Process Improvement Roadmapping - How to Max Out Your Process

by

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Completed Research Paper

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Abstract

Process improvement is the most value-adding activity in the BPM lifecycle. Despite the mature body of knowledge related to process improvement, there is a lack of prescriptive knowledge that takes a single-process/multi-project perspective, covers a broad range of improvement opportunities, and accounts for the characteristics of the process in focus. Against this background, we propose a decision model that helps determine an optimal process improvement roadmap in line with the principles of project portfolio selection and value-based management. A process improvement roadmap is a set of improvement projects scheduled to multiple planning periods, each of which enhances the performance of the process in focus. The decision model particularly considers process characteristics that reflect how work is performed and organized. These characteristics are inspired by established industrialization strategies, i.e., automation, sourcing, flexibility, and standardization. As for evaluation, we report on feature comparison, an expert interview, prototype construction, and a demonstration example.

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

Introduction

Process orientation is an accepted paradigm of organizational design and a source of corporate performance (Kohlbacher and Reijers 2013; Skrinjar et al. 2008). Due to constant attention from industry and academia, the business process management (BPM) community has proposed mature approaches, methods, and tools that support process design, analysis, enactment, and improvement (Harmon and Wolf 2014; van der Aalst 2013). Process improvement is the most value-creating activity within the BPM lifecycle (Dumas et al. 2013; Zellner 2011). This is why approaches to process improvement are still in high demand (van der Aalst 2013).

The body of knowledge on process improvement provides numerous process improvement approaches and related classifications. The most fundamental classification is that into continuous process improvement and business process reengineering, where the first builds on incremental and the second on radical process change (Niehaves et al. 2011; Trkman 2010; vom Brocke et al. 2011). Van der Aalst (2013) proposed a classification into model- and data-based process analysis. Data-based analysis supports process improvement while processes are executed by discovering bottlenecks, waste, or deviations. Model-based analysis, which may build on the results of data-based analysis, supports process improvement during redesign. Focusing on model-based process analysis, Vergidis et al. (2008) classify improvement approaches based on whether diagrammatic, mathematical, or execution-oriented process models are used. For instance, diagrammatic models allow for observational analysis, mathematical models for validation, verification, and optimization, and execution-oriented process models enable simulation and performance analysis.

Across all classifications, there is consensus that there is a lack of concrete guidance on how to put process improvement into practice as well as that each class of improvement approaches has individual strengths and weaknesses (van der Aalst 2013; Vergidis et al. 2008; Zellner 2011). Following the classification by Vergidis et al. (2008), process improvement approaches based on diagrammatic models are susceptible to subjective biases and cause considerable manual effort (Bolsinger et al. 2015). By nature, they take a single-process perspective (Zellner 2011). Improvement approaches based on mathematical process models have the potential to overcome the weaknesses just mentioned, but are criticized for being extremely specialized and, due to the complexity of mathematical modeling, for being restricted to very few application domains (Vergidis et al. 2008). They cover the spectrum of process improvement opportunities only fragmentarily, e.g., focusing on automation, sourcing, or flexibility or on distinct process types (Afflerbach et al. 2014; Braunwarth et al. 2010; Buhl et al. 2012). For the same reason, they mostly take a single-process and single-project perspective. Few approaches based on mathematical process models take a multi-process and/or multi-project perspective, covering a broad range of improvement opportunities. In doing so, they focus on how to prioritize processes or improvement projects as well as on how to plan process improvement and the development of an organization's BPM capability in an integrated way (Bandara et al. 2015; Darmani and Hanafizadeh 2013; Ohlson et al. 2014). As an example, Lehnert et al. (2014) propose a decision model that determines BPM roadmaps including projects that improve single processes or an organization's BPM capability. Due to the multi-process and multi-project perspective, they capture different project types and interactions among projects. Consequently, they analyze single processes on a high level of abstraction and neglect process characteristics beyond performance that reflect how work is performed and organized.

This analysis reveals that most process improvement approaches – be it approaches based on diagrammatic or on mathematical process models – take a single-process/single-project or a multi-process/multi-project perspective. The first group tends to be narrow in scope, to cover selective improvement opportunities, and to neglect the opportunity to improve a process in terms of multiple projects. The second group, in contrast, examines individual processes from a high level of abstraction, neglecting interesting characteristics beyond performance. In sum, there is a lack of prescriptive knowledge that takes a single-process/multi-project perspective on process improvement to cover a broad range of improvement opportunities and to account for process characteristics in detail. Thus, we address the following research question: *Which projects should an organization implement to improve a distinct process, particularly accounting for process characteristics that reflect how work is performed and organized?*

To answer this question, we propose and instantiate a decision model for valuating process improvement roadmaps in line with the principles of project portfolio selection (PPS) and value-based management (VBM). A process improvement roadmap is a set of process improvement projects scheduled to multiple planning periods, each of which enhances the performance of the process in focus. Since our decision model has the features of a model and a method, we adopted the design science research (DSR) paradigm (Gregor and Hevner 2013). Following the DSR reference process, we discuss the identification of and motivation for the research problem, objectives of a solution, design and development, and evaluation (Peffers et al. 2008). In the design and development phase, we used normative analytical modeling to specify the decision model (Meredith et al. 1989). With this paper, we extend our prior research on process improvement by focusing on process characteristics and by covering a broad range of improvement opportunities inspired by multiple established industrialization strategies (Lehnert et al. 2014; Linhart et al. 2015).

The paper is organized as follows: We first provide justificatory knowledge related to BPM, PPS, and VBM, while deriving design objectives for solutions to the research question (*objectives of a solution*). We then introduce our decision model (*design and development*) and report on the results of feature comparison, an expert interview, prototype construction, and a demonstration example (*evaluation*). We conclude with reviewing our key results, discussing limitations, and pointing to opportunities for future research.

Theoretical Background and Design Objectives

Process Improvement and Process Performance Measurement

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, p. 1). Thereby, it combines knowledge from information technology and the management sciences (van der Aalst 2013). BPM takes care of all corporate processes, which split into core, support, and management processes (Harmon 2010).

Process improvement is implemented via projects (Lehnert et al. 2014). To determine the effects of process improvement projects on process performance, performance indicators are used (Leyer et al. 2015). Process performance indicators can be grouped according to the Devil’s Quadrangle, a framework that comprises time, cost, quality, and flexibility as dimensions (Reijers and Limam Mansar 2005). The Devil’s Quadrangle owns its name from the fact that improving one 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 performance indicators (Dumas et al. 2013). To better understand how improvement projects affect process performance, the process characteristics provide useful information. Process characteristics are “information about the process itself [including] definition[s] of the activities, control flow[s], [...] business rules [and] resource requirements” (Sidorova et al. 2015, p. 428). Exemplary process characteristics are the number of process variants, the number of process instances per period, or the extent of automation and sourcing (Bolsinger et al. 2015; Braunwarth et al. 2010; Linhart et al. 2015).

To structure the vast amount of improvement projects, we refer to the paradigm of industrialization, which is known from the manufacturing domain and has also been transferred to the services domain (Levitt 1976). Industrialization is associated with increasing productivity and production volumes as well as with decreasing costs (Karmarkar 2014). To achieve these objectives, distinct industrialization strategies have established over time (Gileadi and Leukert 2013; Karmarkar 2004). Four industrialization strategies, i.e., standardization, automation, sourcing, and flexibility, have often been discussed in relation to process improvement. Business process standardization refers to the alignment of context-specific process variants with a master process, leading to a reduction or a unification of process variants (Beimborn et al. 2009b; Tregear 2015). The master process is an ideal-typical process variant that can be applied to all process contexts, i.e., all environments or situations in which a process is executed (Münstermann et al. 2010). Business process automation considers the internal handling of processes, focusing on the control flow or the tasks of a process (Ouyang et al. 2015; Sidorova et al. 2015; Ter Hofstede et al. 2010). The control flow can be automated by workflow management systems, i.e., software systems “which [pass] information from one participant to another” (Dumas et al. 2013, p. 298). Tasks can be automated via traditional application systems or services from service-oriented architectures (Cummins 2015). If processes or tasks are no longer handled internally, business process outsourcing or business process activity outsourcing come into place (Braunwarth 2010; Dorsch and Häckel 2014). Outsourcing is “the delegation of one or more entire business processes to third party providers, including the software and hardware that support those processes” (Wüllenweber and Weitzel 2007, p. 2). Accessing specialized process expertise in order to focus on one’s core competencies are common arguments in favor of outsourcing (Davenport 2005). Finally, business process flexibility combines volume and functional flexibility, allowing processes to cope with risky demand and to create different as well as unplanned outputs (Afflerbach et al. 2014; Goyal and Netessine 2011). Volume flexibility can be addressed by demand-side measures, e.g., reservation systems or dynamic pricing

(Jerath et al. 2010), or by supply-side measures such as customer integration, outsourcing, automation, or cross-training (Fitzsimmons and Fitzsimmons 2013). As for functional flexibility, strategies like flexibility-by-design, flexibility-by-deviation, flexibility-by-underspecification, flexibility-by-by-change can be leveraged, including recent advances such as declarative process design (Haisjackl et al. 2014).

Although the industrialization strategies were largely treated separately, some researchers investigated the relations among them. Standardization can be seen as a prerequisite for outsourcing (Ramakurnar and Cooper 2004). The effects of standardization on process performance are also known to be reinforced by the IT intensity of a process, which again is linked to automation (Beimborn et al. 2009a). The relationship between standardization and flexibility is ambiguous, i.e., there is a trade-off between loosing flexibility and realizing performance effects by standardization (Wimble et al. 2010). Moreover, there is a link between flexibility and sourcing, as volume flexibility can be achieved by using external capacity (Linhart et al. 2015). Even an increase in functional flexibility can be obtained by sourcing, as sourcing enables an appropriate use of internal resources (Yang et al. 2007). Finally, if a process is subject to automation and outsourcing, the sequence in which both strategies are implemented is crucial (Buhl et al. 2012). Against this backdrop, we specify the following design objective:

(O.1) *Process improvement and performance measurement*: Process performance must be conceptualized in a multi-dimensional manner. To better estimate the performance effects of improvement projects, performance indicators should be complemented by specific process characteristics.

Project Portfolio Selection

There is a mature body of knowledge on PPS, including quantitative and qualitative approaches (Carazo et al. 2010; Frey and Buxmann 2012; Perez and Gomez 2014). 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 and screening, all projects are evaluated individually and eliminated in case they violate critical thresholds of relevant performance indicators. The optimal portfolio selection stage establishes the project portfolio that best meets the performance indicators, considering interactions among projects (e.g., mutual exclusion, predecessor/successor) and case-specific constraints (e.g., latest finishing, restricted budgets) (Liu and Wang 2011; Müller et al. 2015). Finally, decision makers may adjust the optimal project portfolio.

Considering interactions among projects is a challenging but necessary requirement for PPS decisions (Lee and Kim 2001). As for IS/IT projects, multiple interaction types must be considered, i.e., inter- vs. intra-temporal, deterministic vs. stochastic, and scheduling vs. no scheduling interactions (Kundisch and Meier 2011). Intra-temporal interactions affect 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). Scheduling interactions occur if projects may start at different points. We specify the following design objective:

(O.2) *Project portfolio selection*: Determining the optimal process improvement roadmap requires that only projects be considered that both affect the process in focus and align with the organization’s strategy. The optimal process improvement roadmap must be determined according to the performance effects of the pre-selected projects, interactions among these projects, and further case-specific constraints.

Value-based Management

Building on the seminal work of Copeland et al. (1990), Rappaport (1986), and Stewart (1991), VBM considers maximizing the long-term company value, based on discounted cash flows, as the primary objective of all business activities. Companies must be able to quantify not only their value on an aggregate level, but also the value contribution of individual activities and decisions, including process decisions. To comply with the principles of VBM, decisions must be based on cash flows, consider risks, and incorporate the time value of money (Bolsinger 2015). Due to its long-term orientation, VBM complies with the stakeholder value approach and other approaches to multi-perspective corporate management (Danielson et al. 2008). Functions to be used for determining the value contribution depend on the decision situation and the decision makers' risk attitude (Berger 2010). Under conditions of certainty, decisions can be made based on the NPV of future process cash flows. In case of risk with risk-neutral decision makers, decisions can be made based on the expected NPV. In case of risk-averse decision makers, decisions can be made using the NPV's risk-adjusted expected value or a risk-adjusted interest rate. Against this backdrop, this leads to the following design objective:

(O.3) *Value-based management*: The optimal process improvement roadmap is that with the highest value contribution. Determining the value contribution of process improvement roadmaps requires accounting for cash flow effects, the decision makers' risk attitude, and the time value of money.

Artefact Description

In line with the principles of PPS and VBM, the decision model aims at identifying the process improvement roadmap with the highest value contribution. A process improvement roadmap is a portfolio of scheduled improvement projects, each of which enhances the performance of the process in focus. Improvement projects can affect process performance directly or indirectly via process characteristics. To transform the effects of improvement projects stepwise into the value contribution of a process improvement roadmap, we structure the decision model into four connected layers, i.e., the project layer, process characteristics layer, process performance layer, and economic valuation layer. Figure 1 provides a high-level, single-period overview of the decision model's structure and core components, which are presented in detail throughout this section. The project layer covers process improvement projects and their effects. As one of the decision model's main contributions, the process characteristics layer reflects how work is performed and organized inspired by established industrialization strategies. The process performance layer captures the outcome of the process via non-monetary performance indicators. Finally, the economic valuation layer considers all monetary and monetized performance indicators and integrates these indicators into the periodic cash flow, which in turn is an essential input for the value contribution of a process improvement roadmap. When we present the decision model below, we first elaborate on the economic valuation layer to make the general setting and the objective function clear. After that, we introduce the process performance and the process characteristics layer. We provide a discussion of the decision model's assumptions in the evaluation section. An overview of all mathematical variables is included in the Appendix.

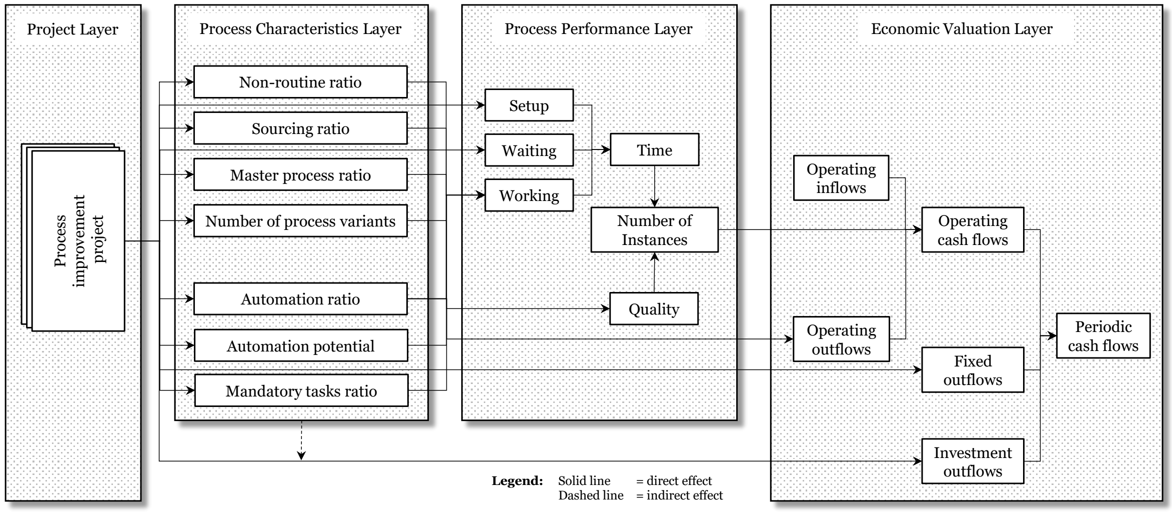

Figure 1. High-level structure and components of the decision model (single-period view)

Economic Valuation Layer and General Setting

The decision model considers a single mature process within a distinct organization, multiple projects, and a multi-period planning horizon. In order to improve the process, the organization has pre-selected process improvement projects and checked these projects for appropriate strategic fit. In line with our focus on how work is performed and organized, the decision model only considers supply-side measures as improvement projects. Taking a single-process perspective, the decision model allows for implementing one project per period. However, projects can take multiple periods. If more projects are to be implemented, they must be scheduled to the periods of the planning horizon and compiled into process improvement roadmaps. When compiling roadmaps, the decision model must account for interactions among the projects and case-specific constraints. Exemplary interactions and constraints are inter-/intra-temporal interactions among projects (e.g., a project must be implemented before another) as well as project-specific (e.g., earliest beginning), process-specific (e.g., critical boundaries for performance indicators), and period-specific constraints (e.g., available budget) (Liu and Wang 2011; Müller et al. 2015; Perez and Gomez 2014).

To determine the value contribution of a distinct process improvement roadmap r in line with the principles of VBM, we use the expected NPV as the sum of all discounted periodic process cash flows (Bolsinger 2015). To do so, we take a planning horizon Y and a risk-adjusted discount rate z as input. For each period y of the planning horizon, the periodic cash flows splits into investment outflows I_y, fixed outflows f_y, and operating cash flows. Investment outflows are for implementing projects. If the implementation takes more periods, the outflows are split linearly. Fixed outflows capture outflows that accrue independently from the number of instances, e.g., for operating a workflow management system. The operating cash flows are driven by the expected number of instances D_y and by the operating inflows p and outflows v_y. The number of instances reflects the internal and external demand for the process in a distinct period. The operating inflows capture the external sales price or internal transfer price of the process output. While the investment outflows and the fixed outflows are due at the beginning of each period, the operating cash flows are due at the end of each period (Lehnert et al. 2014). This leads to the following objective function:

$$r^* = \underset{r \in R}{\operatorname{argmax}}\, NPV_r = \underset{r \in R}{\operatorname{argmax}} \sum_{y=0}^{Y} \left[-\frac{I_y + f_y}{(1+z)^y} + \frac{D_y \cdot (p - v_y)}{(1+z)^{y+1}} \right] \tag{1}$$

Process Performance Layer

The decision model adopts a multi-dimensional conceptualization of process performance. In line with the Devil's Quadrangle, it focuses on the performance dimensions time, quality, costs, and flexibility (Dumas et al. 2013). While costs have already been covered in the economic valuation layer in terms of inflows and outflows, the process performance layer focuses on time and quality. Flexibility is tackled implicitly because the extent to which a process is flexible can be expressed by different components of time (Ray and Jewkes 2004). In line with our focus on supply-side measures, the decision model considers the price for executing a process instance as given and constant throughout the planning horizon. Thus, the number of instances generally depends on time and quality. If the process in focus is a business process, customers make their purchase decisions based on the time and quality observed in the previous period (Linhart et al. 2015). Depending on the process at hand, it may also be the case that the number of instances is driven by either performance dimension. In the case of support processes, the number of instances may even be invariant regarding the time and quality performance. We assume:

A1: The expected number of instances D_y in a period y can be forecast using the total processing time t_{y-1}^{total} and the total quality q_{y-1}^{total} of the previous period.

The total processing time splits into waiting time $t_{\text{wait},y}$, setup time $t_{\text{setup},y}$, and working time $t_{\text{work},y}$ (Dumas et al. 2013). Waiting time includes queueing and other waiting time. Queueing time refers to the time an instance waits before the first activity starts. As the decision model abstracts from capacity and resource constraints, instances start immediately. Thus, the waiting time expresses the time spent between two successive tasks during the execution of a single instance. The setup time refers to the time where resources (e.g., machines, devices, and employees) are prepared for executing a specific instance (Cheng and Podolsky 1996). The working time is the time where work is performed (Curry and Feldmann 2011). Unless indicated differently, the decision model refers to average time values.

Within the Devil's Quadrangle, quality can be viewed internally and externally. Internal quality refers to the error-proneness of executing process instances, typically measured in terms of error rates or availability. In contrast, external quality draws from the concept of perceived quality and is typically measured in terms of customer satisfaction (Johnston et al. 2012; Parasuraman et al. 1985). With the evaluation of the process and its output not being part of the model, we only account for the quality of internally q_y^{int} and externally handled instances q_y^{ext} (see process characteristics layer). As quality is capped (e.g., error rate cannot exceed 100%), the decision model also uses an upper quality boundary $q^{\max}$ (Dumas et al. 2013).

Process Characteristics Layer

While time, quality, and cost take an ex-post perspective on performance, the process characteristics, which indicate how work is performed and organized, take an ex-ante and ex-nunc perspective. Thus, they help estimate time, quality, and cost more precisely. As highlighted below, the process characteristics used in the decision model are inspired by the industrialization strategies automation, flexibility, standardization, and sourcing. It also becomes clear that these strategies should not be analyzed separately. For a better understanding, we illustrate in Figure 2 how the number of process instances D_y can be decomposed based on process characteristics from the left to the right.

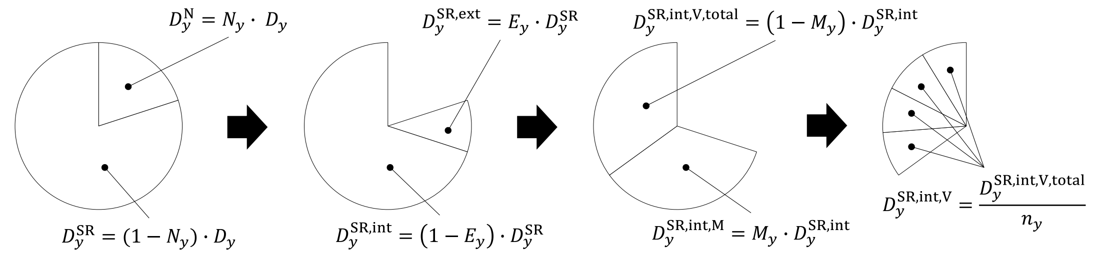

Figure 2. Decomposition of the number of process instances based on process characteristics

From a standardization and flexibility perspective, process instances split into three instance types, namely standard, routine, and non-routine instances (Lillrank 2003). Standard instances have well-defined inputs and outputs, whereas routine instances are composed of standard activities. As both instance types can be performed similarly, the decision model treats them as standard/routine instances (SR) (Neuhuber et al. 2013). Non-routine instances (N) are instances whose input and output variety cannot be entirely captured at design time. Thus, they require a complex handling and functional flexibility (e.g., extensive preparatory activities, additional tasks and resources, configurable IT services, and flexible process-aware information systems). Usually, the non-routine ratio (N_y) is much smaller than the ratio of standard/routine instances (Linhart et al. 2015). Against this backdrop, we can derive the number of standard/routine and non-routine instances as shown in Figure 2. The relationship between non-routine and standard/routine instances is expressed in terms of the mandatory tasks ratio $\alpha_y \in]0;1]$ of standard/routine instances. Thereby, α_y is a one-sided indicator taking a standard/routine perspective, as the amount of additional and potentially instance-specific tasks in non-routine instances cannot be foreseen ex-ante.

As for the sourcing perspective, the sourcing ratio (E_y) separates internally (int) executed from externally (ext) executed standard/routine instances (Dorsch and Häckel 2014). Non-routine instances are executed internally due to their high complexity. When outsourcing standard/routine instances, the organization can choose between non-scalable and scalable models of external capacity supply, a decision that affects how strongly fixed outflows and operating outflows depend on the sourcing strategy (Aksin et al. 2008). From a standardization perspective, the internally executed standard/routine instances can be allocated either to a context-agnostic master process or to one of n_y context-specific process variants according to the master process ratio (M_y). To capture differences between the master process and the process variants, we rely on dimension-specific multipliers (i.e., γ_y^{time}, γ_y^{qual}, γ_y^{cash}). These multipliers can be understood as a discount for the master process or a surcharge for the process variants based on the idea that the master process typically outperforms the process variants (Münstermann et al. 2010). We assume:

A2: Each process instance is executed either internally or externally. All relevant performance indicators for externally executed process instances are specified via service level agreements (SLA). The process instances not allocated to master process are equally distributed to context-specific process variants.

Internally executed instances must not only be differentiated according to whether they are allocated to the master process or process variants, but also according to the extent by which they are executed automated or manually. As all internally executed instances, not only standard/routine instances, can be automated, automation is orthogonal with respect to instance types. This is why automation is not included in Figure 2. In general, process instances are executed partly manually and automated according to the automation ratio A_y and the automation potential φ_y^{auto} (Figure 3). Note that the automation ratio is defined relatively to the automation potential, indicating which fraction of the potential is tapped. Moreover, the automation ratio and potential are restricted to the task perspective of process automation. We assume:

A3: The organization is able to estimate reference points for the performance dimensions time, quality, and costs for the scenario where the automation potential is fully tapped (i.e., all automatable activities have been automated) as well as for the scenario where all tasks are performed manually.

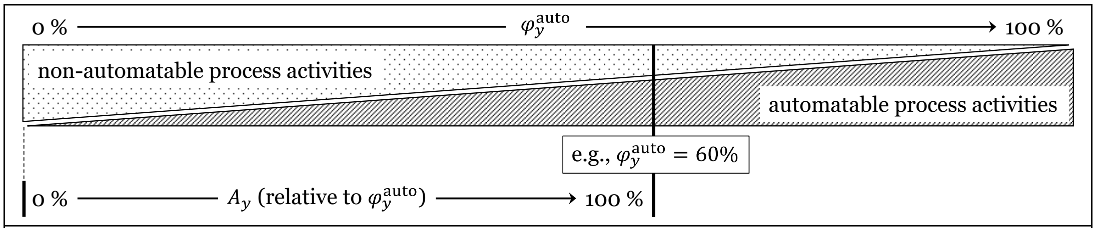

Figure 3. Relationship between automation ratio and automation potential

Having specified process characteristics based on industrialization strategies, we can now model the link between the process characteristics layer and the process performance layer mathematically. As for the time dimension, we distinguish different components for standard/routine and non-routine instances. The processing time of standard/routine instances consists of waiting time and working time. The setup time only applies to non-routine instances. As non-routine instances are much more complex, they also require additional working time $\Delta t_{\text{work},y}^{\text{N}}$. For the same reason, additional activities cannot be automated. Thus, the automation ratio and potential result in a mixed calculation for the working time of standard/routine instances. In line with the mandatory tasks ratio, the working time of standard/routine instances influences the working time of non-routine processes. The waiting time of non-routine instances, in contrast, does not depend on the mandatory tasks ratio. This is why we consider a specific waiting time for non-routine instances. Thus, the average total processing time in a distinct period is calculated as follows:

$$t_y^{\text{total}} = t_y^{\text{SR}} \cdot (1 - N_y) + t_y^{\text{N}} \cdot N_y \tag{2}$$

$$t_y^{\text{N}} = t_{\text{setup},y}^{\text{N}} + t_{\text{wait},y}^{\text{N}} + t_{\text{work},y}^{\text{N}} \tag{3}$$

$$t_{\text{work},y}^{\text{N}} = \alpha_y \cdot t_{\text{work},y}^{\text{SR,int}} + \Delta t_{\text{work},y}^{\text{N}} \tag{4}$$

$$t_y^{\text{SR}} = t_y^{\text{SR,int}} \cdot (1 - E_y) + t_y^{\text{SR,ext}} \cdot E_y \tag{5}$$

$$t_y^{\text{SR,int}} = t_{\text{wait},y}^{\text{SR,int}} + t_{\text{work},y}^{\text{SR,int}} \tag{6}$$

$$t_{\text{work},y}^{\text{SR,int}} = t_{\text{work},y}^{\text{SR,int,M}} \cdot \left(M_y + (1 - M_y) \cdot \gamma_y^{\text{time}}\right) \tag{7}$$

$$t_{\text{work},y}^{\text{SR,int,M}} = \frac{A_y}{\varphi_y^{\text{auto}}} \cdot t_{\text{work},y}^{\text{SR,int,M,auto}} + (1 - A_y) \cdot t_{\text{work},y}^{\text{SR,int,M,man}} \tag{8}$$

The quality dimension cannot be discussed as detailed as time because quality must be operationalized first. Hence, there is no relationship between the quality of non-routine and standard/routine instances. That is, the quality of non-routine instances and standard/routine instances must be assessed separately. Moreover, the quality of externally executed standard/routine instances must be extracted from the SLA. The quality of internally executed standard/routine instances shows a structural analogy with the time dimension concerning the execution of activities, i.e., it is determined based on the automation ratio and potential. This leads to the average total quality shown below.

$$q_y^{\text{total}} = q_y^{\text{SR}} \cdot \left(1 - N_y\right) + q_y^{\text{N}} \cdot N_y \tag{9}$$

$$\overset{\uparrow}{q}_y^{\text{SR}} = q_y^{\text{SR,int}} \cdot \left(1 - E_y\right) + q_y^{\text{SR,ext}} \cdot E_y \tag{10}$$

$$\overset{\uparrow}{q}_y^{\text{SR,int}} = q_y^{\text{SR,int,M}} \cdot \left(M_y + \left(1 - M_y\right) \cdot \gamma_y^{\text{qual}}\right) \tag{11}$$

$$\overset{\uparrow}{q}_y^{\text{SR,int,M}} = \frac{A_y}{\varphi_y^{\text{auto}}} \cdot q_y^{\text{SR,int,M,auto}} + \left(1 - A_y\right) \cdot q_y^{\text{SR,int,M,man}} \tag{12}$$

While the performance indicators for time and quality are aggregated to total average values before serving as input for determining the number of process instances, the economic dimension can be distinguished by instance types. The operating outflows for the master process and the process variants are, analogously to time and quality, influenced by the automation ratio and potential. To appropriately capture the effects of standardization and automation, we also incorporate experience curve effects on manual work (Henderson 1973). The more instances are handled by a distinct process variant including the master process, the more that variant benefits from experience effects. The reason is that the operating outflows are known to drop by a constant percentage each time the cumulated number of instances doubles. This effect is expressed by a power law function with a constant elasticity a for both the master and the other variants. We assume:

A4: The operating outflows for manual work are constant within a period. The process is such mature that the experience curve is at its flat end. If the operating outflows are affected by improvement projects, we receive several experience curves for the process in focus as the calculation base changes.

$$v_y^{\text{SR,int,M}} = \frac{A_y}{\varphi_y^{\text{auto}}} \cdot v_y^{\text{SR,int,M,auto}} + \left(1 - A_y\right) \cdot v_y^{\text{SR,int,M,man}} \tag{13}$$

$$\overset{\uparrow}{v}_y^{\text{SR,int,M,man}} = v_0^{\text{SR,int,M,man}} \cdot \left(\sum_{j=0}^{y-1} D_j^{\text{SR,int,M}}\right)^{-a} \tag{14}$$

$$v_y^{\text{SR,int,V}} = \left(\frac{A_y}{\varphi_y^{\text{auto}}} \cdot v_y^{\text{SR,int,M,auto}} + \left(1 - A_y\right) \cdot v_y^{\text{SR,int,V,man}}\right) \cdot \gamma_y^{\text{cash}} \tag{15}$$

$$\overset{\uparrow}{v}_y^{\text{SR,int,V,man}} = v_0^{\text{SR,int,M,man}} \cdot \left(\sum_{j=0}^{y-1} D_j^{\text{SR,int,V}}\right)^{-a} \tag{16}$$

The operating outflows for non-routine instances are based on the operating outflows for the master process and the other variants, linked by the mandatory tasks ratio. As the position of mandatory tasks within the process and their amount can slightly change across the master process and the process variants, a mixed calculation applies best for non-routine instances. Further, additional operating outflows are needed. The fixed outflows in a distinct period split into fixed outflows for externally executed instances, outflows for internally executed standard/routine and for non-routine instances. Fixed outflows for standard/routine instances are needed to perform the standard tasks (e.g., wages, resource consumption, and IT support). Fixed outflows for non-routine instances accrue for performing extraordinary tasks (e.g., preparatory tasks, additional tasks and resources, and configurable IT services). Fixed outflows for external instances can relate to the sourcing process (e.g., contract negotiation) or to capacity (e.g., non-scalable capacity).

$$v_y^{\text{N}} = \left(M_y \cdot v_y^{\text{SR,int,M}} + \left(1 - M_y\right) \cdot v_y^{\text{SR,int,V}}\right) \cdot \alpha_y + \Delta v_y^{\text{N}} \tag{17}$$

$$f_y = f_y^{\text{SR,int}} + f_y^{\text{SR,ext}} + f_y^{\text{N}} \tag{18}$$

Finally, the decision model accounts for sales or transfer prices for standard/routine instances p^{SR} and for non-routine instances p^{N} because customers may be willing to pay a premium for non-standard instances.

Project Layer

Improvement projects can affect process performance directly or indirectly via process characteristics. Depending on the project, effects can be relative or absolute as well as positive, negative, or neutral. For example, the waiting time can be increased by 50%, decreased by 20 minutes, or left unchanged. Relative effects must be linked multiplicatively from one period to another, absolute effects must be linked additively (Lehnert et al. 2014). It must be considered that the ratios used in the decision model, e.g., the automation or sourcing ratio, are limited to the interval $[0; 1]$. Depending on the case, the upper boundaries can also be smaller, e.g., if the organization strategically decides that at most 75 % of instances should be outsourced.

The most complex effects are those caused by standardization. The reason is that standardization affects the number of process variants, which in turn influences the master process ratio, the sourcing ratio, and the non-routine ratio. The decision model allows for two scenarios. The first scenario is that the number of process variants is reduced to exploit experience curve effects and to leverage the performance surplus of the master process. This scenario requires shifting standard/routine instances that were so far allocated to context-specific variants to the master process. As a reduction of process variants may reduce the output variety of the process, the organization may lose its ability to assign an instance to the process variant that fits best (Ludwig et al. 2011). Therefore, only a distinct fraction λ of the shifted instances is allocated to the master process, whereas the other instances become non-routine instances (Figure 4).

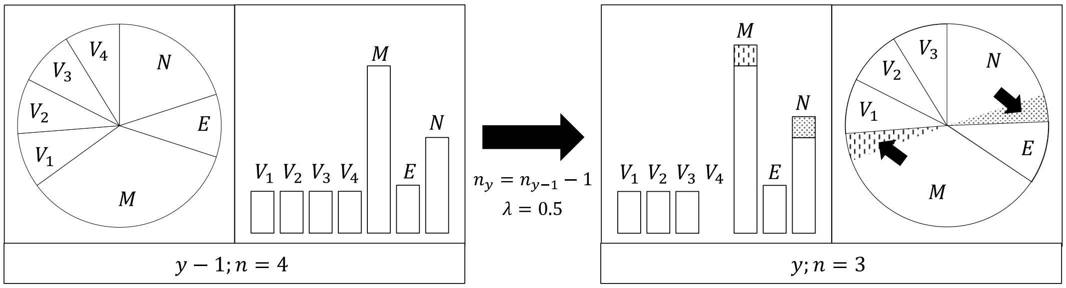

Figure 4. Shifting standard/routine instances to the master process and non-routine instances

Assuming that there are no other projects effects, the master process ratio, the sourcing ratio, and the non-routine ratio can be specified as follows for the first scenario of standardization:

$$M_y = \frac{M_{y-1} + \frac{1}{n_{y-1}} \cdot (n_{y-1} - n_y) \cdot (1 - M_{y-1}) \cdot \lambda}{1 - \frac{1}{n_{y-1}} \cdot (n_{y-1} - n_y) \cdot (1 - M_{y-1}) \cdot \lambda} \tag{19}$$

$$E_y = \frac{E_{y-1}}{1 - \frac{1}{n_{y-1}} \cdot (n_{y-1} - n_y) \cdot (1 - M_{y-1}) \cdot \lambda} \tag{20}$$

$$N_y = N_{y-1} + \frac{1}{n_{y-1}} \cdot (n_{y-1} - n_y) \cdot (1 - M_{y-1}) \cdot \lambda \cdot (1 - E_{y-1}) \cdot (1 - N_{y-1}) \tag{21}$$

The second scenario is that standardization leads to additional variants. If some non-routine instances can be executed similarly, the organization can design a new process variant. As all process variants are treated equally with respect to the number of allocated instances, the shift results from the number of instances per variant as valid in the previous period. In this case, no special ratio is needed. For this second scenario, the master process ratio, the sourcing ratio, and the non-routine ratio can be calculated as follows.

$$M_y = \frac{M_{y-1} \cdot (1 - E_{y-1}) \cdot (1 - E_{y-1})}{(1 - E_y) \cdot (1 - N_y)} \tag{22}$$

$$E_y = \frac{E_{y-1} \cdot (1 - N_{y-1})}{1 - N_y} \tag{23}$$

$$N_y = N_{y-1} - \frac{1}{n_{y-1}} \cdot (n_{y-1} - n_y) \cdot (1 - M_{y-1}) \cdot (1 - E_{y-1}) \cdot (1 - N_{y-1}) \tag{24}$$

Finally, each process improvement project causes investment outflows. These investment outflows may not only depend on the size and complexity of the project itself, but also be driven by the values of some process characteristics that hold in the period for which the project is scheduled, depending on the relations among the industrialization strategies outlined in the theoretical background. For example, automating a process or outsourcing some instances may depend on the number of process variants. Moreover, standardizing the process may depend on the automation ratio. Modelling the investment outflows as also driven by process characteristics caters for inter-temporal interactions among projects, as the process characteristics depend on which projects from the improvement roadmap have been implemented earlier.

Evaluation

Evaluation Strategy

To evaluate the decision model, we followed the evaluation framework proposed by Sonnenberg and vom Brocke (2012). The framework comprises the four activities EVAL1 to EVAL4, which refer to ex-ante and ex-post as well as to artificial and naturalistic evaluation methods (Venable et al. 2012). With EVAL1 aiming at justified problem statements and design objectives, we derived the need for advancing extant prescriptive knowledge on process improvement as a meaningful DSR problem via a literature review. We also derived design objectives from justificatory knowledge related to BPM, PPS, and VBM to assess whether an artefact helps solve the research problem. EVAL2 strives for validated design specifications. We therefore discussed the decision model against the design objectives in terms of a feature comparison, an ex-ante and artificial evaluation method. Complementarily, we conducted an interview with four industry experts, an ex-ante and naturalistic evaluation method, to gather preliminary insights into whether organizational stakeholders consider the decision model's design specification as valid. We present the results of feature comparison and the expert interview jointly with a particular focus on discussing the decision model's assumptions. As for EVAL3, aiming at validated artefact instantiations, we built and tested a software prototype. A scenario analysis in an artificial setting confirmed applicability. To make the prototype demonstration more realistic, we used anonymized data from our discussions with industry experts. So far, we have not yet conducted activity EVAL4 involving real tasks, real systems, and real people, which would corroborate the decision model's applicability and usefulness in naturalistic settings. This is planned for future research.

Feature Comparison, Expert Interview, and Discussion (EVAL2)

We discuss the results of feature comparison and the expert interview along the design objectives previously derived from justificatory knowledge. We pay particular attention to assumptions as the assumptions must be considered when interpreting the decision model's recommendations. The decision model addresses all design objectives. The interviewed experts agreed with the decision model's idea and design specification. However, there are also weaknesses and areas for future research.

(O.1) Process improvement and performance measurement

The decision model focuses on process improvement projects, i.e., projects that improve the performance of a single process. To assess the effects of such projects, we adopt a multi-dimensional conceptualization of process performance based on the Devil's Quadrangle. Each performance dimension is operationalized via performance indicators (e.g., time via working, setup, and waiting time). Process improvement projects affect process performance directly or indirectly via process characteristics. The characteristics used in the decision model are inspired by established industrialization strategies such as automation (e.g., automation ratio and automation potential), standardization (e.g., number of process variants and non-routine ratio), flexibility (e.g., setup time), and sourcing (e.g., sourcing ratio). Interactions among the industrialization strategies are covered via the investment outflows of process improvement projects, a means also used to incorporate interactions among projects. Interactions among projects also covered via multiplicative and additive effects on performance indicators, which are cascaded over time. The industry experts supported the structuration into multiple layers as well as the idea of incorporating process characteristics into process decision-making. The experts agreed with the included industrialization strategies, process characteristics, and performance indicators. They also indicated that, in their domain, risk and flexibility-to-change should be considered. We agree that risk can be treated as an outflow component, while flexibility-to-change can be modelled as a variable that moderates the effects of improvement projects or their investment outflows.

As for the decision model's assumption, we assumed that the expected number of periodic instances can be forecast using the total processing time and the total quality of the previous period (A1). Instead, we could have used other approaches from time-series analysis and forecasting literature, e.g., moving average with exponential smoothing. If only the previous period is used, the demand is comparatively volatile. However, the advantage is that effects of process improvement projects can be analyzed unambiguously as they are only counted once. In addition, we assume each process instance to be executed exclusively internally or externally and all relevant performance indicators for externally handled process instances to be specified in SLAs with third party providers (A2). Relaxing this assumption would imply distinguishing between sub-processes as well as to analyze which sub-processes are outsourced and how strongly the sub-processes influence the performance indicators. It would also be necessary to allocate project effects to sub-processes and consider effects of hand-over complexity. Since this alternative would extremely increase the calculation complexity and the data collection effort associated with the decision mode, we decided to work with exclusively internally or externally handled instances. Using the contractual limits specified in SLAs complies with the idea of risk-averse decision-making as third party providers are likely to deliver better performance over time than specified in the SLA. Otherwise, they would be replaced. As an alternative, actual performance values can be retrieved from regular reports, which however in turn would imply higher data collection effort. Next, we assumed process instances that are not handled via the master process to be equally distributed to process variants (A2). We made this assumption to reduce complexity. Otherwise, we had to capture topics such as arrival rates, waiting queues, and time-variant distributions of process instances to variants. This, however, would not fit the decision model's purpose as it does not aim at predicting the value contribution of one process improvement roadmap best possible, but at providing a framework for consistently comparing process improvement roadmaps in terms of the value contribution. However, the key effect of process standardization, i.e., stronger experience curve effects due to a stronger concentration of the periodic number of process instances, is covered sufficiently despite this assumption. Finally, we assumed the organization to be able to estimate reference points for the performance indicators related to time, quality, and outflows for the scenarios where the automation potential is fully tapped and where all task are performed manually (A3). This assumption is not a simplification. Rather, it allows for considering not only the automation level, but for differentiating between project effects on the automation ratio and the automation potential, which may occur independently.

(O.2) *Project portfolio selection*

The decision model takes multiple projects as input. We assumed that, in the prescreening stage of the PPS process, all projects have been checked for strategic fit and that, in the individual project analysis stage, all project effects were determined as single values. The decision model also accounts for selected constraints (e.g., predecessor/successor, restricted budgets) and considers deterministic, scheduling, intra-, and inter-temporal interactions. In order to be able to incorporate process characteristics in great detail, the decision model takes a single-process perspective. Due to its focus on process improvement, the decision model neglects projects that develop BPM as an organizational capability. We assumed that all project effects are deterministic and remain constant over time. In real-world cases, project effects can vary depending on the period of implementation and also be of stochastic nature. As the decision model includes many parameters whose values must be estimated by experts, we decided to abstract from time-variant and stochastic project effects. According to our industry experiences, this is reasonable as experts are not able to estimate such a high number of parameters depending on time. With many stochastic and interacting parameters, it would be extremely difficult to interpret the recommendations provided by the decision model. To account for uncertainty and estimation inaccuracies, we recommend conducting scenario and sensitivity analyses.

(O.3) *Value-based management*

The decision model ranks process improvement roadmaps according to their value contribution, measured as the roadmaps' expected NPV based on a risk-adjusted interest rate. The NPV reflects all monetary and monetized effects caused by the implementation of improvement projects and process execution over time. The decision model accounts for the decision makers' risk attitude via the risk-adjusted interest rate, which is an indirect way of accounting for risk. As improvement projects are scheduled over multiple periods, the decision model also considers a multi-period planning horizon. The risk-adjusted interest rate accounts for the time value of money. Having discussed pros and cons of industrialization strategies, the industry experts highlighted that the economic valuation must be aligned with strategic considerations. For example, while process automation and outsourcing promise cost savings, they also cause knowledge drain. A similar argumentation holds for standardization and automation. To account for such considerations as far as possible, the decision model allows for specifying critical thresholds for distinct process characteristics such as the automation and the sourcing ratio.

As for the decision model's assumptions, we assumed that operating outflows for manual work are constant within a period and the process in focus is such mature that the experience curve is at its flat end (A4). As the experience curve effect depends on the cumulated number of instances, it theoretically decreases for each single instance. As a simplification, we calculate the operating outflows once per period based on the cumulated number of instances up to the previous period. This is why operating outflows remain constant within a period. This approach is reasonable for mature processes, as the experience curve gets the flatter the higher the cumulated demand is. The estimation inaccuracy is negligible. Further, treating the operating outflows as constant per period is risk-averse since this means working with higher outflows than necessary.

Prototype Demonstration (EVAL3)

To demonstrate the software prototype, we present an example that relies on discussions with our industry partners from the financial services industry. Owing to confidentiality, all data had to be anonymized and slightly modified. In the example, a period lasts three months. The planning horizon amounts to eight periods and the risk-adjusted interest rate amounts to 2.5%. The overall budget for improving the process in focus was set to 950,000 EUR for the entire planning horizon.

We consider a mortgage loan process and six improvement projects. The process includes the activities advisory, proposal preparation, and contract management. The process starts when a customer gets in contact with the service provider, and ends when a contract is signed. The department in focus works as a cost center and receives an internal transfer price of 650 EUR per advised customer. The demand for the process is primarily driven by the processing time. Time that results from delays caused be the customer is excluded. All input parameters regarding the process characteristics and process performance indicators of the mortgage loan process prior to implementing any improvement project are shown in Table 2. Besides the process itself, input parameters regarding all pre-selected improvement projects must be collected. All project descriptions and data are shown in Table 3, where relative and absolute effects are expressed in terms of ($*$) and (+/-), respectively. For each project, we estimated effects on the process, interactions, and constraints. The investment outflows of each project comprise a fixed amount as well as a variable amount that depends on the number of process variants and the automation ratio.

Table 2. Input parameters regarding process characteristics and performance

Process characteristics	N_0	10%	Time indicators	$t_{\text{work},0}^{\text{SR,int,M,man}}$	345 min	Economic indicators	$v_0^{\text{SR,int,M,auto}}$	150 EUR
	E_0	0%		$t_{\text{work},0}^{\text{SR,int,M,auto}}$	210 min		$v_0^{\text{SR,int,M,man}}$	718 EUR
	M_0	61%		γ_0^{time}	1.2		Δv_0^{N}	230 EUR
	α_0	90%		$t_{\text{wait},0}^{\text{SR,int}}$	120 min		γ_0^{cash}	1.2
	A_0	30%		$t_{\text{wait},0}^{\text{N}}$	130 min		f_0	900,000 EUR
	φ_0^{auto}	70%		$t_{\text{setup},0}^{\text{N}}$	130 min		a	0.005
	n_0	3		$\Delta t_{\text{work},0}^{\text{N}}$	80 min		p^{SR}	650 EUR

Demand function	$D_y = 5{,}000 \cdot e^{\frac{650}{t_{y-1}^{\text{total}}}} - 8{,}000$

Based on the input parameters, we applied the software prototype that implements the decision model to determine the optimal and worst process improvement roadmap for several scenarios. Table 4 contains all results. Scenario (A) is the starting point. This scenario serves as foundation for calculating scenarios (B) to (E), varying one process characteristic per scenario (ceteris paribus).

Consider scenario (A) as example: The optimal process improvement roadmap includes five projects and has a value contribution of 3.51 mio. EUR. The worst roadmap would lead to a value contribution of -3.71 mio. EUR. Project (1) is scheduled for period 1 as it strongly increases the automation ratio, leading to major savings since the operational outflows for automated tasks are significantly lower than for manual tasks. In addition to this indirect effect, project (1) directly affects the operational outflows. In period 2, project (6) is scheduled. This project affects the automation ratio and consequently has similar effects as project (1). Implementing this project is reasonable as the automation potential has not yet been completely tapped. In periods 3 to 5, project (3) is scheduled, whose implementation takes three periods. Implementing project (3) after projects (1) and (6) is reasonable as its investment outflows depend on the automation ratio, which is positively influenced by both prior projects. Project (4) is implemented in period 6. This is reasonable as project (4) has a positive stand-alone business case and is independent from the automation ratio. In period 7, no project is scheduled. Project (5) is mandatory and negatively affects the working time. Therefore, it is consistent to implement this project in the last period of the planning horizon. Project (2) is not included in any optimal roadmap as it does not pay off in the given planning horizon. The investment outflows and the negative effects on the operational outflows exceed the positive effects on waiting time.

As the additional scenarios are based on varying one process characteristic each, we restrict our discussion to the most significant changes compared to scenario (A). In scenario (B), relating more to standardization, the NPV of the optimal roadmap is smaller than in scenario (A). The reason is that, as shown by the master process ratio, more instances are allocated to the more expensive and slower process variants. Thus, project (4) is implemented earlier, reducing the number of process variants and increasing the master process ratio. Project (3) is skipped as its expensive and late effects on waiting time are exceeded by the cheap and early learning curve effects of project (4). Scenarios (C) and (D) show similar results. In scenario (E), project (3) is skipped because its investment outflows also depend on the number of process variants. In scenario (F), the reduced mandatory tasks ratio leads to a high NPV. The reason is that non-routine instances become cheaper and faster. The positive effect on the working time, in turn, highly influences the process demand. Moreover, projects (4) and (6) switch places because reducing the number of process variants not only improves the master process ratio, but also further increases the non-routine ratio. In scenario (G), the NPV is much higher than in all other scenarios. The reason is the increased automation ratio that positively affects the operating outflows and the working time, starting with period 1. Moreover, as the effect of projects (1) and (6) on the automation ratio are relative, their absolute effect is much higher in this scenario.

The demonstration example showed that, based on the prototype, the decision model yields interpretable results. It indicated that the industrialization strategies cannot be reasonably analyzed stand-alone. We were able to consistently compare process improvement roadmaps and scenarios. In addition, the optimal process improvement roadmaps were relatively constant across the scenarios, which is a first hint on the decision model's robustness against estimation errors.

Table 3. Input parameters regarding pre-selected process improvement projects

Project	Description, direct effects, constraints, investment outflows
(1)	*Process automation* • Effects: increases the automation ratio by 40% (∗), increases operating outflows for automated work by 80 EUR (+), and reduces operating outflows for manual work by 120 EUR (-) • Constraints: no • Investment outflows (in EUR): $120{,}000 + 20{,}000 \cdot A_y$ • Duration: 1 period
(2)	*Introduction of app-based contract approval* • Effects: decreases manual working time of standard/routine instances by 7% (∗) • Constraints: requires prior implementation of project (6) • Investment outflows (in EUR): $200{,}000 + 30{,}000 \cdot n_y$ • Duration: 2 periods
(3)	*Implementation of workflow management system* • Effects: reduces waiting time for standard/routine and non-routine instances by 30 min (-) and increases fixed outflows by 15,000 EUR (+) • Constraints: no • Investment outflows (in EUR): $140{,}000 + 40{,}000 \cdot n_y - 10{,}000 \cdot A_y$ • Duration: 3 periods
(4)	*Reduction of number of process variants* • Effects: reduces number of process variants by 1 (-), demand is reallocated by 50% (λ) to master process (*), and fixed outflows decrease by 50,000 EUR (-) • Constraints: no • Investment outflows (in EUR): 45,000 • Duration: 1 period

(5)	*Introduction of specific documentation for customer consultancy* • Effects: increases manual working time of standard/routine instances by 10 minutes (+) • Constraints: mandatory project due, latest implementation in period 8 • Investment outflows (in EUR): $80{,}000 + 30{,}000 \cdot n_y$ • Duration: 1 period
(6)	*Update of the advisory software* • Effects: increases automation ratio by 15% $(*)$ • Constraints: no • Investment outflows (in EUR): $200{,}000$ • Duration: 1 period

Table 4. Optimal and worst process improvement roadmaps created by the decision model

Scenario	Changes compared to (A)	Optimal result	Worst result
(A)		Roadmap: (1, 6, 3, 3, 3, 4, -, 5) NPV: 3.51 mio. EUR	Roadmap: (5, -, -, -, 3, 3, 3, 6) NPV: -3.71 mio. EUR
(B)	Reduce master process ratio $(M_0 = 33\%)$	Roadmap: (1, 6, 4, -, -, -, -, 5) NPV: 0.57 mio. EUR	Roadmap: (5, -, -, -, 3, 3, 3, 6) NPV: -6.71 mio. EUR
(C)	Increase non-routine ratio $(N_0 = 25\%)$	Roadmap: (1, 6, 4, -, -, -, -, 5) NPV: 0.89 mio. EUR	Roadmap: (5, -, -, -, 3, 3, 3, 6) NPV: -5.81 mio. EUR
(D)	Reduce automation potential $(\varphi_0^{\text{auto}} = 60\%)$	Roadmap: (1, 6, 4, -, -, -, -, 5) NPV: 0.58 mio. EUR	Roadmap: (3, 3, 3, 5, 6, 2, 2, 1) NPV: -4.78 mio. EUR
(E)	Increase number of variants $(n_0 = 5)$	Roadmap: (1, 6, 4, -, -, -, -, 5) NPV: 3.40 mio. EUR	Roadmap: (5, -, -, -, 3, 3, 3, 6) NPV: -3.88 mio. EUR
(F)	Reduce mandatory tasks ratio $(\alpha_0 = 50\%)$	Roadmap: (1, 4, 6, 3, 3, 3, -, 5) NPV: 7.06 mio. EUR	Roadmap: (5, -, -, -, 3, 3, 3, 6) NPV: -1.51 mio. EUR
(G)	Increase automation ratio $(A_0 = 50\%)$	Roadmap: (1, 6, 3, 3, 3, 4, -, 5) NPV: 11.97 mio. EUR	Roadmap: (5, -, -, -, 3, 3, 3, 6) NPV: 4.75 mio. EUR

Conclusion

In this paper, we examined which projects an organization should implement to improve a distinct process, particularly accounting for process characteristics that reflect how work is performed and organized. To address this research question, we specified and instantiated a decision model in line with the principles of value-based management and project portfolio selection. Assisting in the valuation of process improvement roadmaps, the decision model contributes to the body of prescriptive knowledge on process improvement and process decision-making. Among possible improvement roadmaps, the decision model recommends selecting that with the highest value contribution in terms of the roadmap's expected net present value. The model extends existing approaches to process improvement by not only focusing on process performance (e.g., time, quality, and costs), but by especially accounting for process characteristics that reflect how work is performed and organized (e.g., number of process variants, fraction of non-routine instances, fraction of instances handled externally, degree of automation, and automation potential). This is different compared to other single-/multi-process approaches. The characteristics used in the decision model were inspired by established industrialization strategies, i.e., automation, sourcing, standardization, and flexibility. Hence, the decision model does not only cover one, but any combination of these industrialization strategies. As process improvement projects often refer to more than one industrialization strategy, this is closer to reality compared to existing approaches. Further, linking project effects not only with performance indicators, but also with process characteristics allows for a more detailed planning compared to existing approaches. Beyond providing insights into process value drivers, process characteristics cater for interactions among industrialization strategies and improvement projects. We evaluated the decision model in line with the framework proposed by Sonnenberg and vom Brocke (2012). In this paper, we reported on the results of feature comparison, an expert interview, prototype construction, and a demonstration example including a scenario analysis in order to fulfill the requirements of the evaluation activities EVAL1 to EVAL3.

However, the decision model suffers from limitations that stimulate further research. Some of the decision model's assumptions simplify reality. For instance, the decision model simplifies the treatment of process variants, as the number of internally processed standard/routine instances was assumed to be equally distributed over all process variants. We already discussed the consequences of the assumptions in the evaluation section. In future research, the decision model should be carefully extended, taking into account that it does not aim at predicting the value contribution of a process improvement roadmap best possible, but at providing a framework for consistently comparing multiple process improvement roadmaps in terms of their value contribution. The feature comparison and the expert interview revealed further challenges. The experts highlighted that determining some input parameters, e.g., cash flows on the single process level, is difficult in naturalistic settings. Thus, the decision model will benefit from further evaluation. Particularly real-world case studies such as recommended by evaluation activity EVAL4, where the decision model and the prototype are applied in naturalistic settings, will help gain more experience in data collection and build up a knowledge base. The case studies should also be used to challenge the decision model's usefulness for organizational stakeholders involved in process improvement and the prioritization of improvement projects. In order to enable real-world case studies, the current software prototype should also be extended toward more sophisticated visualization and analysis functionality. With the decision model abstracting from specific application domains, another worthwhile endeavor for future research is to work on domain-specific sets of process characteristics such as for the services or the manufacturing industry. Finally, our long-term research vision is to extend the decision model such that is covers not only multiple projects, but also multiple interdepending processes.

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Appendix

General Setting	
r	Process improvement roadmap
Y	Planning horizon
y	Planning period within the planning horizon
z	Risk-adjusted discount rate
Process Characteristics Layer	
N_y	Non-routine ratio: fraction of process instances classified as non-routine instances
α_y	Mandatory tasks ratio: fraction of mandatory tasks in SR instances
E_y	Sourcing ratio: Fraction of instances handled entirely externally
n_y	Number of context-specific process variants
M_y	Master process ratio: fraction of instances handled by the master process
A_y	Automation ratio: fraction of tasks carried out automatically relative to automation potential
φ_y^{auto}	Automation potential: highest fraction of tasks that can be automated
λ	Fraction of instances shifted to the master process when reducing process variants
Process Performance Layer	
t_y^{total}	Total processing time
$t_{\text{setup},y}$	Setup time: time where resources are prepared for the execution of specific instances
$t_{\text{wait},y}$	Waiting time: queueing and other waiting time
$t_{\text{work},y}$	Working time: time where process tasks are performed
t_y^{SR}	Total processing time of SR instances
$t_y^{\text{SR,ext}}$	Total processing time of SR instances (external handling)
$t_y^{\text{SR,int}}$	Total processing time of SR instances (internal handling)
$t_{\text{wait},y}^{\text{SR,int}}$	Waiting time of SR instances (internal handling)

$t_{\mathrm{work},y}^{\mathrm{SR,int}}$	Working time of SR instances (internal handling)
$t_{\mathrm{work},y}^{\mathrm{SR,int,M}}$	Working time of SR instances (internal handling by the master process)
$t_{\mathrm{work},y}^{\mathrm{SR,int,M,man}}$	Working time of SR instances (internal handling by the master process, manual)
$t_{\mathrm{work},y}^{\mathrm{SR,int,M,auto}}$	Working time of SR instances (internal handling by the master process, automated)
t_y^{N}	Total processing time for non-routine instances
$t_{\mathrm{setup},y}^{\mathrm{N}}$	Setup time for non-routine instances
$t_{\mathrm{wait},y}^{\mathrm{N}}$	Waiting time for non-routine instances
$t_{\mathrm{work},y}^{\mathrm{N}}$	Working time for non-routine instances
$\Delta t_{\mathrm{work},y}^{\mathrm{N}}$	Additional time for executing tasks of non-routine instances
q_y^{total}	Total quality
q_y^{SR}	Quality of SR instances
$q_y^{\mathrm{SR,ext}}$	Quality of SR instances (external handling)
$q_y^{\mathrm{SR,int}}$	Quality of SR instances (internal handling)
$q_y^{\mathrm{SR,int,M}}$	Quality of SR instances (internal handling by the master process)
$q_y^{\mathrm{SR,int,M,man}}$	Quality of SR instances (internal handling by the master process, manual)
$q_y^{\mathrm{SR,int,M,auto}}$	Quality of SR instances (internal handling by the master process, automated)
q_y^{N}	Quality of non-routine instances
q^{max}	Upper quality boundary: highest level of process quality that can be reached
γ_y^{time}	Performance multiplier regarding master process and variants concerning time
γ_y^{qual}	Performance multiplier regarding master process and variants concerning quality
γ_y^{cash}	Performance multiplier regarding master process and variants concerning outflows
Economic Valuation Layer	
I_y	Investment outflows
f_y	Fixed outflows
$f_y^{\mathrm{SR,int}}$	Fixed outflows of SR instances (internal handling)
$f_y^{\mathrm{SR,ext}}$	Fixed outflows of SR instances (external handling)
f_y^{N}	Fixed outflows of non-routine instances
D_y	Expected number of process instances to be handled
p	Operating inflows
p^{SR}	Sales or transfer price of SR instances
p^{N}	Sales or transfer price of non-routine instances
v_y	Operating outflows
$v_y^{\mathrm{SR,ext}}$	Operating outflows of SR instances (external handling)
$v_y^{\mathrm{SR,int,V}}$	Operating outflows of SR instances (internal handling by a process variant)
$v_y^{\mathrm{SR,int,V,man}}$	Operating outflows of SR instances (internal handling by a process variant, manual)
$v_y^{\mathrm{SR,int,M}}$	Operating outflows of SR instances (internal handling by the master process)
$v_y^{\mathrm{SR,int,M,man}}$	Operating outflows of SR instances (internal handling by the master process, manual)
$v_y^{\mathrm{SR,int,M,auto}}$	Operating outflows of SR instances (internal handling by the master process, automated)
v_y^{N}	Operating outflows of non-routine instances
Δv_y^{N}	Additional operating outflows for non-routine instances
a	Constant elasticity used for the calculation of experience curve effects

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