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An assisted approach to business process redesign

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Abstract

For many organizations, the continuous optimization of their business processes has become a critical success factor. Several related methods exist that enable the step-by-step redesign of business processes. However, these methods are mainly performed manually and require both creativity and business process expertise, which is often hard to combine in practice. To enhance the quality and effectiveness of business process redesign, this paper presents a conceptualization of assisted business process redesign (aBPR). The aBPR concept guides users in improving business processes based on redesign patterns. Depending on the data at hand, the aBPR concept classifies four types of recommendations that differ in their level of automation. Further, this paper proposes a reference architecture that provides operational support for implementing aBPR tools. The reference architecture has been instantiated as a prototype and evaluated regarding its applicability and usefulness in artificial and naturalistic settings by performing an extensive real-world case study at KUKA and interviewing experts from research and practice.

Keywords: Business Process Redesign, Reference Architecture, User Guidance, Business Process Management

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1. Introduction

Transforming business processes at an accelerating pace is essential for companies to meet increasing competition and customer needs [1, 2]. With the two simple statements, “all work is process work” and “a good process is better than a bad process” ([3, p. 11]), an equally simple yet business-critical question arises: How can business processes be improved? In business process management (BPM), business process redesign (BPR) is concerned with the improvement of business processes to address previously identified process-related issues [4]. BPR projects entail vast human and technical investments but also yield promising returns [2]. Therefore, BPR is commonly considered the most value-adding stage in the BPM lifecycle [4–7].

Organizations often conduct workshops with consultants and diverse process stakeholders to analyze challenges and opportunities and manually generate BPR options [7]. Despite the importance of BPR projects and the abundant availability of BPR methods, 60-80% are reported as failed [5, 8, 9]. The failure of BPR projects is rooted in the fact that redesign itself still “happens in a black box” ([7, p. 217]). For example, process redesign patterns, which reflect good practices, rarely consider process context and often lack instructions that guide users through steps to redesign alternatives [6, 8, 10]. Hence, the quality and effectiveness of BPR depend on the creativity and expertise of the project team to find valuable solutions [11].

Apart from methods, tools are an essential means to manage the complexity of business processes and to help with improvement and deployment [9]. Currently, the demand for BPM tools is growing, as evidenced by Celonis’ $11 billion valuation[1] or SAP’s acquisition of Signavio[2] [9]. While most of the literature that presents BPR methods fails to embrace tool support, some approaches build on redesign patterns to generate tool-based suggestions for their application on business processes

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[1] `https://www.forbes.com/sites/alexkonrad/2021/06/02/celonis-process-mining-raises-at-11-billion-valuation/`

[2] `https://news.sap.com/2021/03/signavio-acquisition-complete/`

[9, 10, 12]. However, they come with limitations, e.g., (1) they rely on data that is difficult to retrieve, (2) are inflexible due to hard-coded assumptions, and (3) only a few approaches offer the possibility to include a variety of redesign patterns [11]. Hence, it is questionable to what extent such tool-based approaches can handle the complexity of and the extensive information on the business process and make actionable suggestions for redesigning business processes [11].

While this research gap has been recognized in the literature, no interactive and assistive approach combines both worlds in a guided process [11, 13]: tool-based automation and guidance of BPR tasks on the one hand and the incorporation of domain expertise on the other hand. Thus, we formulate our research question as follows: *How can assistive tools improve BPR?*

We address this research question by proposing a conceptualization of assisted business process redesign (aBPR). As the central artifact, the aBPR concept guides users (i.e., process designers or managers) in improving business processes based on redesign patterns. The aBPR concept introduces four types of recommendations that differ in their automation level to assist the redesign process: low, moderate, elevated, and high. Additionally, we propose a reference architecture (RA) that builds on the aBPR concept and guides implementing aBPR tools. We validate the design specification of the aBPR concept by means of expert interviews. Further, we provide a prototypical instantiation of the aBPR RA and involved BPM experts from academia and industry to evaluate the artifact's applicability. Finally, we underpin the artifact's usefulness in naturalistic settings via a case study at KUKA [14].

Adopting the design science research (DSR) paradigm [15, 16] in conjunction with RA development [17] as a research method, the remainder of this manuscript is structured as follows: Section 2 provides a background on relevant justificatory knowledge. Section 3 provides an overview of our research method and evaluation strategy. Section 4 derives design objectives (DOs), introduces the aBPR concept

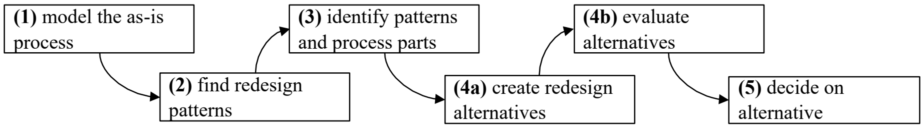


Figure 1: Reference process for applying and evaluating redesign patterns with simulation experiments adopted from Jansen-Vullers and Reijers [20].

and RA design specification and describes the prototypical instantiation. In Section 5, we report on our evaluation results. Section 6 concludes the paper.

2. Theoretical Background

As a part of their BPM activities, organizations pursue BPR to stay competitive and ensure future revenue generation [4]. BPR refers to the design and change of business processes within and beyond organizational boundaries [4]. Both methods and software tools are deemed to be critical success factors for BPR [7, 18]. This section introduces concepts from BPR and presents related BPR tools and techniques.

BPR methods help complete BPR projects successfully by taking a normative perspective, i.e., through guidance in a step-wise manner [19]. This research focuses on tool-supported incremental and evolutionary approaches to business process improvement as a subset of BPR. A structured procedure helps make BPR results more reproducible [20]. Jansen-Vullers and Reijers [20] describe five consecutive steps (see Figure 1) for generating change options for existing process models based on redesign patterns and their evaluation with simulation experiments that have been adopted in other works [11, 12, 21, 22].

Step 1, process modeling, poses several challenges, such as the availability of data, an agreed abstraction level, and the ever-changing nature of processes that are hard to capture [4]. In most organizations, this step is facilitated by notations such as business process modeling notation (BPMN) and tools [23]. Data-based discovery techniques (i.e., process mining) support generating *as-is* process models from system logs [24, 25]. To generate realistic process models amenable to simulation, techniques have been proposed to discover simulation models from event data automatically and consider additional perspectives (e.g., data/rules and resource/organization) required on top of the control-flow perspective [24, 26, 27].

Step 2 results in a list of applicable redesign patterns and process parts. In information systems (IS) research, patterns are widely used to document proven knowledge that has worked for solving problems in particular contexts [28]. BPR patterns (also known as good practices or redesign heuristics) "suggest particular changes to an existing process to influence its operation in certain ways" ([29, p. 193]). Hence, redesign patterns broaden the solution space of redesign options, facilitate the outcome-oriented search for novel process designs, and encourage goal-oriented BPR initiatives [6, 10]. Reijers and Limam Mansar [6] present 29 redesign patterns derived from literature and practical experience of BPR projects. Further pattern collections focus on process aspects such as customer centricity [30] or the control-flow [31]. Netjes et al. [32] calculate global process measures to suggest specific redesign patterns if the process measures match certain condition statements (e.g., the suggestion to eliminate tasks if the *level of control* measure exceeds an expert-defined threshold). Limam Mansar et al. [33] provide a process-wide assessment for redesign patterns resulting in a ranked list. However, both approaches do not identify process parts to which specific redesign patterns could be applied. For a set of three redesign patterns from Reijers and Limam Mansar [6], Souza et al. [34] identify suitable process parts and apply the process redesign using implemented heuristics. While they present algorithmic heuristics for selected redesign patterns, they assume specific data in the model and require users to evaluate the options.

Step 3 concerns the decision on the specific change options. Challenges within this step lie in the potentially large number of possible change options [35] and the uncertainty about the actual impact of the redesigns on the business process at hand [36]. To address the cognitive overload users face with too many modeling options, process model recommender systems suggest generic design choices from a process repository ranked based on user preferences [37, 38]. At this step, an evaluation of concrete redesign choices would help the user to make informed decisions [11].

Step 4a concerns redesigning the process by applying the selected redesign pattern(s) to the identified process part. This step can be performed manually, with the modeling tools described in step 1 or using (semi-) automated approaches. Netjes et al. [39] introduce formal algorithms to verify whether a set of four complex redesign operations (i.e., parallel, sequence, unfold, and merge functions) can be applied to specific process parts and execute the operation to redesign the process.

Process performance is a multi-dimensional construct that mainly considers the four generic dimensions time, quality, cost, and flexibility [6]. Performance objectives defined at the beginning of BPR initiatives help purposefully redesign the process. Assessing the change options' value and effect on performance objectives before implementing those is crucial for the success of BPR projects [26, 40]. Step 4b concerns the evaluation via employing simulation studies. In BPR projects, simulation has been proven useful for evaluating the effects of redesign patterns on process performance [26, 36, 41]. Schunselaar et al. [35] present a technique to simulate multiple automatically generated process variants from a configurable family of simulation models at once. However, their approach does not consider the adoption of redesign patterns. The work of López-Pintado et al. [42] presents a multi-objective process performance optimization concerning the trade-off between cycle time and resource costs based on simulation techniques. Further, Pourbafrani et al. [43] propose an interactive approach that simulates and compares configurable process alternatives modeled as process trees.

Step 5 concerns the decision on *to-be* process models. Tools can support the comparison of different redesign alternatives. Data returned from simulation experiments often comes in the form of event logs. These event logs can then be analyzed using the same process mining techniques applied when examining real-world event logs [26]. In an alternative approach, van Zelst et al. [44] suggest measuring the time-based performance of processes based on historically logged event data to predict performance. However, the final validation is made by experts [34].

Executing these five steps leads to new process designs. However, there are only a few approaches available that integrate combinations of the steps presented. Three related artifacts are presented in the following. The PrICE toolkit [12, 32, 39] suggests iterating over steps 2-4 (i.e., find, select, create, and evaluate) so that performing local updates to an existing process aims to improve performance incrementally. The toolkit conceptually envisions a structured and iterative approach, which is only loosely supported in their implementation. Essam and Limam Mansar [11] propose iterate over steps 1-5 fully automated but lack evaluation and instantiation of their proposal. The dBOP approach [45–47] is a business process optimization platform consisting of three architectural layers that help to integrate, analyze, and optimize processes continuously (steps 1-5). The dBOP enforces a rigorous methodology that may limit flexibility and creativity. Their solution provides (semi-)automated business process improvement based on automated data analysis. However, it lacks interoperability as the entire process must be built up around the system, whereby only computer-driven workflows benefit from the approach.

To the best of our knowledge, the selected artifacts represent promising approaches to assisted BPR, which, however, come with specific limitations. With the present work, we therefore aim to contribute to this area.

3. Research Design

We adopt the DSR paradigm [15, 16] to address our research question and propose the aBPR concept and aBPR RA as the resulting artifacts. We follow the DSR reference process [16], which includes six phases: (1) problem identification, (2) definition of DOs, (3) design and development, (4) demonstration, (5) evaluation, and (6) communication. In the following, we describe each of these steps in detail.

(1) Problem identification and (2) definition of DOs. We identified and justified the research problem in Section 1. To organize the design and development process in a goal-oriented manner, we defined DOs for a solution in Section 4.1 that we infer from the identified problem and knowledge on BPM and BPR.

(3) Design and development. The design and development phase is a search process within the solution space defined by the DOs [16]. For the ABPR concept, we derive a procedure for creating a process redesign option from existing literature and identify possibilities to automate these steps. For the development of the ABPR RA interconnected with the ABPR concept, we follow guidelines for an empirically-based RA [17] along six design steps (a-f):

Regarding (a) the decision of the RA type, since the RA facilitates and inspires the design and implementation of ABPR tools before such tools exist in practice [17], our ABPR RA represents a *preliminary, facilitating RA designed to be implemented in multiple organizations constructed by research centers* (variant 5.1 in [48]). Regarding (b) the design strategy, we build the ABPR RA from scratch in correspondence with its preliminary nature and draw from related research to inspire its design [17]. Hence, in terms of (c) empirical data acquisition, we derive valuable information on architecture parts and process knowledge on BPR in Section 2 and explicitly define DOs to enact the ABPR concept. Further, we acquire empirical data in interviews (Section 5.1) with domain experts when presenting the RA as an intermediate design result. We (d) construct the ABPR RA as an integrated system consisting of multiple components, connectors, interfaces, and algorithms [48]. Since the ABPR RA should facilitate instantiations, we describe the main components in semi-detail on a medium level of abstraction [17]. Further, we (e) design for variability by describing and annotating variation points and highlighting outbound interfaces that ensure interoperability with other tools [17]. We present the ABPR concept and the ABPR RA in Section 4 as a component diagram and provide a textual description.

(4) Demonstration and (5) Evaluation. We present the first instantiation facilitated by the ABPR RA in Section 4.4. Aligning with both the DSR (phases 4 and 5) and the RA design principles (design step f), we incorporate multiple evaluation activities in the development process [16, 17]. To guide the demonstration and evaluation of our ABPR concept and RA, we apply the DSR evaluation framework by Sonnenberg and vom Brocke [14], proposing four evaluation activities (EVAL1 to EVAL4) structured along two dimensions: ex-ante/ex-post (i.e., before/after instantiation) and artificial/naturalistic (i.e., evaluation in laboratory/real-world settings) [49]. EVAL1 concerns the ex-ante justification of the research problem, the research gap, and the derivation of DOs, which we conducted in Sections 1, 2, and 4.1 based on a literature scan. EVAL2 concerns the validity of design specifications. Therefore in Section 5.1, we assess the specification of the proposed ABPR concept based on expert interviews. EVAL3 concerns validated instantiations of the artifact. To validate the RA regarding its effectiveness, we implemented a software prototype in an artificial setting (Section 4.4). We show the prototype to experts and conduct pre-tests in laboratory settings to validate the artifact's applicability (EVAL3) in Sections 5.1 and 5.2. Finally, EVAL4 concerns validating the artifact's usefulness in naturalistic settings. Thus, we apply the prototype in a real-world case study with practitioners utilizing a warehousing process at KUKA (Section 5.3).

(6) Communication. This manuscript is the first means to share our findings on constructing the ABPR concept and the ABPR RA that facilitates designing decision support systems to assist BPR. We also publish the source code of the prototype.

4. Design Specification

This section outlines DOs before introducing the ABPR concept and a supporting RA that facilitates implementing ABPR tools.

4.1. Design Objectives

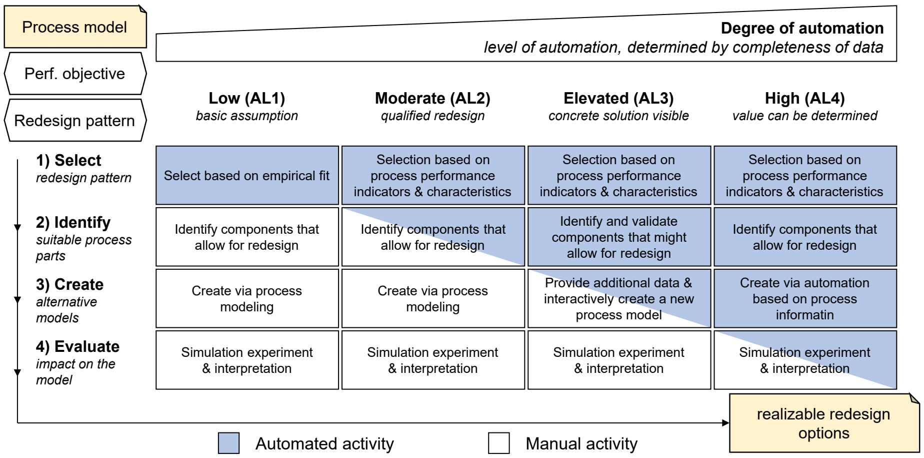
To guide the development, we define DOs for ABPR. We derive these DOs from the knowledge on BPR as introduced in Section 2: The literature calls for close guidance through BPR, propagates redesign patterns to encourage thinking about process redesign in a more structured way, and demands an objective way to compare redesign alternatives. For novel artifacts that aim to assist BPR, we, therefore, derive:

DO 1 (Process redesign guidance). ABPR *should support structured guidance along the phases of process redesign, i.e., model the as-is process, find and identify relevant process redesign options, create new process designs and evaluate the effect of process redesigns on the process.*

DO 2 (Facilitation of redesign patterns). ABPR *should support the integration of proven redesign patterns for discovering business process redesign options.*

DO 3 (Performance objectives). ABPR *should support determining the anticipated effect of process redesign options on the process performance objectives to compare alternative process designs and thus provide the user with a basis for decision-making.*

Integrating domain and use-case knowledge is both effective and necessary for BPR [25, 34]. Hence, providing an interactive assistive approach to BPR ensures that automated detection of potential process redesign options is enhanced by incorporating use case and domain knowledge. As process data improves BPR [24], but its collection poses several difficulties [4], the flexible incorporation of process data as it becomes available is also beneficial. Therefore, we derive:



	Low (AL1) basic assumption	Moderate (AL2) qualified redesign	Elevated (AL3) concrete solution visible	High (AL4) value can be determined
1) Select redesign pattern	Select based on empirical fit	Selection based on process performance indicators & characteristics	Selection based on process performance indicators & characteristics	Selection based on process performance indicators & characteristics
2) Identify suitable process parts	Identify components that allow for redesign	Identify components that allow for redesign	Identify and validate components that might allow for redesign	Identify components that allow for redesign
3) Create alternative models	Create via process modeling	Create via process modeling	Provide additional data & interactively create a new process model	Create via automation based on process informatin
4) Evaluate impact on the model	Simulation experiment & interpretation	Simulation experiment & interpretation	Simulation experiment & interpretation	Simulation experiment & interpretation

Figure 2: Conceptualization of ABPR.

DO 4 (Interactive integration of domain knowledge). ABPR *should support integrating interactive customization of process improvement opportunities to address specific use cases and incorporate the user's domain knowledge.*

DO 5 (Flexible incorporation of data). ABPR *should allow interoperability with other tools by building on standardized (process) data formats and making flexible use of the available process data.*

To ensure that related artifacts presented in Section 2 do not already provide an answer to the research question, we evaluate them according to their fulfillment of the DOs. While all competing artifacts utilize redesign patterns (DO 2) in a varying structured approach (DO 1), none covers all steps required to apply an extensible set of redesign patterns including their evaluation along performance objectives (DO 3). Further, no existing artifact integrates domain knowledge during tool application to improve the quality of redesign suggestions (DO 4) and only one tool envisions flexible use of appropriate algorithms, depending on the source data (DO 5). Thus, we conclude that none of the competing artifacts comprehensively addresses the DOs.

4.2. ABPR *concept*

The ABPR concept encompasses a structured procedure for finding and developing redesign options for process improvement that align with a predefined performance objective. The concept embeds established process redesign patterns and generates recommendations to support the search for improvement ideas. The approach considers a process' status quo derived from documentation, data, and implicit domain expertise provided by users. The status quo process model must describe the activities, control flow, and context in sufficient detail such that process performance can be assessed realistically via simulation experiments and expert judgment. Hence, data about the process and a performance objective are mandatory inputs for ABPR that users must provide.

Four activities derived from related work (see Section 2) guide the development of redesign options using patterns in a step-wise manner as can be seen in Figure 2: step 1) *select* suitable redesign patterns, step 2) *identify* suitable process parts, step 3) *create* alternative models, and step 4) *evaluate* the performance of these alternative models. The execution of these four steps results in redesign options that may improve the process under investigation depending on the evaluation outcome. The structured application of redesign patterns aligns with DO 1 and DO 2. ABPR tools, as we envision them, deeply integrate these steps and guide users through their structured application. As shown in Section 2, the literature provides process improvement procedures that automate the steps of selecting patterns, identifying suitable process parts, creating alternative models, or evaluating their performance for certain redesign patterns. Taking advantage of this automation potential, tools that implement the ABPR concept execute these steps in the background and present their results as redesign recommendations. Users manually complete the remaining steps using their expertise to develop recommendations into redesign options. Combinations of (semi-)automated and manual steps lead to different types of recommendations that automate more and more individual steps. We defined four recommendation types for our research in increasing automation levels (ALs) in Figure 2. For naming, we refer to the renowned scale for automation by Parasuraman et al. [50], from which we identify *low* (AL1) and *high* (AL4) as the two extreme manifestations of ALs and derive two intermediate manifestations, *moderate* (AL2) and *elevated* (AL3). We describe each recommendation type and provide examples for specific pattern implementations in the following.

Low (AL1): This recommendation type automatically selects suitable redesign patterns (step 1). A set of patterns is recommended that have proven useful for achieving the performance objective predefined by the user. While no instructions for implementing a pattern can be given at this high abstraction level, this recommendation type encourages the user to think about possible applications for the pattern by performing the following steps manually. Beyond empirical data, as found in [6, 29], AL1 recommendations do not require further data. For example, the “knock-out” pattern [6] could be recommended to optimize cycle time, inspiring the user to search for possible early termination criteria.

Moderate (AL2): This type of recommendation (semi-)automates the selection of redesign patterns and the identification of suitable process parts(steps 1 and 2) and reveals flaws in the process. Patterns that align with the performance objective are suggested to the user to address these flaws. Procedures that integrate static process measures, conditional rules, or process mining analyses, among others, facilitate the generation of such recommendations. Accordingly, this recommendation type places higher demands on process data, depending on the specific procedure implementation. An example recommendation, based on static process measurements, argues for using the “empower” pattern when increased management involvement for authorization tasks is measurable [6, 32].

Elevated (AL3): This type of recommendation (semi-)automates steps 1-3 through user interaction. Process improvement procedures often need to validate assumptions before an alternative model can be created. If these assumptions cannot be validated against the available data or additional input is required to create alternative models, AL3 recommendations interactively request this information from the user. Incorporating the additional information, a redesign pattern can be applied automatically. For example, In the modeling commonly used in practice, no information is available about whether case differentiation is possible for process instances to apply the “triage” pattern [6].

High (AL4): At high automation, redesign options are generated without user intervention and can thus be simulated in the background for evaluation. The procedures for generating such recommendations rely on extended process information or guiding rules to derive assumptions for feasible redesigns. Formal or generative approaches based on artificial intelligence could be considered for finding solutions. For example, “extra resources” or “task parallelization” [6] can be automatically modeled and simulated to determine the impact on the process.

Various methods for generating recommendations in different recommendation types are already available for individual redesign patterns (see Section 2), which can be significantly expanded via further research. Since their implementations can generate multiple recommendations, e.g., for different process parts, the set of recommendations quickly becomes overwhelming for users. Therefore, it is desirable to highlight a few top recommendations that are not similar. We propose presenting a diversified and ranked selection of top recommendations to the user while initially retaining less valuable or too similar recommendations. For this purpose, their potential and similarity must be evaluated: A scoring function implemented in ABPR tools estimates each recommendation’s impact according to the performance objective that guides redesign. The impact of recommendations is not directly comparable across recommendation types as recommendations on higher ALs are more specific than recommendations from lower ALs. The scoring function uses empirical information to estimate the potential impact if no specific impact is measurable. Examining the impact of redesign options and recommendations through a scoring function based on the performance objective is consistent with DO 3. The similarity is calculated as a measure that integrates information on the redesign pattern (e.g., process aspect, pattern identifier) and the specific recommendation (e.g., the overlap of affected elements).

The more complete and high-quality the process data is, the more accurate and applicable the procedures for creating recommendations. However, high-quality and up-to-date process data are challenging to obtain. aBPR tools aim to improve processes in an evolutionary approach, where process data from different data sources can also be completed and improved in evolutionary steps. Besides formal process documentation (e.g., as BPMN), information can also be derived from event logs and, not to be underestimated, from the knowledge of domain experts. The information content of a process model can increase through applying aBPR so that the picture of the process becomes more transparent and new procedures can be applied. Both types of knowledge are integrated into the redesign steps and the evaluation activity. While simulation can provide the basis for quantitative evaluation of cost and time, evaluating quality, flexibility, feasibility, or the implementation effort is a task for human decision-makers. The integration of additional data and knowledge addresses DO 4 and DO 5.

4.3. aBPR *reference architecture*

To implement aBPR tools, Figure 3 shows the aBPR RA as a component diagram. The RA is composed of five components, which are described below.

The **model provider** component serves as an external interface for data. It maintains a consistent and unified process model that spans the different aspects of the process and its contexts, such as the control flow, data, resources, simulation con-

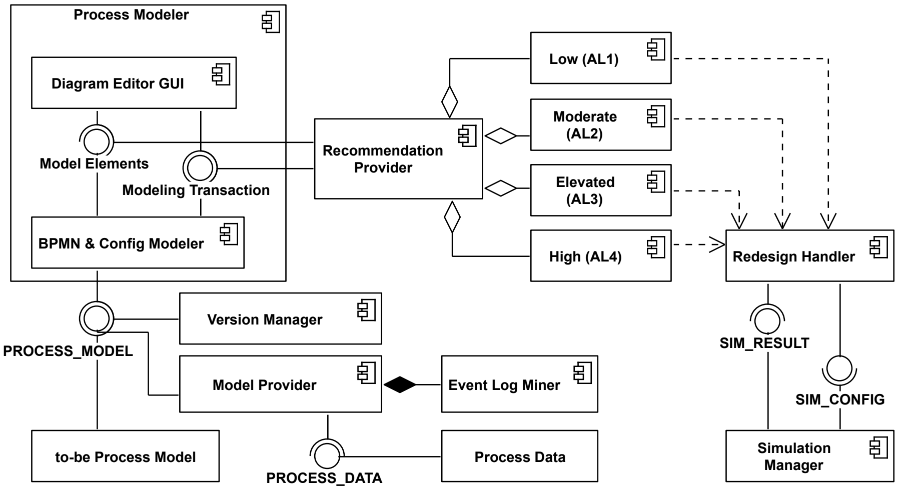


Figure 3: Assisted business process redesign (ABPR) reference architecture.

figuration, and process performance metrics. Concerning external data, different transfer formats (e.g., BPMN, colored Petri nets, or event logs), abstraction levels, and data quality must be merged into one model. Process discovery techniques may extract process models and simulation configurations from event logs. The component provides read and write access for other components to manipulate the process model as the tool is used. Process information can also be exported to allow for interoperability.

The **process modeler** component enables user interaction and provides modeling capability. The modeler graphical user interface (GUI) renders the process diagram based on model provider input. Modeling operations are first validated and then transferred back to the data model via the model provider. The set of available modeling elements should be limited to core elements that are easy to understand and usable by algorithmic methods. The component also offers all other user interactions, such as selecting recommendations.

The **simulation manager** component provides an interface for process models and executes simulation experiments according to the simulation configuration.

The component safeguards the validity of simulation experiments and assists the user in determining suitable parameters for the simulation. Hence, properties such as the warm-up period, the replication length, and the number of replications need to be defined to represent the actual work represented in a simulation. The quality of the simulation, expressed in intervals of confidence, can be determined from multiple parallel experiments. Also, historical event data can be used to initialize the simulation (*fast-forward* simulation) [26]. Several simulations can be parallelized to speed up the experiments.

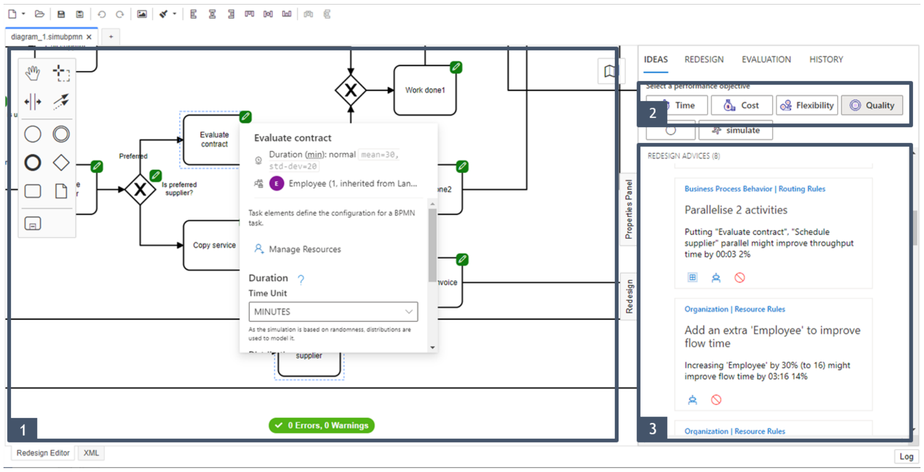
The **redesign handler** component ensures that the four steps indicated in Figure 2 are followed in sequence for each redesign option. A redesign option consists of change operations to the as-is model that can be evaluated and accepted as a new process model. Implementing process improvement procedures, specific instantiations of redesign handlers intend to automatically execute one or more sequential steps to apply redesign patterns. If further information is required, additional input is requested from the user.

Triggered by changes in a process model, the **recommendation provider** repeatedly checks the potential of redesign handlers and diversifies them to create a list that fosters user creativity.

The **version manager** records the evolution of all change options. This allows to document and revert redesigns options, compare different process alternatives, and select process alternatives as candidates for further improvement iterations.

4.4. Implementing ABPR

We implement ABPR as a prototype application providing an instantiation of the RA [17]. Except for the simulation manager, which is outsourced as a cloud service for load balancing, and the event log miner, which is not part of this implementation, all components are implemented as modules of a desktop application based on



Evaluate contract

Duration (min): normal `mean=30, std-dev=20`

E Employee (1, inherited from Lan...

Task elements define the configuration for a BPMN task.

Manage Resources

Duration ?

Time Unit

MINUTES

As the simulation is based on randomness, distributions are used to model it.

REDESIGN ADVICES (8)

Business Process Behavior | Routing Rules

Parallelise 2 activities

Putting "Evaluate contract", "Schedule supplier" parallel might improve throughput time by 00:03 2%

Organization | Resource Rules

Add an extra 'Employee' to improve flow time

Increasing 'Employee' by 30% (to 16) might improve flow time by 03:16 14%

Organization | Resource Rules

Figure 4: Software prototype - general overview with GUI elements (1) diagram editor, (2) performance objective selection, and (3) list of recommendations.

the Camunda Modeler[3], illustrated in Figure 4. The source code and technical documentation are available online[4]. The application starts from an empty canvas or an existing BPMN diagram. It enables the user to edit the process model and provides recommendations for its redesign after selecting a unique performance objective, such as time, cost, flexibility, or quality. We implement and publish[5] an $A*$ heuristic [51] to diversify recommendations. The top recommendations are displayed in a list. Each recommendation details the process aspect, the heuristic category, its name, a short description, and optionally the expected redesign impact and affected process elements. The user can accept or reject these recommendations and evaluate their impact via simulation experiments and expert judgment. This approach is repeated until satisfaction with the process model is achieved, and the improved process model is exported.

We implement an extension of the BPMN metamodel[6] to capture simulation

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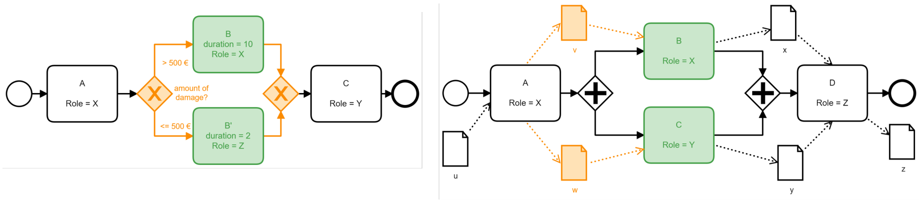
[3] https://github.com/camunda/camunda-modeler

[4] https://github.com/dtdi/assisted-bpr-modeler

[5] https://github.com/dtdi/div-top-k

[6] https://github.com/dtdi/bsim-moddle



a) Triage b) Parallelization

Figure 5: Implementation of two redesign patterns

configuration, performance data, and ABPR-specific annotations. This allows information to be stored consistently in the model and imported and exported as a BPMN file. The available shapes in the process modeler are restricted to a set supported by the redesign handlers, which can be mapped to the process data model. A model linter identifies modeling problems by detecting misconfigurations or missing properties and provides visual feedback to fix the model. Each of our metamodel extensions is safeguarded by custom linting rules.

The prototype supports all patterns from Reijers and Limam Mansar [6] in varying types of recommendation: The *triage* (see Section 4.4.1) and *activity automation* patterns are implemented on AL3, the *parallelism* (see Section 4.4.2), and *extra resources* patterns are implemented on AL4, whereas the remaining are implemented as AL1 and AL2 recommendations.

4.4.1. Implementation of the triage pattern as AL3 recommendation

The pattern is *selected* when aiming for quality improvements [6]. Dividing a general activity into alternative activities can only have a considerable effect if the following conditions are satisfied: (1) A split criterion is defined to distinguish different cases or resources, (2) the information to make the split decision is available before executing the activity, and (3) different treatments can be applied to different types of cases. The examination of these conditions relies on information not expected in the process data. Hence, for *identification*, the implementation relies on domain knowledge. In a wizard, users manually mark activities that are potential candidates for the triage pattern (or do not qualify for the triage pattern) and provide a split criterion for routing the cases. The user choice and input are added to the model. To *create* the alternative model, the original activity is duplicated and encapsulated by exclusive gateways. A second wizard guides the users through the redesign. In addition to the splitting criterion, the simulation requires branching probabilities for each branch. Further, the activity is reconfigured with updated name, resources, and execution durations for each alternative path. Figure 5 shows the applied redesign. Quality cannot directly be interpreted from the simulation results for *evaluation*. Hence, the expert user is therefore required to interpret the quality of the redesign himself.

4.4.2. Implementation of the parallelization pattern as AL4 recommendation

Parallelization is *selected* if the redesign aims to improve on the time dimension [6]. Putting activities in parallel can only be done and have a considerable effect if the following conditions are satisfied: (1) The activities are in sequence. (2) The activities have no data dependency upon one another. (3) The duration times of the activities are of the same order of magnitude. (4) Resources from different roles execute the activities (or more than one resource available with that role). (5) There is no overloading of any role because of putting activities in parallel. Therefore, sets of tasks elements in a straight sequence are *identified*: A sequence is preceded by either a *start event* or an *intermediate catch event* with $len(outgoing) > 1$ or $len(incoming) > 1$. Any successor is added to the sequence until the next element is not of type *task*, $len(outgoing) > 1$, or $len(incoming) > 1$. Figure 5 shows how data dependencies also influence the identification of candidates. Each remaining set of activities is a candidate for applying parallelization. The redesign is *created* by encapsulating the activities in parallel gateways.

5. Evaluation

We complete the justification of our research topic and the derivation of DOs from relevant literature (EVAL1) in Sections 1 and 2. In line with the evaluation strategy, we present an expert interview-backed validation of the design specification (EVAL2) in Section 5.1. Afterward, we assess the artifact's applicability using the prototype instantiation (EVAL3) (Section 5.2). Finally, we present the results of a real-world case study that underpins the usefulness of ABPR (EVAL4) (Section 5.3).

5.1. Ex-ante Evaluation: Design Validation (EVAL2)

EVAL2 was conducted prior to the approach's instantiation. For the naturalistic evaluation, we presented ABPR to experts and gathered their feedback in qualitative semi-structured interviews as Venable et al. [49] recommended. Each interview was split into two parts. First, we requested feedback on the ABPR concept and its characteristics against the DOs derived from justificatory knowledge to validate whether the ABPR's design specification (EVAL2) suitably addresses the research question and the DOs [14]. To discuss features of ABPR's design specification beyond the DOs, we also requested feedback on the ABPR concept regarding its understandability and feasibility before demonstrating the prototype to gather further feedback on its applicability (EVAL3, Section 5.2). We iterated through two rounds of interviews. For round A, we interviewed four doctoral candidates and one post-doc in the BPM field from Germany, whereas for round B, we interviewed three senior academics with practical BPR experience from Australia (post-docs or professors). The eight interviews (each between 45 and 75 minutes) were conducted by at least one author and transcribed and coded.

Table 1 summarizes statements made by the experts regarding and beyond the fulfillment of ABPR's design specification against the defined DOs. Statements with similar content are merged and sorted to the top. The experts confirmed that the outlined problem setting is relevant and that process improvement is crucial in

Table 1: Qualitative comments on the ABPR conceptualization

Positive	Negative
• The four types of recommendation constitute a comprehensible and elegant representation of suitable degrees of automation. • ABPR solves a real problem that is relevant for academia and practice. • The incorporation of domain knowledge is useful for improving recommendations. • The approach makes redesign patterns more usable. • The extensibility of the RA is helpful for the concrete application.	• Process models in practice are often outdated and therefore not usable. • The data collection effort could exceed the value of the solution. • Simulation should not provide an oversimplified solution for evaluating complex performance measures (e.g., quality). • Traditional collections of redesign patterns are considered difficult to apply.

academia and practice. They found ABPR overall understandable and highlighted its simplicity as it follows a structured approach to creating BPR options and guides instantiating new tools. The main points of criticism address the collection of simulatable process data that is often not available in practice. We agree with their feedback and seek to address their comments on data collection in future work.

In summary, the expert interviews support the design of the artifact and its underlying concept. From a stand-alone perspective, the experts confirm that ABPR addresses all DOs. They agree that ABPR covers all steps required to apply an extensible set of redesign patterns (DO 2) and supports their evaluation along performance objectives (DO 3). Further, they acknowledge that ABPR features structured guidance through the redesign process (DO 1). According to the experts, the interactive integration of domain knowledge (DO 4) poses a major strength of our design specification. Finally, it is also confirmed that ABPR accounts for flexible data integration (DO 5). Overall, when considering the analysis of related artifacts (Section 2), we infer that ABPR is the first approach that addresses the defined DOs comprehensively, which further underpins the research need and design specification of ABPR.

5.2. Ex-post Evaluation for Applicability: Artificial Setting (EVAL3)

EVAL3 strives for proof of applicability through valid instantiations of the artifact [14]. We describe an instantiation of ABPR in Section 4.4 and demonstrate the proto-

Table 2: Qualitative comments on the ABPR prototype

Positive	Negative
• The prototype instantiation addresses the design specification in a very logical way. • The simulation statistics include the required metrics. • The recommendations are comprehensible and easy to understand. • The prototype is easy to use, and its' GUI is sophisticated and intuitive. • It is easy and efficient to improve the process model. • The prototype makes redesign patterns more operational.	• The ranking in the list of recommendations is not transparent. • More patterns should be implemented. • Simulation results alone are not sufficient for evaluation. • Operationality is questionable for very large process models. • The absence of the event log miner component reduces the effectiveness.

type's application utilizing an artificial service request process in a video referenced in the code repository[7] to validate the artifact in terms of feasibility. We interactively demonstrated the prototype based on the artificial service request process to the eight EVAL2 interview participants to evaluate ABPR's feasibility and operationality. In a second iteration, we conducted two case studies with practitioners engaged in real-world BPR projects in an experimental setting. In the first case, we involved three consultants from a process consulting firm. For the second case, we involved a consultant and a process owner. Each of these professionals brought several years of experience in their roles.

Table 2 provides a summary of qualitative comments on the prototype. All interviewees confirmed understanding the process at hand and could follow and participate in the demonstration and the case studies. The application of the prototype led to feasible redesign options in all settings. Many experts had not used redesign patterns in their previous BPR projects. In applying the prototype, they quickly identified and validated opportunities for process redesign with the recommendations. Overall, respondents rated the direct evaluation through simulation very highly. The larger share of respondents saw BPR consultants or BPM experts within the organi-

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[7] `https://github.com/dtdi/assisted-bpr-modeler`

Table 3: Results of two experimental case studies

Order-to-Cash Process	Software Development Process
• The process model lacked specificity to apply AL4 recommendations. • A feasible scenario in which the rework effort was reduced by 40% resulted in a 10% reduction in lead time. Here, the patterns *customer teams* and *contact reduction* were implemented.	• The triage pattern was applied to define three types of development applications with different processing. • The redesign option promises to focus resources to increase quality and accelerate development.

zation as the end-user of the tool in a workshop situation together with a domain expert. Several experts saw significant potential in overcoming data collection challenges through process mining, as conceptualized with the event log miner component but not yet implemented in the prototype.

The two cases were made between artificial and natural evaluation situations. For this purpose, we involved practitioners from two organizations utilizing their own processes. In both cases, the organizations provided a process model in advance that was used as input for the prototype. In a subsequent interactive workshop lasting around 90 minutes each, the prototype has been operated by a researcher and applied and evaluated regarding its applicability. In the first case, a process consultancy conducted process improvement at a customer in the manufacturing industry to reduce lead time. The customer documented the process in semi-detail. The Order-to-Cash process was medium-sized and included 36 activities across six participants. The simulation data was estimated during the pre-test. In the second case, a large German municipal company redesigned their medium-sized software development process with 50 activities and six participants to improve quality and compliance. Similar to the first case, the simulation data was estimated, and the process model was refined during the workshop. Table 3 summarizes the results of the redesign in both cases. The ABPR approach proved to be useful in the application. However, the requirements for a good data model turned out to be particularly important here.

As DSR is a search process [15], we iteratively incorporated feedback into the design specification and the prototype for improvement. Following up on early interviews, we further highlighted the importance of flexible data incorporation in the RA. In addition to what has already been mentioned, we have (1) extended the set of available BPMN elements, (2) improved ease of use with tooltips and explanations, (3) and implemented an import to initialize regular BPMN diagrams with simulation properties. Further, we made (4) interpreting the simulation results easier and integrated additional metrics in the visualization. Most feedback was incorporated into the prototype early on, allowing most experts in EVAL3 and the following EVAL4 activity to evaluate an enhanced version of the tool.

5.3. Ex-post Evaluation for Usefulness: Real-world Case Study (EVAL4)

To validate the usefulness of ABPR in a naturalistic setting (EVAL4), we present a case study that builds on anonymized and slightly modified data collected at KUKA.

KUKA AG is a global automation corporation with sales of around 2.6 billion euro and roughly 14,000 employees. The company is headquartered in Augsburg, Germany. As one of the world's leading suppliers of intelligent automation solutions, KUKA offers customers everything they need from a single source: from robots and cells to fully automated systems and their networking in markets such as automotive, electronics, metal & plastic, consumer goods, e-commerce/retail, and healthcare. Therefore, groups of components, functional devices (FDs), must be delivered to the site on time. To ensure on-time delivery, externally purchased components are also initially stored in the KUKA warehouse, which ensures punctual delivery but causes overhead. The components must be treated as a production order by the enterprise resource planning (ERP) system for further processing to be upgraded to a functional device. Originally, this non-value-adding warehouse process was designed for only a few hundred cases per year. However, contrary to initial expectations, the process is executed much more frequently in daily operations (3,000 cases/year). In an initial effort, KUKA's dedicated BPM team supported the logistics department in finding and implementing improvements that have already reduced cycle time by 30% to 3 hours. In this course, the process was modeled (see Figure 6), and activity lead times were obtained. KUKA hopes to identify further improvements by applying ABPR in a workshop with the BPM team and two process domain experts.

We applied the ABPR prototype in a workshop setting to create process improvements options. The tool generated 21 recommendations, including five top recommendations considered first (see Table 4). The tool guided the development of the redesign options: First, a promising recommendation was selected before the process was remodeled with the modeler GUI. The process domain experts estimated the adjusted lead times or changed cost rates. After modeling, the scenario was simulated, and the results were evaluated concerning the estimated effort to implement the redesign. Promising options were kept, others were discarded.

Of the recommendations, two had to be discarded since they were infeasible. The remaining top recommendations could be applied to the process model result-

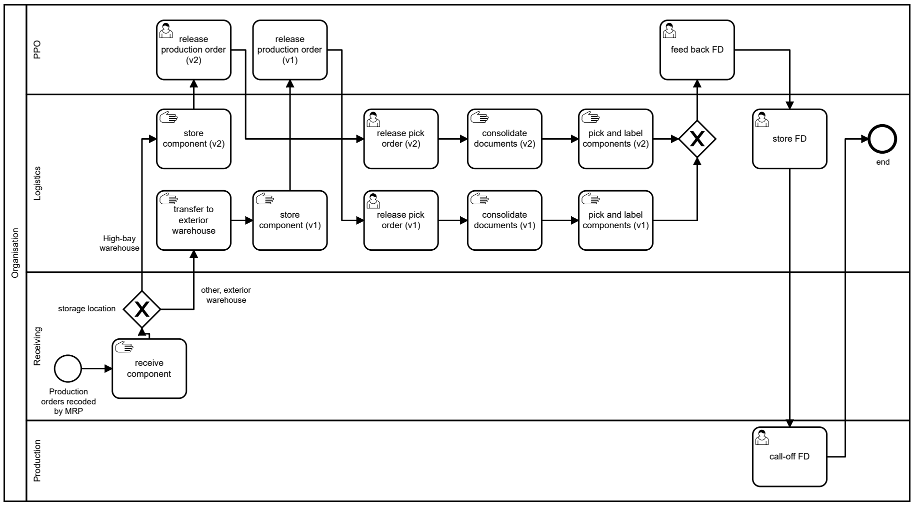

Figure 6: Initial process model of KUKA's warehouse process.

Table 4: The recommendations created by the prototype with ALs elevated and high.

Redesign pattern (AL)	Generated recommendation	Assessment of the recommendation by experts
Parallelization (high)	Putting “release production order (a)”, “release pick order (a)”, “consolidate documents (a)” parallel might improve throughput time by 2%	The proposed 2% performance increase cannot be realized since the model did not include activity dependencies.
Parallelization (high)	Putting “store component (b)”, “release production order (b)”, “release pick order (b)” parallel might improve throughput time by 3%	The proposed 3% performance increase cannot be realized since the model did not include activity dependencies.
Extra Resources (high)	Add extra Resources to the “Logistics” department for up to 29% improvement.	The assumptions from the simulation were estimated to be too high. Nevertheless, logistics could be identified as a bottleneck.
Triage (elevated)	Apply triage to up to 15 activities.	The experts assess several activities as possible candidates for the triage pattern.
Automation (elevated)	Automate up to 7 activities.	Several activities are carried out within the ERP system. Here, the experts see the potential for automation.

ing in three specific redesign options (Table 5). The final process model exhibits a time improvement of 39% compared to the first simulation. The biggest improvement was that half of the FDs consisted of only one component, which allowed significant parts of the process to be skipped. Though KUKA’s experts had already been working on the process, they were pleasantly surprised by the case study’s outcome.

We discuss the ABPR’s applicability and usefulness based on criteria compiled and assessed in Sonnenberg and vom Brocke [14] as relevant for evaluation activity EVAL4. The case study demonstrated that ABPR is *applicable* in naturalistic settings. As the development of redesign options follows a structured procedure based on generated recommendations and includes simulation of process scenarios, the ABPR approach could not be applied without the prototype. The expert feedback revealed that ABPR particularly fits organizations that aspire to a well-developed BPM capability. An issue that impacts applicability is that the ABPR requires collecting and estimating process data, a non-trivial and resource-intensive task. The software prototype allows for editing the process model during a workshop to cope with data collection issues, which are inevitable in naturalistic settings. ABPR has a positive

Table 5: Adopted redesign options

Pattern	Description	Change in the process model
I) Triage & Automation *Time: 35%*	For FDs that consist of only one component (50%), the repeated storage and retrieval can be skipped. Instead, the component can be labeled directly in the receiving area, and the component can be automatically converted into an FD by an RPA bot.	a) New process path for single component FDs. b) New resource “RPA” offered with low cost and high availability. c) Assign the three automatable activities to the RPA bot; decrease activity duration. d) Combine the manual tasks of receiving goods and the labeling component.
II) Activity Automation *Time: 5%*	The task "Confirmation of FD" can be automated. According to a fixed pattern and preconditions, the FD must be marked as available in the ERP system.	a) Assign the three automatable activities to the RPA bot b) decrease activity duration
III) Extra Resources	The load in the process is foreseeably increased seasonally. Additional resources then help to compensate for increased loads. No data was available for the simulation of the effects.	No alternative model was created because no precise assumptions could be made.

impact on the artifact environment and its users as it encourages users to think about BPR in an integrated manner.

On the one hand, ABPR fosters creativity to find new ideas to address process issues. On the other hand, it guides the redesign process in an objective and structured way, keeping discussions within factual and effective boundaries. The experts from KUKA and other case study partners agreed that ABPR enhances the organization’s process redesign capabilities. The covered process and case study setup demonstrates ABPR’s *fidelity with real-world phenomena.* The experts from KUKA confirmed that the instantiation addresses real-world circumstances. The experts from KUKA agreed that the software prototype could be *effectively* used to improve business processes in a guided and step-wise manner. Limitations of effectiveness lie in the amount of currently implemented redesign patterns, which should be improved in further research. As for *efficiency*, the preparation of the data model and the workshop took 10-12 hours and resulted in promising results. Concerning data model size, big and complex processes might limit the effectiveness and efficiency of ABPR since the complexity of the model needs to be both understood by the users and searched for improvements within the tool.

On the one hand, this discussion indicates that ABPR and the prototype address all criteria. On the other, it becomes evident that in order for ABPR to be applicable in a utility-creating manner, some prerequisites must be met.

6. Conclusion and Outlook

BPR is a key to long-term business success for many organizations. Therefore, in this research, we addressed how assistive tools can improve BPR and proposed a conceptualization for ABPR. The approach requires process data as input and interactively supports the user in iteratively improving the business process to achieve a specified performance objective. Four types of recommendations (AL1-4) assist users by utilizing increasing domain and use case knowledge. The design of a RA is an appropriate endeavor to address the research problem since similar problems in the BPM domain have benefited from RAs. The proposed ABPR RA lends itself as a template for new instantiations to address the lack of tools. We conducted several evaluation activities to verify that ABPR helps identify and evaluate process improvement options. First, we provided evidence of the research gap and its novelty. In a second step, we showed that its design specification addresses the design objectives derived from literature. Third, we presented a prototype instantiation and demonstrated its functionalities on artificial process data. Further, we discussed the design specification and the prototype with experts from academia and industry to show its applicability. Finally, we conducted a case study in a naturalistic setting to demonstrate ABPR's usefulness. Overall, we are confident that we have conducted a solid evaluation, based in particular on external assessments.

Our research adds to the prescriptive knowledge on BPR by building on and extending existing approaches [52]. ABPR provides a novel approach for applying redesign recommendations with varying levels of automation and interactivity. This poses another milestone in BPR research, as previous approaches focused on only one of the two options, posing barriers to their applicability to diverse business processes. While previous works deal with the (semi-) automated application of redesign patterns, our work is the first to interactively integrate domain and use case knowledge into the pattern application. Furthermore, our results show that process redesign patterns can be applied more understandably through tool support. Finally, aBPR offers a way to categorize and embed existing approaches for pattern application in a structured process and provides a framework that guides the implementation of additional redesign handlers. For practitioners and researchers, the aBPR RA guides creating new tools that support BPR and an approach in which multiple options for process improvement can be compared side-by-side to save time, foster creativity, and effectively leverage domain knowledge.

Nonetheless, our research comes with limitations that stimulate future research. First, the aBPR concept should provide further guidance in acquiring high-quality process models in terms of input data. The evaluation showed that the data required to create accurate simulation models is not readily available. A comprehensive end-to-end approach should integrate approaches to derive the initial process models from data available to the redesign team, such as event logs or other documents. Our approach could partially address this limitation by implementing the optional event log miner component. Even though the approach is suitable for many real-world processes, it should be investigated how aBPR behaves for larger process models and how it can be adapted if necessary. Moreover, the aBPR prototype in its current state is designed to only optimize the process towards a single performance objective, such as time or costs. While the evaluation revealed that we could already reach significant process performance improvements, we believe that multi-objective process performance optimization (see [42, 44]) can further enhance aBPR's process improvement recommendations. We see further limitations regarding the prototype in the set of implemented redesign patterns. While we could show that the implemented redesign patterns are feasible and useful, a greater range of patterns would be helpful to achieve better support. In particular, the implementation of further automated recommendations provides the basis for additional qualitative and quantitative evaluations in the field. Finally, while we describe how to enhance incremental BPR, further research might investigate approaches that assist in radical BPR and process innovation, which does not or cannot build on existing process models.

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