above, we provide only a short justification here. Design proposition (P.1), which deals with the processes' individual need for improvement, becomes manifest in the processes Payment and Payroll. Payment has a higher PNI than Payroll. Both processes have no connections to other processes. Consequently, Payment has a higher $NPNI$ than Payroll. Design propositions (P.2) and (P.3), which address direct ingoing and outgoing use relations, can be discussed based on the processes GA Staffing and Recruitment. Without considering network effects, GA Staffing is ranked better than Recruitment. As GA Staffing uses Recruitment, the $NPNI$ of Recruitment exceeds that of GA Staffing, in line with design proposition (P.2). This case also holds true as for design proposition (P.3). As GA Staffing uses Recruitment, the $NPNI$ of Recruitment exceeds that of GA Staffing. The processes Invoicing and Taxes help discuss design proposition (P.4), dealing with transitive relations. Both processes are used by a single but different process and do not use other processes. Although Invoicing has a higher individual need for improvement than Taxes, it is used by a process with a lower $NPNI$ (i.e., Billing) than Taxes (i.e., Accounting). Together with the effects of the amount of executions and the number of use instances, Taxes is in the end ranked better in the network-adjusted ranking. When discussing the design propositions, consider that design propositions are idealized axioms building on a 'ceteris paribus' assumption. While the design propositions help guide the design of the PPR, their effects are not separable in practice. Typically, design propositions take effect simultaneously if the PPR is applied to prioritize processes in real-world settings.

To assist decision-makers in assessing the quality of the PPR results and identifying those input parameters that strongly influence process prioritization decisions, we finally report on the robustness analysis offered by our software prototype. The prototype uses simulation where decision-makers can define the number of iterations, the value range to be analyzed, the category of input parameters to be investigated (e.g., number of use and stand-alone instances, amount of executions, custom weights, dampening factor, and the processes' actual and target performance). In each iteration, the prototype randomly draws values of the chosen parameter category from the predefined intervals. The prototype finally compares the simulation results with the original results using the average Spearman rank correlation coefficient. In our demonstration example, we chose 1.000 iterations and set the value range of the input parameters to [-30%; +30%]. The average Spearman rank correlation coefficient was 0.980 when varying the number of use and stand-alone instances and amount of executions. Furthermore, it was 0.992 for the dampening factor and 0.994 for the custom weights. These results show that the PPR results are very robust regarding variations of these parameters. Hence, estimation inaccuracies hardly affect the PPR results. This is good as these input parameters tend to be hard-to-estimate. By contrast, varying the processes' actual and target performance influences the PPR results more strongly. A variation within the interval [-10%; +10%] yields an average rank correlation coefficient of 0.468. This is reasonable as the actual and target performance are relevant for each process. It would be surprising if the PPR results did not change in case of different performance values. Further, process performance is easier to estimate compared to other parameters such that a higher variation is tolerable.

As part of EVAL3, the demonstration example illustrated that the PPR efficiently applies to larger process networks – in this case: based on a real BPA of a European nearshoring IT provider – and yields interpretable results. The results were robust regarding inaccuracies of hard-to-estimate input parameters (e.g., the number of use and stand-alone instances) as well as sensitive regarding input parameters related to process performance, which are comparatively easy to assess. As part of EVAL2, the example showed that the *PPR* implements the design propositions.

6. Conclusion

6.1. Summary and Contribution

With process prioritization being a critical success factor of effective process improvement, this study investigated how business processes should be prioritized based on their own need for improvement and interconnectedness. Adopting the DSR paradigm, we developed the *ProcessPageRank* (*PPR*) that ranks processes from a given BPA in line with their network-adjusted need for improvement. The *PPR* draws from descriptive knowledge on process performance management and BPA as well as from prescriptive knowledge related to network analysis, particularly the Google PageRank. The *PPR* interprets processes as connected nodes and extends the Google PageRank as a popular centrality measure to identify central nodes in process networks. The network-adjusted need for improvement integrates the processes' individual need for improvement, building on multiple process performance dimensions (i.e., cost, quality, time), with their interconnectedness in the process network, captured via use relations. In the *PPR*, use relations are annotated with the number of use instances (i.e., how often a process uses another process) and a dependence intensity (i.e., how strongly a process' performance depends on the processes it uses) in order to not only reflect whether, but also how intensely processes are interconnected.

Following the evaluation framework as per Sonnenberg and vom Brocke (2012), we validated the *PPR*'s design specification by conducting an in-depth expert interview at a global online retailer and discussing it against design propositions in the course of a demonstration example. We derived the design propositions from the descriptive knowledge on process performance management and BPA, operationalized them using prescriptive knowledge on network analysis, and validated them with BPM experts from academia and industry. Finally, we instantiated the *PPR*'s design specification as a software prototype and applied the prototype to a real BPA from a European nearshoring IT provider.

The *PPR* adds to the prescriptive knowledge on process prioritization as it is the first approach to account for process interconnectedness when prioritizing processes for improvement purposes. The *PPR* also is the first approach to apply the mature knowledge on centrality measures to process decision-making in general as well as to process prioritization in particular.

6.2. Limitations and Future Research

While validating the *PPR*'s design specification and applicability, we identified directions in which the *PPR* should be advanced. Below, we present these directions together with ideas for future research.

Regarding its design specification, the *PPR* quantifies the need for improvement of individual processes based on performance indicators to operationalize process dysfunctionality. Even though the *PPR* allows for the integration of indicators from virtually any performance dimension, we only specified it for the cost, time, and quality dimensions as well as for indicators with the same polarity. Thus, the *PPR* should be extended to include other performance dimensions, depending on the domain in which it is applied. In addition, the *PPR* prioritizes processes according to their network-adjusted need for improvement. Depending on the project candidates available for process improvement, however, improving the process with the highest network-adjusted need for improvement is not necessarily optimal. If processes A and B are ranked first and second, but the project candidate for process B requires far lower investment than that for process A, it might be reasonable to improve process B first. The same holds if a much less risky project candidate is available for process B. This argument relates to the 'difficulty to improve' construct already used in non-performance-based process prioritization approaches. Therefore, the *PPR* should be extended regarding an economic valuation and a project management perspective. Regarding the validation of the design propositions based on which we developed the *PPR*, we concede that the expert group only included ten members, even if these members were very experienced. Regarding the in-depth interview with the expert from the global online retailer, we admit that the expert's assessment may be positively biased due his great BPM experience and the retailer's mature BPM capabilities.

Currently, the *PPR*'s applicability is limited due to its high data requirements. While some parameters are readily available in enterprise information systems or can be estimated in a straightforward manner (e.g., actual and target performance), other parameters must be assessed by subject matter experts (e.g., number of use instances, boundaries regarding time and quality performance). This, however, does not only limit the *PPR*, but all data-driven BPM approaches, e.g., process mining. Due to the uptake of process-aware information systems, we are confident that sufficient high-quality process data will be available in the near future to enhance the *PPR*'s applicability. Although the presented demonstration example builds on a real-world BPA and was inspired by our industry experience, it is not a full-fledged real-world case study.

Depending on available process data, future research should focus on conducting further interviews in different contexts to further validate the *PPR*'s real-world fidelity as well as case studies to validate the *PPR*'s applicability. Thereby, future research should set up a knowledge base to institutionalize data collection routines. To facilitate further real-world case studies, we also recommend advancing the software prototype such that it can be used more conveniently in industrial settings and implements more sophisticated analysis functionality.

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V. The Future of Business Process Management in the Future of Work

Research Paper 6:
The Future of Business Process Management in the Future of Work

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Abstract: Business process management (BPM) is a corporate capability that strives for efficient and effective work. As a matter of fact, work is rapidly changing due to technological, economic, and demographic developments. New digital affordances, work attitudes, and collaboration models are revolutionizing how work is performed. These changes are referred to as the future of work. Despite the obvious connection between the future of work and BPM, neither current initiatives on the future of BPM nor existing BPM capability frameworks account for the characteristics of the future of work. Hence, there is a need for evolving BPM as a corporate capability in light of the future of work. As a first step to triggering a community-wide discussion, we compiled propositions that capture constitutive characteristics of the future of work. We then let a panel of BPM experts map these propositions to the six factors of Rosemann and vom Brocke's BPM capability framework, which captures how BPM is conceptualized today. On this foundation, we discussed how BPM should evolve in light of the future of work and distilled overarching topics which we think will reshape BPM as a corporate capability.

Keywords: Business Process Management, Capability Development, Future of Work

1. Introduction

Process orientation has evolved into a widely used paradigm of organizational design and proved to be a valuable source of corporate performance (Kohlbacher and Reijers, 2013; Skrinjar et al., 2008). As a result, business process management (BPM) receives constant attention from industry and academia (Dumas et al., 2013; Harmon and Wolf, 2014). In the last years, the BPM community has proposed mature approaches for the design, analysis, enactment, and improvement of business processes (van der Aalst, 2013). Currently, the BPM community focuses ever more on the organizational impact of BPM as well as on the development of BPM as a corporate capability (Pöppelbuß et al., 2015; Trkman, 2010; van Looy et al., 2014). Developing BPM is thus regarded as a prerequisite for successful processes, i.e., for efficient and effective work (Rosemann and vom Brocke, 2015; Harmon, 2014).

The nature of work is changing rapidly. Contemporary technological, demographic, and economic developments are revolutionizing how work is performed. New digital affordances, such as virtual collaboration tools as well as mobile applications and devices, enable innovative collaboration models and emancipate work from context factors such as time and location (Allen, 2015; Brynjolfsson and McAfee, 2014; McAfee, 2009). A connected work environment allows for dynamically assembling workers into project teams that compete in real-time for high-value tasks all over the world (Ardi, 2014). The emerging digital mindset also propagates customization and flexibility as core values, while challenging work practices that rely on predictability, uniformity, and consistency (Notter, 2015). The term future of work is widely used to refer to a new world of work brought about by technological trends in global connectivity, smart machines, and new media as well as changing social, political, and economic factors. While, due to its broad scope, the future of work impacts various disciplines, it directly influences organizational strategy and design (Malone, 2004). Thus, there is an obvious connection between the future of work and BPM, which in turn is “the art and science of overseeing how work is performed” (Dumas et al., 2013, p. 1). In the recent past, valuable initiatives started to reason about the future of BPM research and practice (Recker, 2014; Rosemann, 2014; vom Brocke et al., 2011; vom Brocke et al., 2014). These initiatives, however, do not explore the connection between the future of work and BPM. Similarly, existing capability frameworks, which capture how BPM as a corporate capability is or should be conceptualized, do not account for the characteristics of the future of work (Rosemann and vom Brocke, 2015; van Looy et al., 2014). Recker (2014) criticizes that many BPM capability areas “have too readily been accepted and taken for granted” (p. 12). Against this background, there is a need for evolving how BPM is conceptualized today in light of the future of work. Thus, we investigate the following research question: *How does BPM as a corporate capability need to evolve in light of the future of work?*

We approach this research question using a three-phase research method. To understand what the future of work actually is about, we conducted a structured literature review and compiled propositions that capture constitutive features of the future of work. To examine in a structured manner how the future of work impacts BPM, we used Rosemann and vom Brocke's (2015) seminal BPM capability framework as a reference point and asked BPM experts to map the propositions related to the future of work to the six factors of BPM of Rosemann and vom Brocke's framework (strategic alignment, governance, methods, IT, people, and culture). Using Rosemann and vom Brocke's (2015) framework is sensible as it has been extensively referenced by fellow BPM researchers and captures how BPM is conceptualized today. Based on the mapping of propositions to BPM factors, we discussed how the capability areas of the BPM framework should evolve in light of the future of work. Thereby, we believe that the related changes are more of an evolutionary than a revolutionary nature. In our study, we take an operational perspective on work, which we define as "the application of human, informational, physical, and other resources to produce products/services" (Alter, 2013, p. 75).

Since the connection between the future of work and BPM is complex, this study can only be an initial attempt to explore relevant changes in the way BPM is conceptualized. We are aware that our findings may suffer from subjective influences, as we did not involve the entire BPM community so far. Nevertheless, with this study we aim at complementing existing initiatives on the future of BPM, triggering a discussion in the BPM community, and providing initial insights into implications of the future of work.

The study is organized as follows: In section 2, we provide theoretical background on BPM in general and on BPM capability development in particular. In section 3, we elaborate on the research method. In section 4, we present the results of each research phase. In section 5, we point to key limitations of our work and directions for future research.

2. Theoretical Background

BPM comprises "the skills and routines necessary to successfully apply measures of both incremental and radical change with the goal to improve the effectiveness and efficiency of business processes" (Pöppelbuß et al., 2015, p. 3). BPM is closely related to capability development, a field that builds on the resource-based view and on dynamic capability theory (Niehaves et al., 2014). Conceptualizing and investigating BPM from a capability perspective is very popular in BPM research (Forstner et al., 2013; Niehaves et al., 2014; Rosemann and vom Brocke, 2015; Trkman, 2010; van Looy et al., 2014). As its practical suitability has also been empirically validated (Plattfaut, 2014), we adopted the capability perspective when exploring how BPM needs to evolve in light of the future of work.

According to the resource-based view, capabilities refer to the ability to perform a set of tasks for achieving a particular result (Helfat and Peteraf, 2003). From a dynamic capability theory perspective, capabilities split into operational and dynamic capabilities (Pavlou and El Sawy, 2011). Operational capabilities refer to an organization's basic functioning, whereas dynamic capabilities help to integrate, build, and reconfigure operational capabilities to increase their fit with the environment as well as their effectiveness and efficiency (Kim et al., 2011; Winter, 2003). In the literature, processes and their execution are equated with operational capabilities, whereas BPM is treated as a specific dynamic capability (Forstner et al., 2013; Pöppelbuß et al., 2015).

Research on BPM as a corporate capability follows three streams. The first stream focuses on the structuration of BPM and on developing related capability frameworks (Jurisch et al., 2014; Rosemann and vom Brocke, 2015; van Looy et al., 2014). The common approach is to group similar capabilities into capability areas and eventually into factors (Rosemann and vom Brocke, 2015). Jurisch et al. (2014), for instance, derive process management as well as IT and change management capabilities needed for business process change. Van Looy et al. (2014) present six capability areas with 17 sub-areas for business process maturity. The most prominent and holistic BPM capability framework is that by Rosemann and vom Brocke (2015). As we rely on this capability framework as a reference point in our research, we provide more details below. The second research stream is concerned with describing how organizations typically develop their BPM capability and how different types of BPM capability development can be explained (Niehaves et al., 2014; Pöppelbuß et al., 2015). The third research stream related to BPM capability development takes a prescriptive perspective, providing methods and recommendations on how to develop BPM in light of different organizational contexts (Darmani and Hanafizadeh, 2013; Lehnert et al., 2014). In this context, maturity models were long-time seen as the most appropriate tool for capability development (Forstner et al., 2013; Röglinger et al., 2012). However, as they have been criticized for ignoring path dependencies and for propagating a one-size-fits-all approach, they significantly lost popularity in BPM research over the last years (Lehnert et al., 2014; Niehaves et al., 2014).

Table 1. The BPM Capability Framework by Rosemann and vom Brocke (2015)

Strategic Alignment	**Governance**	**Methods**	**Information Technology**	**People**	**Culture**	**Factors**
Process Improvement Planning	Process Management Decision Making	Process Design & Modelling	Process Design & Modelling	Process Skills & Expertise	Responsiveness to Process Change	**Capability Areas**
Strategy & Process Capability Linkage	Process Roles and Responsibilities	Process Implementation & Execution	Process Implementation & Execution	Process Management Knowledge	Process Values & Beliefs	
Enterprise Process Architecture	Process Metrics & Performance Linkage	Process Monitoring & Control	Process Monitoring & Control	Process Education	Process Attitudes & Behaviors	
Process Measures	Process Related Standards	Process Improvement & Innovation	Process Improvement & Innovation	Process Collaboration	Leadership Attention to Process	
Process Customers & Stakeholders	Process Management Compliance	Process Program & Project Management	Process Program & Project Management	Process Management Leaders	Process Management Social Networks	

In order to examine in a structured manner how the future of work impacts BPM, we rely on Rosemann and vom Brocke's (2015) BPM capability framework (Table 1). We use this BPM capability framework as a reference point as it captures well how BPM is conceptualized today. Rosemann and vom Brocke's (2015) capability framework is based on a rigorous Delphi study and takes a holistic perspective, covering a broad spectrum of topics associated with BPM research and practice. As the framework has been referenced by many fellow BPM researchers, it can not only be seen as a comprehensive, but also as the most prominent BPM capability framework to date. Rosemann and vom Brocke's framework comprises six factors critical to BPM, i.e., strategic alignment, governance, methods, IT, people, and culture. Each factor, in turn, includes five capability areas. Strategic alignment is concerned with the synchronization between processes and an organization's strategic goals. Governance investigates the roles and responsibilities as well as decision-making processes related to BPM. Methods comprises the "set of tools and techniques that support and enable activities along the process lifecycle and within enterprise-wide BPM initiatives" (Rosemann and vom Brocke, 2015, p. 111). IT emphasizes the IT support across the BPM lifecycle. People refers to the role of employees in processes, whereas culture reflects "collective values and beliefs in regards to the process-oriented organization" (Rosemann and vom Brocke, 2015, p. 118). Table 1 provides an overview of the individual factors and capability areas in the capability framework.

3. Research Method

In order to examine how BPM as a corporate capability needs to evolve in light of the future of work, we follow a three-phase research method. In the first phase, we used a structured literature review to compile propositions from the existing body of knowledge that capture constitutive features of the future of work. In the second phase, a panel of BPM experts mapped the resulting propositions to the six factors of Rosemann and vom Brocke's (2015) BPM capability framework. In the third phase, we discussed the factors and capability areas included in the BPM capability framework according to the mapping results.

In the first phase, two authors performed separate structured literature reviews using the "future of work" as full-text search term in SpringerLink (http://link.springer.com), AISeL (http://aisel.aisnet.org), and ScienceDirect (http://www.sciencedirect.com). The goal of this phase was to identify constitutive characteristics of the future of work as contained in the existing body of knowledge. When conducting the literature review, both authors adhered to the guidelines established by vom Brocke et al. (2015) as well as Webster and Watson (2002). Content-wise, the literature review was restricted to work from an operational viewpoint, which complies with the focus of BPM (van der Aalst, 2013). Consequently, publications that examine interfaces between the future of work with areas such as labor law or remuneration policies were excluded. Due to the very sporadic occurrence of the term "future of work" in sources published before the year 2000, the literature review was further restricted to the time period between 2000 and 2015. To get a holistic picture of the future of work, we also included four reports from leading consulting and government agencies as well as three seminal books, i.e., "The Future of Work" (Malone, 2004), "Enterprise 2.0" (McAfee, 2009), and "The Second Machine Age" (Brynjolfsson and McAfee, 2014). Each author checked all identified sources for quotations with a definitional character, collected these quotations, and aggregated these quotations into initial propositions each of which covers a constitutive feature of the future of work. We consolidated the initial propositions in five workshops within the entire author team to eliminate redundancies and achieve a consistent level of abstraction. We also checked that each quotation was covered by one or more propositions and that each proposition was underpinned by several quotations. The intention of starting with the extraction of quotations was to create a comprehensive and detailed list of features regarding the future of work. The purpose of aggregating quotations into propositions was to compile a more manageable, yet still comprehensive picture of the future of work that can be used in the following research phases. In sum, the literature review yielded 23 propositions derived from 526 quotations and 37 sources. All sources are included in the references section marked with an asterisk (*). As final step of the first research phase, we validated the propositions with two external experts (i.e., professors doing research on the future of work with more than 10 years of experience) for completeness and consistency.

In the second phase, we conducted a consensus-based, multi-round mapping process, in which we established a connection between the propositions related to the future of work and the factors of Rosemann and vom Brocke's (2015) BPM capability framework (Fink et al., 1984). This second phase served as an intermediate step to reduce the complexity of our approach and to make our conclusions in the last research phase more transparent. Considering all propositions for each factor would have required to analyze 138 (23x6) combinations, making it impossible to trace the most significant effects. To conduct the mapping of propositions to factors, we asked a panel of ten BPM experts to assign each proposition to those BPM factors that they deem will be affected most strongly by the respective proposition. We decided against letting the BPM experts map the propositions to the 30 individual capability areas for the same reason as mentioned above, as the task complexity would have been too high to solve the mapping in a "timely and economical way" (Fink et al., 1984, p. 981). We had to deal with very specific and rather broad propositions. Some propositions are such specific that it was obvious from the beginning that they do not affect all factors. Moreover, BPM and the future of work have evolved independently such that there is no intuitive or established mapping. Overall, we granted the BPM experts the degree of freedom to choose zero, one, or two BPM factors per proposition and also asked them to validate the propositions regarding understandability. We recruited BPM researchers who had several years of experience in the field and were familiar with Rosemann and vom Brocke's (2015) capability framework. Four of the experts had an IT and the others – a business background. Furthermore, half of the experts had considerable experience in BPM-related industry projects. We measured the consensus among the experts using an adapted version of Cohen's Kappa (Kraemer, 1980). Using an adapted version was necessary as the experts were allowed to assign each proposition to zero, one, or two factors of the capability framework. According to the guidelines on consensus methods, we set a satisfactory consensus level at a Kappa value of 0.61 (Fink et al., 1984), which equals substantial agreement on the Landis and Koch (1977) scale. In the first mapping round, in which the experts worked independently of one another, we achieved a Kappa of 0.43. The second mapping round, in which the experts could access the anonymized and aggregated mapping results of the initial round, yielded a Kappa of 0.63, satisfying our predefined consensus requirement. Thus, the mapping procedure ended after the second round. Thus, the result of the second research phase is a 23x6 matrix (23 propositions, 6 factors), containing the cumulated votes of the second mapping round. As input for the third research phase, we used those mapping results where a proposition received five or more votes regarding a distinct BPM factor, i.e., a consideration by at least 50% of the BPM experts. This selection rule resulted in a manageable number of propositions per BPM factor.

In the third phase, we discussed the capability areas of Rosemann and vom Brocke's (2015) BPM capability framework according to the mapping results. To do so, we again conducted a series of workshops within the author team. In order to structure the discussion and to mitigate subjective influences, each author first considered the influence of each proposition, which has been selected for a distinct BPM factor, on all related capability areas independently. We then consolidated the individual results.

4. Results

4.1. Compiling constitutive features of the future of work

As the result of the first research phase, Table 2 shows 23 propositions that capture constitutive characteristics of the future of work as contained in the existing body of knowledge. Table 2 further indicates how many sources from the structured literature review support each proposition. Finally, Table 2 highlights the number of votes that each proposition received from the BPM experts regarding the factors of Rosemann and vom Brocke's (2015) BPM capability framework in the second research phase. The factors are named by their initial letter, i.e., S for strategic alignment, G for governance, M for methods, I for information technology, P for people, and C for culture.

It can be seen that the propositions vary regarding the extent to which they have already been adopted in current work practices. While the automation of tasks (P10), for instance, is already in full swing and cannot be considered as innovative or disruptive anymore, establishing market principles in organizations (P20) has by far not become a widespread practice yet. Therefore, some propositions refer to well-adopted trends, whereas others are in an early stage of development. This, however, does not imply that well-adopted propositions will not influence the way BPM should be conceptualized in light of the future of work. The automation of tasks (P10), for example, has been and still is central to BPM research and practice. Nevertheless, it drives many of today's developments related to digitalization in general and the Internet of Things in particular (Moore, 2015). In order not to bias the picture of the future of work as contained in the existing body of knowledge, we deliberately included well-adopted propositions in our analysis as well.

Table 2. Propositions capturing the future of work and their mapping to BPM factors

ID	Proposition	Supp.	BPM Factors					
			S	G	M	I	P	C
P01	Ethical and work values as well as reputation will play an important role.	11	2	1	0	0	4	**9**
P02	Technology will complement human abilities.	10	1	0	0	**10**	**5**	2
P03	Work assignments and routines will change constantly.	11	0	**8**	**8**	0	1	0
P04	Work will be carried out independent of time and place.	17	0	0	0	**8**	0	**9**
P05	Work will require higher cognitive and creative capabilities.	15	0	0	0	0	**10**	0
P06	Workers will be highly specialized.	8	0	0	1	0	**10**	0
P07	Workers will be required to learn constantly on the job.	11	0	0	0	0	**10**	2
P08	Workers will require entrepreneurial thinking.	3	0	0	0	0	**9**	**6**
P09	Teams will be assembled and changed dynamically.	6	0	**8**	1	0	2	3
P10	Technology will be used to automate tasks.	11	1	0	2	**10**	0	0
P11	Work will be communication- as well as knowledge-intensive.	26	0	0	2	1	**9**	0
P12	Work will be conducted predominantly in projects.	7	0	**7**	**8**	0	0	3
P13	Workers will be free agents.	15	0	0	0	0	**8**	**6**
P14	Workers will be highly connected in communities.	16	0	0	0	1	**8**	**7**
P15	Collective intelligence will be important in decision-making.	6	0	**5**	1	0	4	**8**
P16	Decision-making will be decentralized.	10	0	**9**	1	0	0	4
P17	Finding and cultivating talents will be a key challenge.	4	**8**	1	0	0	3	**6**
P18	Information will be readily available independent of time and place.	6	0	0	1	**10**	0	1
P19	Low-skill, out-of-competence work will be outsourced.	7	**7**	**10**	0	0	0	1
P20	Market principles will be applied within organizations.	7	**10**	4	0	0	0	3
P21	Organizational hierarchies will be loose and flat.	17	0	**7**	0	0	0	**9**
P22	Organizations will exhibit a core-periphery structure.	4	**8**	**8**	0	0	0	2
P23	Technology will support all kinds of interactions.	5	1	0	2	**9**	0	1

The propositions also differ in the number of supporting sources. We partly attribute this finding to the propositions' different level of adoption in current work practices, as pointed out in the previous paragraph. However, as can be seen, well-adopted propositions need not necessarily be more present in the literature on the future of work. There is a complex connection between a propositions' level of adoption and the number of supporting sources. The second idea that may play a role in the different number of supporting sources is that some propositions may be viewed as more central to the future of work than others. As an example, entrepreneurial thinking (P08) is a very broad proposition that affects operational work only indirectly. The independence of context factors like time and place (P04), in contrast, directly influences how operational work is performed. Analogous to the extent with which propositions have already been adopted in current work practices, we decided not to base the decision whether to include a proposition on its support to provide multiple viewpoints on the future of work.

4.2. Mapping the propositions to BPM factors

As already stated, columns S to C from Table 2 contain the number of votes the individual propositions received from the panel of BPM experts in the second research phase. More precisely, these columns show the total number of votes that the propositions received in the second mapping round, in which we achieved substantial consensus according to the applied Kappa coefficient. The cells highlighted in grey indicate the mapping results we selected as input for the third research phase as they received votes from at least 50% of the involved experts. Table 3 summarizes the numbers and concrete subsets of propositions mapped to the factors of Rosemann and vom Brocke's (2015) BPM capability framework.

The varying number of propositions per BPM factor suggests that the future of work will not influence all facets of BPM with equal strength. In particular, the factors methods, strategic alignment, and IT feature a rather low number of selected propositions. This finding is not surprising as methods and IT have been and still are at the core of BPM research and practice (Rosemann, 2014; van der Aalst, 2013). Similarly, strategic alignment has recently caught up, receiving ever more attention (Buhl et al., 2011; Rosemann, 2014; vom Brocke et al., 2014). In contrast, the soft factors people and culture, which have not yet been the focal points of BPM research (Schmiedel et al., 2014), consequently received a high number of propositions. Therefore, the BPM factors people and culture will be strongly influenced by the future of work, yielding a new balance between the hard and the soft factors of BPM. Most surprisingly, the factor governance, which has been extensively researched and is a core topic of BPM practice (Doebeli et al., 2011), received as many propositions as culture and people. One reason may be that the future of work propagates customization and flexibility as core value, while challenging current practices that rely on predictability, uniformity, and consistency, a development that will disrupt how operational work needs to be governed (Notter, 2015). We provide a more detailed rationale in section 4.3.

Table 3. Selected propositions per BPM factor

BPM Factor	Number of selected propositions	Selected propositions
Strategic alignment	4	P17, P19, P20, P22
Governance	8	P03, P09, P12, P15, P16, P19, P21, P22
Methods	2	P03, P12
Information technology	5	P02, P04, P10, P18, P23
People	8	P02, P05, P06, P07, P08, P11, P13, P14
Culture	8	P01, P04, P08, P13, P14, P15, P17, P21

4.3. Rethinking BPM as a corporate capability

Based on the intermediate results shown in Tables 2 and 3, we now explore how BPM as a corporate capability needs to evolve in light of the future of work. To do so, we present our view on the changes within the BPM factors (i.e., strategic alignment, governance, methods, information technology, people and culture) and capability areas guided by the propositions selected in the second research phase. For each factor, we provide a general introduction before discussing each capability area. In Table 4, which is located at the end of this section, we summarize overarching capability-oriented topics which we think will shape BPM in the future of work across all factors of the BPM capability framework.

4.3.1. Strategic alignment

In Rosemann and vom Brocke's (2015) capability framework, strategic alignment refers to the synchronization between processes and organizational goals. Overall, a much more dynamic organizational periphery (P22) as well as increased outsourcing (P19) will lead to complex and rapidly changing organizational setups. It will be challenging to retain an overview of cross-organizational processes and to maintain their strategic fit. Moreover, it will be necessary to seamlessly integrate external partners rapidly and to ensure process continuity. Finally, the growing need for cultivating talents (P17) will require leveraging human capabilities to match organizational goals.

Process improvement planning will be more difficult due to the variety and heterogeneity of actors (P22) involved. Thus, it will need to be flexible enough to account for different workers at the periphery (P22) as well as for external partners (P19). In addition, the introduction of market principles (P20) has the potential to offer individual workers, teams, and departments appropriate incentives to improve their operations as well as to prioritize process improvement opportunities.

Regarding *strategy and process capability linkage,* the need for cultivating talents (P17) requires an increased effort when matching human capabilities to strategic goals. The opposite will be true, too, i.e., strategic goals must be aligned with the workers' capabilities. The increasing complexity of the organizational ecosystem (P22) will further complicate maintaining the strategic fit of all processes. Moreover, novel performance indicators that result from the use of market principles (P20) will have to be used to measure the synchronization of processes and strategic goals.

Enterprise process architecture, which deals with an organization's process landscape, will need to extend its scope to cover value networks and ecosystems with fast-changing actors (P19, P22). Since organizational boundaries will continuously blur, enterprise process architectures must ensure the integration of business processes across value networks, while maintaining an end-to-end perspective.

Process measures will benefit from market principles (P20) because process outcomes will be exposed to market conditions. Therefore, there will be fewer opportunities for inefficiencies to remain unnoticed. Maintaining an overarching process performance measurement warehouse will allow for the cross-organizational navigation through real-time process performance metrics.

Regarding *process customers and stakeholders*, establishing market principles (P20) will cause organizations to be more attentive to external and internal customers. Coupled with an increased attention on managing the organization's talent pool (P17), this development will require to leverage workers' capabilities more efficiently to satisfy customer needs. Stronger outsourcing (P19) combined with a more volatile organizational periphery (P22) will pose a challenge on coordinating all involved stakeholders.

4.3.2. Governance

BPM governance is "dedicated to appropriate and transparent accountability in terms of roles and responsibilities" (Rosemann and vom Brocke, 2015, p. 114). It also regulates decision-making and reward processes. Since work practices will change constantly (P03) and shift more towards projects (P12), we anticipate process and project management governance mechanisms to merge. Just like the fusion of development and operations (DevOps) is an ever more employed paradigm in software development, the fusion of processes and projects can help organizations deal with the complexity and volatility of future work environments (Hüttermann, 2012). Variation in teams (P09) and work assignments (P03) also requires shifting management attention from single processes to process portfolios, in which synergies can be leveraged and dependencies among processes can be managed (Lehnert et al., 2015).

As for *process management decision-making*, the ability to quickly reconfigure processes will be crucial as work assignments and routines will change constantly (P03). Retaining an overview as well as ensuring consistency will be challenges in case of increasingly decentralized decisions (P16), the loss of control over outsourced work (P19), and flat hierarchies (P21). Another implication of decentralized decision-making (P16) is that processes will depend even more on the workers' capabilities.

Process roles and responsibilities will have to be redefined as the share of project work increases (P12) and the boundary between process and project management blurs. Existing roles will merge with roles employed in project management. Further, novel roles such as process portfolio managers and process team capability managers will emerge in order to ensure the matching of flexible process requirements and workers' capabilities for compiling adequate cross-functional teams.

Clear accountabilities for collecting and evaluating *process metrics and performance linkage* will be required such that it can be carried out fast and reliably in a value network (P22).

Process-related standards will be more difficult to enforce due to the project character of work (P12) coupled with the increased involvement of external partners and a more widespread organizational periphery (P19, P21, P22). Therefore, process-related standards will need to be complemented by service-level agreements and project-related norms.

We do not see significant changes in the capability area *process management compliance*.

4.3.3. Methods

BPM methods comprise the range of tools and techniques that support business processes throughout their lifecycle (Rosemann and vom Brocke, 2015). As pointed out with respect to the factor governance, the emerging variety of work patterns (P03), ranging from knowledge-intensive and creative to routine, will cause the boundary between processes and projects blur. The use and development of hybrid methods at the interface of process and project management will be required to support such work patterns, just as DevOps combines tools from software development and operations to streamline software delivery procedures (Hüttermann, 2012). As a result, the number of processes, for which traditional imperative process models can be designed, will decline.

Process design and modelling will be affected by the increasing project character of work (P12) as well as by rapidly changing work assignments (P03). Routine processes are increasingly giving way to unstructured, knowledge-intensive work (Herrmann and Kurz, 2011). Process design methods, thus, need to be further developed to adequately support such work patterns. As an example, declarative modeling has already been employed by practitioners in conjunction with traditional methods (Reijers et al., 2013). Another example is the application of adaptive case management approaches in knowledge-intensive processes (Herrmann and Kurz, 2011). The speed of identifying suitable process models or fragments as well as creating new models will be crucial and will demand innovative approaches to storing, reusing, composing, and configuring process models (La Rosa et al., 2011).

In the capability area *process implementation and execution*, process definition and go live will need to be much more agile to cope with continuously changing requirements at run time (P03). Similarly, *process monitoring and control* methods as well as performance measures will have to be broadly applicable as process outcomes will vary with constantly changing work assignments and routines (P03).

Due to shorter process life-cycles, *process improvement and innovation* will entail fewer opportunities for operational improvements such as refining process reliability. Instead, process exploration, i.e., the effective and efficient capitalization on emerging process and technical opportunities (Rosemann, 2014), will take center stage.

In our view, the capability area *process program and project management* will not experience significant transformations in light of the future of work.

4.3.4. Information technology

Information technology (IT) encompasses the “software, hardware, and information systems that enable and support process activities” (Rosemann and vom Brocke, 2015, p. 116). IT will be instrumental in disentangling work from context factors such as time and place (P04). However, its domain will spread beyond the sole automation of routine tasks (P10) and management of workflows. On the one hand, IT will acquire its own agency, which allows smart connected things to autonomously interact with process workers at eye level (P23) (Kees et al., 2015; Porter and Heppelmann, 2015). On the other hand, IT will support process workers in creative and knowledge-intensive processes (P02) by managing and optimizing the information flow (P18) as well as by capitalizing on process data through advanced analytics.

Regarding *process design and modelling*, IT will be capable of autonomously generating various types of process models (P02, P10), based on the information flow among process participants and requirements for individual tasks.

As for *process implementation and execution*, smart systems as well as networks thereof will take over process roles similar to those of process workers. The interplay of IT, smart things, and humans (P02, P23) will lead to new forms of interaction in terms of cyber-physical/cyber-human systems (Gimpel and Röglinger, 2015). Further, cognitive assistants will assist workers by organizing and prioritizing information, resource allocation, and taking task control decisions (Lewis, 2014).

Process monitoring and control will face the challenge of dealing with decentralized and loosely coupled human as well as technical activities that have to be coordinated. To cope with that challenge, IT will have to enable simultaneous monitoring and control at runtime. Moreover, smart IT that “understands” the semantics and purpose of interactions (P23) will provide more contextual information about the state of a given process.

Process improvement and innovation will be enhanced by IT’s ability to extract the meaning and predict the behavior of processes. Digital technologies such as recommender systems for process improvement and predictive analytics solutions will be able to automatically spot improvement opportunities as well as compile and suggest respective process fragments, advancing the explorative character of process improvement (Rosemann, 2014).

Just like in the factor methods, we do not anticipate considerable transformations in the capability area *process program and project management* in light of the future of work.

4.3.5. People

The factor people refers to the “individuals and groups who continually enhance and apply their process and process management skills and knowledge to improve business performance” (Rosemann and vom Brocke, 2015, p. 117). Increasing demands on the workers’ creativity (P05), the ability to learn continuously (P07), and the ability to capitalize on existing knowledge (P11) will increase the importance of recruiting procedures. Managing the workers’ capabilities will ever more make the difference in process results, given the dynamic and unstructured nature of work. Fostering entrepreneurial thinking (P08) as well as the workers’ digital skillset and mindset will be crucial for acting upon improvement opportunities. As workers will be highly specialized (P06), organizations will need to pay increased attention to retaining people who can cope with knowledge heterogeneity and act as boundary-spanners (Fleming and Waguespack, 2007).

The capability area *process skills and expertise* will be affected by workers who, as free agents, will not identify themselves with a single organization (P13) and by the rising specialization of the workforce (P06). Leveraging knowledge communities will be central to keeping workers' skills up-to-date given that workers will be increasingly connected (P14) and required to learn constantly on the job (P07).

Process education will put an emphasis on soft skills since work will be communication-intensive (P11) and increasingly driven by collaboration. Continued specialization (P06) increases the need for boundary-spanners with knowledge at the interfaces of different disciplines and communication skills. However, process education will come to its limits when dealing with tasks that require higher cognitive and creative capabilities (P05), which are inherently difficult to train.

Process collaboration will take on various forms as new digital affordances such as smart objects, intelligent systems, and real-time analytics become parts of processes. A connected workforce (P14) with a digital mindset and affinity to technology will quickly utilize the opportunities of digital affordances. Emerging collaboration models will need to effectively support both ad-hoc and unstructured processes due to the decreasing fraction of routine work (P11). Furthermore, workers will be expected to quickly adapt to new process teams and unfamiliar environments (P07).

Process management leaders will be free agents themselves (P13), not necessarily affiliated with a particular organization. Still, they will have to find ways to effectively leverage the intelligence, creativity, and entrepreneurial spirit of workers from multiple organizations and to motivate these workers to perform tasks that demand higher-order skills (P05). One specific challenge for process management leaders will be to create a common understanding of work in teams of free agents (P06, P13). As outlined, bridging different knowledge areas will require the active involvement of boundary-spanners.

In light of future of work, we do anticipate severe changes in the capability area *process management knowledge*, which refers to specific BPM expertise only.

4.3.6. Culture

The factor culture comprises process-related values, beliefs, and behavior workers comply with in organizational settings (Rosemann and vom Brocke, 2015). While this factor mainly focuses on attitudes to process improvement, commitment to processes, and their role in organizations, we expect its meaning to broaden in the future. Since work will be independent of context factors (P04) and increasingly dynamic, culture will need to embrace agility as a core value to quickly adapt to new opportunities and react upon changes in the outside world. This observation is consistent with the CERT value framework, which promotes responsiveness to process output recipients and continuous orientation towards improvement and innovation (Schmiedel et al., 2014). As ideas, work practices, and beliefs spread across traditional structures, organizations need to become more open to avoid a not-invented-here-mentality (Piller and Antons, 2015). The importance of an open culture has already been highlighted in the context of open innovation (Herzog and Leker, 2010), but needs to be interpreted more broadly. Moreover, a strongly pronounced human-centered approach is required since human capabilities will largely determine process outcomes – people will be involved in both decentralized and collective decision-making (P15) and will be expected to act as entrepreneurs (P08) to advance organizational goals.

Responsiveness to process change needs to be fostered as changes in processes will be much more common due to the high variability of the contexts they are executed in (P04). Further, flat hierarchies (P21) will offer low-level workers more opportunities to modify processes, requiring an organization-wide commitment to acting in the best interest of processes stakeholders. Organizations will have to embrace the challenge that processes need to be constantly changed (Schmiedel et al., 2014).

The capability area *process values and beliefs* will undergo changes, too. As workers become increasingly independent from organizational procedures and hierarchies (P04, P13) and observe ethical and work values (P01), their understanding of processes will diverge. Another challenge will be to avoid the thinking-inside-the-box-mentality (P08). The widespread use of collective intelligence mechanisms for decision-making (P15) will also require a high level of commitment (Schmiedel et al., 2014).

In the capability area *process attitudes and behaviors* workers' willingness to be thoroughly engaged in processes may be endangered by an increasing separation of work from physical locations and/or time (P04). An entrepreneurial culture (P08) implies that process improvement will be initiated more often due to strong competition among process teams. Moreover, workers' acceptance of improvement priorities set via collective intelligence (P15) will have to be established.

Leadership attention to process management will play a less significant role as there will be fewer management levels (P21). Rather, it will be crucial that everybody in the organization reflect on processes and adopt a process-oriented mentality.

We do not expect any significant changes in the capability area *process management social networks.*

Table 4. Overarching BPM capability topics in connection with the future of work

BPM as a corporate capability needs to…
1. …support the shift from individual processes to process portfolios.
2. …offer methods that address the blurring boundaries between processes and projects.
3. …enable the integration of smart connected things into processes.
4. …enable levering process data for value creation and innovation.
5. …support the handling of agile and knowledge-intensive processes.
6. …ensure process continuity in rapidly changing ecosystems.
7. …maintain the focus on human capabilities in addition to process technology.
8. …promote the integration of boundary-spanners into process teams.
9. …enable the integration of process partners across value networks.
10. …foster the openness of processes towards external ideas and work practices.

5. Discussion and Conclusion

With the objective of complementing existing initiatives on the future of BPM, we investigated how BPM as a corporate capability needs to evolve in light of the future of work. To this end, we first performed a structured literature review and derived 23 propositions that capture constitutive features of the future of work as included in the existing body of knowledge. In order to examine in a structured manner how the future of work impacts BPM, we then asked a panel of BPM experts to map these propositions to the six factors of Rosemann and vom Brocke's (2015) BPM capability framework, which captures how BPM is conceptualized today. Finally, based on the mapping of propositions to BPM factors, we discussed how the capability areas included in the BPM capability framework will change. Thereby, we highlighted overarching topics which we think will shape BPM as a corporate capability in light of the future of work.

Our study revealed that the future of work will influence our understanding of how BPM can help organizations to ensure effective and efficient work. In the future, BPM will have to deal with processes that are increasingly agile, knowledge-intensive, and data-driven. Work will be characterized by a rapid change of teams, tasks, and goals. It will also be carried out anytime anyplace. Digital affordances will enable and require the fast and far-reaching reorganization of processes. Further, organizations will increasingly utilize market principles, flatten their hierarchies, and decentralize decision-making authorities. We found that the future of work will particularly affect the BPM factors culture, governance, and people. Nevertheless, to live up to these new developments, BPM as a whole needs to evolve. The increasing fraction of project-like and unstructured work will make the distinction between processes and projects blur. Supporting such work requires hybrid methods that build on BPM and project management. Moreover, BPM will have to ensure the smooth functioning of processes confronted with high volatility in teams and ecosystems as well as enable the seamless integration of external partners across value networks. BPM will also have to capitalize on the growing potential of digital technologies to complement human participation in processes and to leverage process data for innovation. At the same time, a human-centric culture that fosters the leading role of people in processes is indispensable since process outcomes will require significant creative, cognitive, entrepreneurial, and boundary-spanning skills. Finally, BPM needs to be open toward ideas and work practices from the outside to avoid complacency with internal procedures and to capitalize on improvement opportunities.

This study is beset with limitations that stimulate further research. As already argued, the propositions that capture constitutive characteristics of the future of work have different levels of adoption in current work practices, a different breadth in scope, and may be viewed differently depending on how central they are for the future of work. Even though the propositions have been validated by two experts from the field of the future of work as well as by additional ten BPM experts who mapped them to the BPM factors, we deem a broader literature review as well as the involvement of more BPM experts in the exploration and validation of propositions regarding the future of work a worthwhile endeavor. Furthermore, we believe the involvement of experts with a more diversified academic as well as professional background will be beneficial for the mapping procedure. When reasoning about how BPM as a corporate capability needs to evolve in light of the future of work using Rosemann and vom Brocke's (2015) BPM capability framework as a reference point, we neither added nor discarded individual capability areas. More importantly, though based on the propositions, our review of the BPM capability framework suffers from subjective influences, as our author team and the involved expert team still is rather small. In order to mitigate these subjective influences and to trigger a broad discussion about the future of BPM in the future of work, we recommend mobilizing more BPM experts from academia and industry in a community-wide initiative. As Rosemann and vom Brocke's (2015) BPM capability framework has been conceived based on a global Delphi study, this method may also shape up sensible for advancing the insights of our study. Thus, we invite fellow researchers to challenge and extend our conclusions and, thereby, help conceptualize the future of BPM in the future of work.

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VI. Summary and Future Research

This chapter summarizes the dissertation along with key findings and outlines potential starting points for future research.

1. Summary

The main objective of this dissertation was the investigation of the intersection of business process improvement and Business Process Management (BPM) capability development. For this purpose, the research field of *process project portfolio management* was invented in this dissertation, which accounts for multiple business objects (e.g., processes, BPM capability areas, projects, performance dimensions) and for interactions among these objects (e.g., interactions among processes, interactions among projects, or interactions among BPM capability areas and processes). For an integrated planning of process improvement and BPM projects it is crucial to consider these process and project interactions. This dissertation presented six research papers, each focusing on a specific aspect in the field of *process project portfolio management*. In the following, the key findings of the corresponding research papers embedded in this dissertation are outlined consecutively.

The second chapter explored the intersection of business process improvement and BPM capability development, by drawing from knowledge on BPM, project portfolio management, and performance management. The focus was on the integrated planning of business process improvement and BPM capability development as this is where both streams have the closest interaction. Therefore, in the second chapter the field of *process project portfolio management* was structured in detail and a research agenda, including several exemplary research questions and potential research methods, was proposed.

The third chapter investigated how organizations can develop their BPM capability and improve individual processes in an integrated manner. The in the third chapter developed planning model assists organizations in determining which BPM and process improvement 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. The planning model recommends selecting projects that, scheduled in a particular way, create the highest value contribution, which is measured in terms of the respective project roadmap's net present value. By differentiating between multiple periods, the planning model captures the long-term effects of 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. The planning model contributes to the prescriptive body of knowledge related to BPM capability development and process decision-making. Finally, the planning model integrates multiple processes, multiple projects, and multiple periods. The in the third chapter introduced Value-based Process Project Portfolio Management (V3PM) tool facilitate process managers for calculating scenarios of non-trivial complexity, including the mentioned multi-project, multi-process and multi-period perspective, to plan projects for process improvement as well as BPM capability development. The developed tool is useful and easy-to-use for decision-making, moreover calculates effectively and efficiently the net present value of quite a lot of BPM roadmaps derived from different scenarios.

The fourth chapter investigated how processes can be prioritized considering both their individual need for improvement and their interconnectedness. The ProcessPageRank (*PPR)* algorithm was invented that ranks processes according to their network-adjusted need for improvement, based on justificatory knowledge from BPM and network analysis. The network-adjusted need for improvement integrates the processes' individual need for improvement, which builds on indicators related to multiple performance dimensions, with the network structure among processes captured via the use relations included in a business process architecture. Thereby, process prioritization decisions require the processes' stand-alone need for improvement, their interconnectedness, and the intensity of the relations among one another to be considered. Overall, the *PPR* is the first approach to consider process interconnectedness when prioritizing processes for improvement purposes. The *PPR*'s design specification was validated by using a panel of BPM experts and by implementing the design specification as a software prototype. Also an in-depth interview with a BPM expert and a demonstration example was conducted to challenge the *PPR*'s applicability and usefulness.

The fifth chapter had the objective to complement existing initiatives on the future of BPM by investigating how BPM as a corporate capability needs to evolve in light of the future of work. To this end, first a structured literature review was performed and 23 propositions that capture constitutive features of the future of work as included in the existing body of knowledge were derived. In order to examine in a structured manner how the future of work impacts BPM, a panel of BPM experts mapped these propositions to the six factors of Rosemann and vom Brocke's (2015) BPM capability framework, which captures how BPM is conceptualized today. Finally, based on the mapping of propositions to BPM factors, the chapter showed how the capability areas included in the BPM capability framework will change and which overarching topics will shape BPM as a corporate capability in light of the future of work. The result is that the future of work will influence the understanding of how BPM can help organizations to ensure effective and efficient work. BPM will have to deal with processes that are increasingly agile, knowledge-intensive, and data-driven. Work will be characterized by a rapid change of teams, tasks, and goals. It will also be carried out anytime anyplace. Digital affordances will enable and require the fast and far-reaching reorganization of processes. Further, organizations will increasingly utilize market principles, flatten their hierarchies, and decentralize decision-making authorities. The increasing fraction of project-like and unstructured work will make the distinction between processes and projects blur. Supporting such work requires hybrid methods that build on BPM and project management. Moreover, BPM will have to ensure the smooth functioning of processes confronted with high volatility in teams and ecosystems as well as enable the seamless integration of external partners across value networks. BPM will also have to capitalize on the growing potential of digital technologies to complement human participation in processes and to leverage process data for innovation. At the same time, a human-centric culture that fosters the leading role of people in processes is indispensable since process outcomes will require significant creative, cognitive, entrepreneurial, and boundary-spanning skills. Finally, BPM needs to be open toward ideas and work practices from the outside to avoid complacency with internal procedures and to capitalize on improvement opportunities.

In summary, the research papers included in this dissertation contributed to research related to the field of *process project portfolio management*. The research of this dissertation also yielded topics for further research that are outlined in the following section.

2. Future Research

Based on the limitations of the research papers embedded in this dissertation, continuative questions emerge that might serve as starting points for further research. These are outlined for each research paper, respectively.

The second chapter main limitation is that it reflects the authors' individual viewpoint based on experiences of several industry projects and prior research. Although the proposed structure for *process project portfolio management* as well as the research questions are based on extant knowledge, both may suffer from subjective influences. Other theoretical lenses for structuring the intersection of business process improvement and BPM capability development might be possible as well. Moreover, the compiled research questions and potential research methods are not exhaustive. These questions and methods serve as starting points for exploring the intersection of both research streams. This limitation is inevitable, as the second chapter had not the aim to propose a final statement about the intersection of business process improvement and BPM capability development, but rather to present opportunities and challenges regarding a neglected research field. Some of these research questions were answered in the third, fourth and fifth chapter. However, there still remain various research questions of the in the second chapter presented research agenda that are not feasible to investigate within a single dissertation.

The third chapter is also beset with some limitations that motivate 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 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, e.g. by integrating results from the fourth chapter. Another extension would be explicitly differentiating multiple capability areas as included in Rosemann and vom Brocke's (2015) BPM capability framework and, correspondingly, modeling the effects of BPM projects in greater detail. 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 out-values the related increases in complexity and data collection effort. As for the planning model's applicability and usefulness, I concede that the planning model was only applied 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, there is neither 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. The developed V3PM tool has still shortcomings towards software quality (ISO/IEC 25010), e.g., introducing an user concept for security reasons. However, the V3PM tool was designed for evaluation purposes. Although the results were discussed with organizations and real-world data was used as input, the V3PM tool is not yet operational in organizations. For instance, there was no test of the user interface with intended users. Thus, the V3PM tool needs further development to mature to a full-featured version for decision support in daily business operations. In addition, a comprehensive user documentation and a web-based, platform-independent tool are possible ways of further research.

The presented results in the fourth chapter suffers from some limitations that warrant further research. The *PPR* quantifies a process' need for improvement based on performance indicators. Even though the *PPR* allows for the integration of indicators from virtually any performance dimension, only the dimensions cost, time, and quality are specified. When validating the *PPR*'s design specification, one expert suggested that integrating the strategic importance of a process would be desirable. The expert involved in validating the *PPR* desired the inclusion of specific staff requirements. Thus, the *PPR* should be extended to include additional performance dimensions depending on the domain in which the *PPR* is applied. When validating the *PPR*‘s applicability and usefulness, both its model and the prototype were challenged against the requirements of a complex real-world setting. While the expert was guided through all steps of the *PPR* and he was interviewed regarding accepted evaluation criteria, no company data were extracted to run the prototype. In future research, applying the *PPR* to real-world data will also help in developing necessary data collection capabilities. Moreover, the *PPR* will benefit from further validation by additional industry experts. The *PPR* yields a prioritization of processes according to their network-adjusted need for improvement. However, depending on the project candidates available for process improvement, improving the highest ranked process might not necessarily be the best solution. If, say, processes A and B are ranked first and second, but the project candidate for process B requires far lower investment than that for process A, the improvement of process B before process A may be reasonable. This may also be the case if a less risky project candidate is available for process B. Therefore, it can be a long-term research vision to extend the *PPR* regarding both an economic and a project management perspective to further advance process decision-making.

The fifth chapter is beset with limitations that stimulates following further research. The propositions that capture constitutive characteristics of the future of work have different levels of adoption in current work practices, a different breadth in scope, and may be viewed differently depending on how central they are for the future of work. Even though the propositions have been validated by two experts from the field of the future of work as well as by additional ten BPM experts who mapped them to the BPM factors, a broader literature review as well as the involvement of more BPM experts in the exploration and validation of propositions regarding the future of work is a worthwhile endeavor. Furthermore, the involvement of experts with a more diversified academic as well as professional background will be beneficial for the mapping procedure. When reasoning about how BPM as a corporate capability needs to evolve in light of the future of work using Rosemann and vom Brocke's (2015) BPM capability framework as a reference point, no individual capability areas were neither added nor discarded. More importantly the review of the BPM capability framework suffers from subjective influences, as the author team and the involved expert team was rather small. In order to mitigate these subjective influences and to trigger a broad discussion about the future of BPM in the future of work, it is recommended to mobilize more BPM experts from academia and industry in a community-wide initiative. As Rosemann and vom Brocke's (2015) BPM capability framework has been conceived based on a global Delphi study, this method may also shape up sensible for advancing the insights of this chapter.

Summarizing, this dissertation addressed several research questions regarding the intersection of business process improvement and BPM capability development. Therefore, it contributed to the existing body of knowledge by introducing different methods and techniques for an integrated planning of process improvement and BPM projects, particularly when and how organizations should improve individual processes and develop their BPM capability. In addition, the dissertation aimed to investigate BPM as a corporate capability and discussed how BPM need to evolve in light of the future of work. The topic of this dissertation is urging for further research, as already stated in the second chapter as well as in section VI.2. I hope that this dissertation opens up worthwhile avenues for interdisciplinary BPM research and contributes a novel perspective to the ongoing BPM research. I would be very happy if fellow researchers and practitioners took my results up and continued the research about how to best explore the intersection of process improvement and BPM capability development.

References

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VII. Appendix

1. Chapter III

Case based on Real-World Data – Processes

i	$O_{i,0}^{\text{fix}}$	n_i	$q_{i,0}$	$t_{i,0}$	I_i^{op}	$O_{i,0}^{\text{op}}$	η_i	$q_i^{\max}$	θ_i
(I)	0 €	$48{,}000 \cdot \left(\ln q + e^{\frac{1}{t}}\right)$	90%	30 min	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 min	-	1.00 €	-	100%	5%
(IV)	0 €	4,000	85%	-	-	1.50 €	5%	100%	-

Case based on Real-World Data – Process-level projects

s	O_s^{inv}	α_s		β_s		γ_s		δ_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%	-	-	-	-	-	-

Case based on Real-World Data – BPM-level projects

s	O_s^{inv}	ε_s		ζ_s		ϵ_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	-	-

2. Chapter IV

2.1. List of Variables

Process-specific variables

TS_i^p	Target state of the performance of process i in the performance dimension p
AS_i^p	Actual state of the performance of process i in the performance dimension p
AE_i	Amount of executions of process i (independent of performance dimension)
DI_{ij}^p	Dependence intensity between the using process i and the used process j in the performance dimension p
DI_{ij}	Dependence intensity between the using process i and the used process j (independent of performance dimension)
PNI_i^p	Process need for improvement index for process i in the performance dimension p
PNI_i	Process need for improvement index for process i (independent of performance dimension)

Relation-specific variables

NUI_{ij}	Number of use instances between the using process i and the used process j
BDI_{ij}^{Time}	Upper boundary for the dependence intensity between the using process i and the used process j in the performance dimension time
$MDI_{ij}^{\text{Quality}}$	Moderating effect on the dependence intensity between the using process i and the used process j in the performance dimension quality
$NSAI_i$	The number of stand-alone instances of process i (independent of performance dimension)

General *PPR* algorithm variables

ρ^p	Importance of the performance dimension p according to the decision-makers' preference (custom weight)
$NPNI_i$	Network-adjusted process improvement index for process i (independent of performance dimension)

(Extended) PageRank formula

d	Dampening factor that balances the network structure term and the individual node weight term
k_i	Individual node weight for node i in the extended PageRank formula
w_{ij}	Individual edge weight for the edge between nodes i and j in the extended PageRank formula
$PR(i)$	PageRank value of node i in the (extended) PageRank formula

2.2. Complete PPR Formula

$$NPNI_i = (1-d) \cdot \frac{PNI_i}{\sum_{j=1}^{n} PNI_j} + d \cdot \left[\sum_{k \in I_i \setminus \mathrm{i}} NPNI_k \cdot \frac{DI_{ki} \cdot NUI_{ki} \cdot PNI_i}{\sum_{l \in O_k \setminus k}(DI_{kl} \cdot NUI_{kl} \cdot PNI_l) + NSAI_k \cdot PNI_k + \sum_{m \in O_k \setminus k}((1-DI_{km}) \cdot NUI_{km} \cdot PNI_m)} + NPNI_i \cdot \frac{NSAI_i \cdot PNI_i + \sum_{n \in O_i \setminus i}((1-DI_{in}) \cdot NUI_{in} \cdot PNI_i)}{\sum_{l \in O_k \setminus k}(DI_{kl} \cdot NUI_{kl} \cdot PNI_l) + NSAI_k \cdot PNI_k + \sum_{m \in O_k \setminus k}((1-DI_{km}) \cdot NUI_{km} \cdot PNI_m)} \right]$$

2.3. Online Questionnaire for the Panel of BPM Experts

Introduction

When prioritizing processes for process improvement, the typical approach nowadays is to determine a set of KPIs for each process and rank the processes according to these KPIs. However, this neglects the fact that improving a process can heavily influence related processes. Therefore, we suggest a process prioritization approach based on the PageRank algorithm, which takes the individual process performance as well as relations between processes into account.

In the following, you will find four arbitrary process networks. For each of them, we suggest a process improvement ranking and argue on how the relations between the processes influence that ranking. We would like to ask you whether you share our opinion or if you would prefer a different ranking.

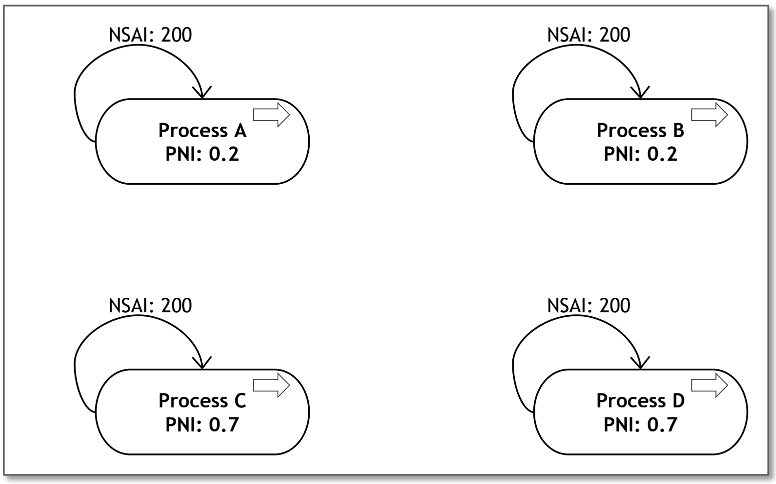
To rank the processes according to their need for improvement while taking their relations into account, the process network needs to contain the processes including their individual need for improvement as well as the relations between the processes.

The processes are represented as nodes in the process network. The individual need for improvement is represented by an index we call *PNI*, which is scaled between 0 and 1. It captures a process' need for improvement in different performance dimensions such as Cost, Time, Quality, and Flexibility in one integrated index. Moreover, the index reflects how often the process is executed. As we measure the need for improvement, a low index (close to 0) means that the process performs rather well and a high index indicates that the process performs relatively poor.

A process can be related to another process in the matter that it synchronously calls another process. We call this a use-relation. Such a use-relation is represented through a directed edge from the using to the used process (we call this index *NUI*). These edges are weighted by the amount of use calls a process makes to the other. Another type of edge is one that points to the same process it originated from. A self-directed edge represents the amount of executions of a process where it does not use another process (we call this index *NSAI*). Introducing these edges gives an overview on how heavily a process depends on other processes or if the process is mostly executed without using any other processes.

Process Network 1

This process network includes four processes A, B, C and D. Processes A and B perform rather well and therefore have a low individual need for improvement (*PNI*). Processes C and D perform not as well and therefore have a higher individual need for improvement (*PNI*). There are no relations between the processes. The network shows solely self-directed relations, which means that the processes do not use each other and are executed stand-alone 200 times.



Process	Process Prioritization
Process A	2
Process B	2
Process C	1
Process D	1

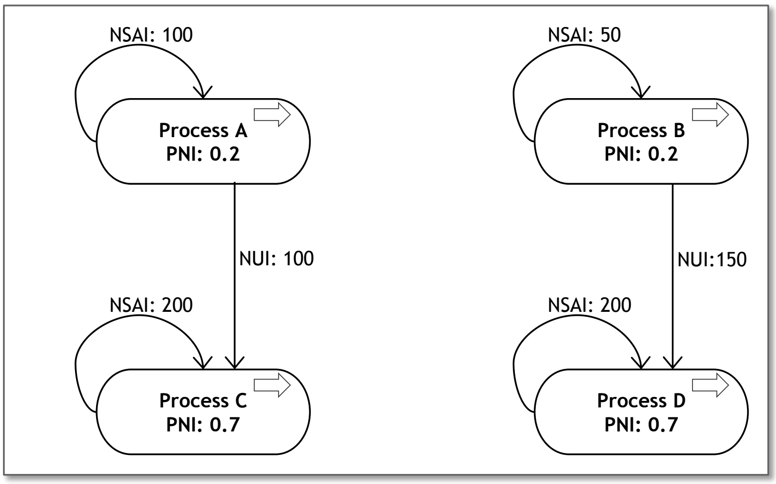
PNI: individual need for improvement for each process
NSAI: Number of instances of a process, where he does not use (synchronously call) another process.
NUI: Number of instances, where one process uses the other.

Processes A and B have the same individual need for improvement. As they are only executed stand-alone without being used or using another process, the prioritization only depends on the individual need for improvement. As the individual need for improvement is equal for both of them, they are ranked equally. The same holds for Processes C and D. Since the prioritization only depends on the individual need for improvement for all processes, C and D are prioritized over A and B as their individual need for improvement is higher.

Can you follow this line of argumentation and would you agree with the resulting process improvement ranking?

Process Network 2

This process network shows the same processes as before. However, this time Process A uses Process C 100 times and Process B uses Process D 150 times (note the directed edges). Process A is therefore executed stand-alone 100 times and Process B only 50 times. Please note: All the processes are still executed 200 times. Keep in mind that the self-directed relation shows the number of executions, the process is executed without using another process.



Process	Process Prioritization
Process A	3
Process B	4
Process C	2
Process D	1

PNI: individual need for improvement for each process
NSAI: Number of instances of a process, where he does not use (synchronously call) another process.
NUI: Number of instances, where one process uses the other.

In this situation, improving Process C or D not only has a positive effect on the process itself but also on the process it is used by (Processes A and B respectively). Example: If we lowered the costs for executing Process C, the overall execution costs for Process A would improve for every execution, where Process A uses Process C. As Process D is, ceteris paribus, used by Process B more often than Process C by Process A, Process D is prioritized over Process C, as improving Process D has a higher effect on Process B than the same improvement of Process C on Process A (due to higher weight of the use relation), while the effect on Processes C or D is the same.

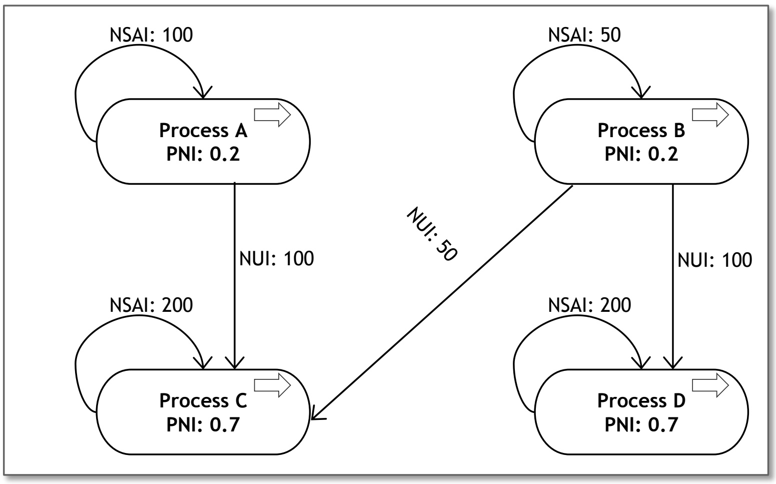
Can you follow this line of argumentation and would you agree with the resulting process improvement ranking?

Again, if we apply the same logic to Processes A and B: The more a process uses another process, the more important it is to improve the used process. Hence, the more a process uses other processes, improving the using process gets less important relative to the other processes. Therefore, Process A is prioritized over Process B.

Can you follow this line of argumentation and would you agree with the resulting process improvement ranking?

Process Network 3

This process network is very similar to the previous one. The only difference is that this time Process B does only use Process D 100 instead of 150 times, but also uses Process C 50 times.



Process	Process Prioritization
Process A	3
Process B	4
Process C	1
Process D	2

PNI: individual need for improvement for each process
NSAI: Number of instances of a process, where he does not use (synchronously call) another process.
NUI: Number of instances, where one process uses the other.

As this situation is very closely related to the previous one, the argumentation about the prioritization is also very similar. As Process C is used by Process A as often as Process D by Process B, but Process C is in addition used by Process B, Process C is prioritized over Process D.

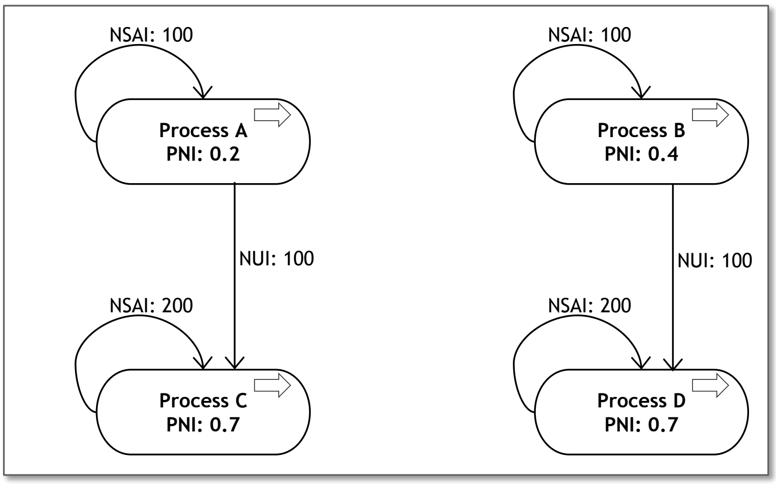
Can you follow this line of argumentation and would you agree with the resulting process improvement ranking?

Again, if we apply that same logic to Processes A and B: The more a process uses another process, the more important it is to improve the used process. Hence, the more a process uses other processes, improving the using process gets less important relative to the other processes. Therefore, Process A is prioritized over Process B.

Can you follow this line of argumentation and would you agree with the resulting process improvement ranking?

Process Network 4

In this process network, Process A again uses Process C 100 times and Process B uses Process D also 100 times. The *PNI* s of Processes C and D are still relatively high at 0.7 while the *PNI* of Process A is still quite low at 0.2. This time, the *PNI* of Process B is higher than before at 0.4.



Process	Process Prioritization
Process A	4
Process B	3
Process C	2
Process D	1

PNI: individual need for improvement for each process
NSAI: Number of instances of a process, where he does not use (synchronously call) another process.
NUI: Number of instances, where one process uses the other.

As Process B has a higher *PNI* than Process A, Process B should be prioritized over Process A. Process A and Process B use Processes C and D equally frequent. However, as Process B has a higher *PNI* than Process A and is, therefore, prioritized over A, the effect of improving Process D on Process B is also higher than the same improvement on Process C would have on Process A. Therefore, Process D is prioritized over Process C.

Can you follow this line of argumentation and would you agree with the resulting process improvement ranking?

General Questions

Please tell us a little bit about your company as well as yourself. If you belong to the academic community, please skip the subsequent three questions.

Which industry does the company belong to?

How many employees does the company have?
[1–100, 101–1.000, 1.001–2.500, 2.501–10.000, More than 10 000]

What is your current position in the company?

How many years of experience do you have in Business Process Management?

If you have any additional comments, please let us know.

2.4. Demonstration Example

Transformation of the Business Process Architecture

To apply the *PPR*, we transformed the BPA of the European nearshoring IT provider into a process network. Following the steps described in Sect. 4.1, we first transferred business and support processes as well as use relations. We did not transfer management processes. As for composed processes, we only transferred sub-processes. We transferred use relations if both the related used and using processes were transferred. Overall, this step reduced the number of processes and use relations included in the process network as shown in Figure 3. Due to confidentiality reasons, we are not allowed to show the provider's initial BPA.

After that, we determined the number of use and stand-alone instances as well as the amount of executions per process. First, we defined the number of use instances per relation. To demonstrate the applicability of our software prototype for larger process networks with a higher number of instances, we chose a quarterly period. Second, we set the amount of executions per process. As processes need to run at least as often as they are used, we limited the amount of executions to values below the respective sum of use instances across all ingoing use relations. The number of stand-alone instances depends on the amount of executions and on the number of use instances. If a process has no outgoing use relations, the number of stand-alone instances needs to equal to the amount of executions. If a process has at least one outgoing use relation, the number of stand-alone instances features a lower and upper boundary. As for the upper boundary, consider a process running without using another processes in all but one instance and, in that instance, every use relation is executed (remember that a process can use another process multiple times per instance). In that case, the number of stand-alone instances equals the amount of executions minus one. As for the lower boundary, consider the process utilizing exactly one relation per instance. The number of stand-alone instances then equals the amount of executions minus the sum over the number of use instances of all outgoing use relations. In real-world settings, relevant data sources are process-aware information systems (e.g., workflow management systems), enterprise software (e.g., enterprise resource planning systems), accounting systems (e.g., for activity-based costing), or service-oriented middleware (e.g., for number of service invocations and dependency graphs). Alternatively, process owners can be asked for a qualitative assessment.

As mentioned in the manuscript, the BPA was under construction when we investigated the European nearshoring IT provider. Thus, we had to generate performance data. To create suitable values, we utilized information about the provider (e.g., number of employees, number of projects per month, monthly sales, and business model) and leveraged our experience from comparable companies. In sum, we estimated values for the actual and target performance. We also determined values for the custom weights and the dampening factor. Two researchers estimated the respective values and discussed them intensely before using them as input for the demonstration example.

We first estimated the actual performance based on our experience. We defined values within the interval $(0;\ 100]$ for each process and performance dimension. As the target performance can never be worse than the actual performance (Sect. 4.2), we restricted the admissible value range to the interval $(0;\ AS_i^p)$ when estimating the target performance. In the time dimension, the dependence intensity between two processes can have an upper boundary. This effect is relevant in cases where a process uses another process in one of multiple parallel streams. To capture this effect in our example, we assigned a specific upper boundary for those processes that use multiple other processes. Consider the Financial Reporting process that uses the Forecasting and the Accounting processes. We assume that these use relations run in parallel. Therefore, the maximum improvement cascading to the using Financial Reporting process is limited by the smaller difference between the actual and target performance of both used processes. Regarding the quality dimension, the dependence intensity between two processes may depend on a moderator effect, which in essence captures the conditional probability of good quality in a using process if the quality of a used process is good after improvement. In our opinion, this is more likely for financial services as they are data-driven. An error in the Accounting process is very likely to affect the Financial Reporting process, while an error in the HR Governance process might not necessarily affect the Hiring process. Therefore, we set the moderating effect slightly higher for ingoing relations of processes from the financial process areas and moderately lower for ingoing relations of processes from the human resources process area. For all other processes, we used a default value. Finally, we had to set custom weights for the involved performance dimensions as well as the dampening factor. As the performance data was generated, we chose to assign equal weights to the performance dimensions. The dampening factor was set to 0.5 for the same reason. In real-world settings, relevant data sources are process-aware information systems (e.g., workflow management systems, process performance management systems, process monitoring systems) as well as accounting systems (e.g., for activity-based costing). Moreover, process performance reviews, data from process improvement projects as well as the assessment of process owners can be used as further data sources.

Dataset

Tables A.1 and A.2 show all data used in the demonstration example.

Using Process	**Used Process**	$NUI/NSAI$	BDI^{Time}	MDI^{Quality}
Accounting	Accounting	3,500	∞	1
Accounting	Taxes	4,000	∞	0.9
Billing	Billing	2,000	∞	1
Billing	Client Feedback	900	∞	0.8
Billing	Client Risk Management	200	∞	0.8
Billing	Invoicing	2,300	∞	0.9
Career Development	Career Development	750	∞	1
Client Feedback	Client Feedback	4,500	∞	1
Client Feedback	Dismissal/Resigning	80	∞	0.7
Client Risk Management	Client Risk Management	1,150	∞	1
Client Risk Management	Dismissal/Resigning	50	∞	0.7
Controlling	Controlling	2,000	∞	1
Controlling	Financial Reporting	2,000	∞	0.9
Customer Request	Customer Request	3,000	∞	1
Customer Request	Industry Staffing	1,750	∞	0.8
Dismissal/Resigning	Dismissal/Resigning	250	∞	1
Dismissal/Resigning	Offboarding	300	∞	0.7
Financial Reporting	Accounting	1,000	10	0.9
Financial Reporting	Financial Reporting	1,000	∞	1

Financial Reporting	Forecasting	1,500	∞	0.9
Forecasting	Forecasting	1,500	∞	1
Fulfilment	Fulfilment	800	∞	1
GA Staffing	GA Staffing	2,000	∞	1
GA Staffing	Hiring	1,700	∞	0.7
GA Staffing	Recruitment	500	∞	0.7
Hiring	Hiring	3,500	∞	1
Hiring	HR Governance	3,000	∞	0.7
Hiring	Onboarding	900	∞	0.7
HR Governance	HR Governance	3,500	∞	1
HR Marketing	HR Marketing	600	∞	1
Industry Staffing	Hiring	1,700	∞	0.7
Industry Staffing	Industry Staffing	1,500	∞	1
Invoicing	Invoicing	3,500	∞	1
Offboarding	Offboarding	400	∞	1
Onboarding	Onboarding	1,200	∞	1
Payment	Payment	8,800	∞	1
Payroll	Payroll	4,400	∞	1
Project Completion	Project Completion	350	∞	1
Recruitment	Recruitment	600	∞	1
Resource Setup	Client Feedback	700	∞	0.8
Resource Setup	Client Risk Management	200	∞	0.8
Resource Setup	Hiring	2,200	∞	0.7
Resource Setup	Resource Setup	500	∞	1
Sales	Sales	1,500	∞	1
Service Adjustment	Client Feedback	1,100	∞	0.8
Service Adjustment	Client Risk Management	400	∞	0.8
Service Adjustment	Service Adjustment	500	∞	1
Service Approval	Client Feedback	1,500	∞	0.8
Service Approval	Client Risk Management	400	∞	0.8
Service Approval	Service Approval	1,500	∞	1
Taxes	Taxes	5,500	∞	1

Table A.1: Dataset of the demonstration example (number of use and stand-alone instances, boundary and moderating effects)

Process	AS^{C}	TS^{C}	AS^{T}	TS^{T}	AS^{Q}	TS^{Q}	AE
Accounting	77	67	90	75	52	48	6,500
Billing	85	84	26	4	82	59	2,300
Career Development	26	20	94	81	6	3	750
Client Feedback	36	30	84	60	97	70	4,600
Client Risk Management	90	50	91	43	40	8	1,200
Controlling	93	92	66	7	93	92	2,500
Customer Request	66	59	6	5	67	14	3,500
Dismissal/Resigning	86	63	73	53	72	39	300
Financial Reporting	93	43	72	32	3	2	2,000
Forecasting	39	13	80	70	62	40	1,500
Fulfilment	2	1	57	14	80	43	800
GA Staffing	72	34	5	3	4	3	2,500
Hiring	26	10	42	20	27	16	6,000
HR Governance	56	40	1	0	93	64	3,500
HR Marketing	37	29	48	20	95	94	600
Industry Staffing	82	70	86	42	4	0	2,000
Invoicing	12	8	50	10	56	22	3,500
Offboarding	58	12	97	89	22	13	400
Onboarding	18	15	25	18	83	2	1,200
Payment	96	40	39	33	12	10	8,800
Payroll	11	10	92	84	67	30	4,400
Project Completion	52	15	86	58	4	0	350
Recruitment	56	18	58	35	98	91	600
Resource Setup	36	29	95	20	53	17	2,000
Sales	68	37	51	36	40	16	1,500
Service Adjustment	12	1	69	40	53	34	800
Service Approval	60	20	20	9	26	14	2,000
Taxes	51	45	82	62	61	44	5,500

Table A.2: Dataset of the demonstration example (actual and target performance, amount of executions)