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Enhancing Process Improvement: Tackling Challenges and Leveraging Technological Advancements in Business Process Management

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“A good process is better than a bad process.”

Michael Hammer

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Abstract

Business process improvement and innovation is considered the most value-adding stage in the business process management lifecycle, to increase efficiency, free up scarce resources and ensure alignment between strategy and operations to create and sustain value. Given the dynamic nature of organizational environments, business processes must be continuously adapted to various changes. Effective business process improvement and innovation requires proficiency across multiple dimensions: mastery of methods and tools, in-depth process knowledge and the ability to execute related initiatives. As business processes become more complex and the need for rapid adaptation increases, research into supportive methods and tools for business process improvement and innovation is essential. This thesis aims to advance process improvement and innovation, with the former focusing on incremental refinements and the latter on radical innovations in the context of current technological and societal trends. Therefore, this cumulative dissertation comprises eight research papers addressing three overarching objectives.

First, fundamental research on systems that provide computational support for the overall business process improvement and innovation stage is required to structure existing literature and conceptual knowledge. Existing knowledge is scattered, and it is unclear how such systems function or should be designed in the future. To address the identified research needs, this paper presents two contributions that address these gaps: Research Paper P1 analyzes the literature on systems for business process improvement and innovation and structures their functionality with conceptual knowledge in a taxonomy. Existing artifacts are analyzed to reflect the status quo of current research. Research Paper P2 drafts principles for the design of novel process improvement and innovation systems.

Secondly, the activities in business process improvement include the analysis of current processes as well as the development, evaluation and selection of process design options. Four research articles in this dissertation aim to contribute new methods and tools to support these activities. Research Paper P3 develops an interactive approach that supports the analysis of traces of historical process execution data (event logs) by matching analysts' requirements with the principles of visual analytics. Research Paper P4 presents an interactive system for process improvement as a reference architecture. The approach assists users by utilizing existing process data, progressively incorporating higher levels of automation. Research Paper P5 presents a method for converting process improvement best practices into programmed rule sets that enable their repeated application to multiple event logs. In addition, Research Paper P6 provides an approach to improve vehicle routing in meal delivery, a customer-oriented process, by introducing minor process changes during execution.

Third, this dissertation emphasizes the critical role of people and culture in business process management. Process improvement knowledge is often communicated through best practices. Research Paper P7 provides a catalog of process improvement patterns tailored to the allocation of human resources. To comprehensively integrate the human element into process improvement, Research Paper P8 introduces process improvement methodology with a particular focus on employee involvement.

The dissertation concludes by reflecting on limitations that suggest avenues for future research. The included research papers significantly contribute to advancing business process improvement and innovation. The thesis establishes a foundation for understanding and designing systems that automate business process improvement and innovation through computational support. Second, four artifacts are presented that focus on data-driven business process improvement. Finally, the thesis presents two artifacts that emphasize the integration of people and culture in business process improvement and highlight the crucial role of human and cultural factors in process improvement.

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1 Introduction

1.1 Motivation

Business processes are flows of events and activities that coordinate resources and decision-making to produce outcomes that deliver value to customers (Dumas et al., 2018; Groß et al., 2019). Aligned with the organizational strategy, they are a crucial asset for success and value generation (Buhl et al., 2011). The context in which business processes operate is influenced by digital transformation and other (rapid) developments in competition, society, environment, economy, and customer expectations (Beverungen et al., 2021; Denner et al., 2018; vom Brocke et al., 2021). Consequently, organizations face the ongoing challenge of adapting to these evolving conditions and refining their business processes to sustain (Malinova et al., 2022). While function-oriented thinking remains prevalent in most organizations, an increasing number incorporate a process-oriented mindset, especially in turbulent times (Celonis, 2024; Harmon & Garcia, 2020). This trend is driven by the evidence that efficient and effective business processes can provide a competitive advantage (Davenport, 1993; Grisold et al., 2024; Groß et al., 2024; Hammer, 2015).

The field focusing on business processes in academia and practice is known as business process management (BPM) (Hammer, 2015; Reijers, 2021). After an initial hype around the term "business process reengineering" in the 1990s subsided, the core principles of process orientation resurfaced, supported by empirical evidence and success stories from organizations that have successfully implemented BPM (Dumas et al., 2018). A key factor in this shift towards process orientation was the advent of centralized databases found in process-aware information systems (PAISs) (e.g., customer relationship management and enterprise resource planning systems), which can effectively bridge information silos in function-oriented organizations (Dumas et al., 2018).

BPM is an ongoing endeavor whose core activities can be described through a lifecycle model with continuous stages: *Process Design and Modeling* involves identifying and documenting business processes to create models. *Implementation and Execution* bring these designs to life by transitioning from current practices to the envisioned processes. *Monitoring and Control* track performance, while *Improvement and Innovation* focus on refining and enhancing processes. *Project and Program Management* ensures alignment with strategic goals, coordinating all phases for successful outcomes (vom Brocke et al., 2021). Amongst all stages that constitute the BPM lifecycle, the *business process improvement and innovation (PII)* phase is often considered most value-adding (Beverungen et al., 2021; Groß et al., 2021; Huang et al., 2015; van der Aalst et al., 2016; Zellner, 2011). For one, business process improvement (BPI) typically focuses on regular incremental changes and refinements of existing processes to improve cost, time, quality, or other performance metrics such as customer-centricity (Beerepoot et al., 2023; Kreuzer et al., 2020; Malinova et al., 2022). In contrast, process innovation aims to introduce new and creative approaches to value creation and delivery, allowing radical transformations to create new ways of achieving organizational goals (Beerepoot et al., 2023; Groß et al., 2019). Despite the recognized importance of BPI, as many as 60%–80% of BPI projects are reported as failed (Groß et al., 2021; vom Brocke et al., 2021; Zuhaira & Ahmad, 2021). Parts of this high ratio are rooted in the fact that the search for improvement options itself often "happens in a black box" (Zellner, 2011, p. 217). The success and quality of BPI heavily rely on the project team's creativity and expertise in finding valuable solutions (Essam & Limam Mansar, 2012). For instance, workshops with consultants and stakeholders are commonly used to manually analyze issues and generate BPI options through ideation (Zellner, 2011). The capability and availability of experts providing method expertise and process knowledge limit the scale and speed at which PII can be conducted (Beerepoot et al., 2023). Yet, to keep up with growth, fast change, and competition, PII must be performed comprehensively and frequently (Beverungen et al., 2021).

Today, the rise of novel technologies, such as process mining (PM) and artificial intelligence (AI), will continue to energize the BPM movement (Feuerriegel et al., 2023; Grisold et al., 2024; vom Brocke et al., 2024). Practitioners call for support via methods and tools for PII that support this stage (Grisold et al., 2024; Groß et al., 2021; Zuhaira & Ahmad, 2021). Given its importance, there has been relevant foundational research on data-driven BPI: BPM and process science research offer computationally supported analysis methods for historical process execution data stored in PAISs, providing transparency and a factual basis for decision-making (van der Aalst, Adriansyah, et al., 2012; vom Brocke et al., 2024). While these PM techniques are robust at their core, their application and transfer to PII via methods and tools are under active research (Zellner, 2013; Zuhaira & Ahmad, 2021). Often, PII methods lack tool support or do not emphasize the novel opportunities provided through data-driven methods.

Beyond data-driven tools that address specific challenges for optimizing business processes, few existing information system (IS) artifacts comprehensively support the end-to-end process of PII that requires both process insights and method expertise. Tool-based automation and guidance of PII methods on the one hand and the incorporation of process knowledge on the other hand is required to foster PII adoption at scale (Beerepoot et al., 2023). Systems that aim to (semi) automatically conduct PII demand a fundamental understanding before they can provide benefit at large (Beerepoot et al., 2023).

While data-driven methods and tools are essential for meeting the demands of BPM, they cannot fully substitute employees' unique value in business processes in the foreseeable future. At the same time, modern (Western) societies are experiencing significant changes: Shifts in age demographics lead to a shortage of available workers. New entrants to the workforce, particularly from Generation Z and Alpha (born after 1995), seek work-life balance, physical and mental well-being, continuous development, and alignment between their jobs and personal values (Börsch-Supan, 2003; Nguyen Ngoc et al., 2022). Hence, changing human- and culture-specific considerations demand careful attention and oversight from BPM (Grisold et al., 2024). A survey reveals that 83% executives believe that strategically leveraging employees and allocating them right can drive value (Atsmon, 2016). The literature backs this assumption but lacks understanding and support for the human factor (Arias et al., 2016, 2018; Pereira et al., 2020). Moreover, the impact of digital technologies on work practices requires structures and active employee involvement to achieve successful digital transformation (Berend & Brohm-Badry, 2022; Denner et al., 2018; Schoch et al., 2022).

Overall, a comprehensive approach is required to manage PII across BPM's core elements: strategic alignment, governance, methods & information technology (IT), people, and culture (Kerpedzhiev et al., 2021; vom Brocke et al., 2016). This thesis aims to advance PII by leveraging the novel technical opportunities and addressing challenges of current BPM.

1.2 Research Objectives

In light of the opportunities presented by data-driven technologies and the various challenges in BPI discussed above, this thesis focuses on three main objectives:

First, research on computationally supported PII has predominantly focused on developing various individual approaches, often presented in a dispersed manner. There is a need to structure existing work to understand better how process improvement and innovation systems (PIISs) operate before guiding the design of future systems. This thesis aims to contribute to research by analyzing PIISs artifacts and by outlining design principles as a foundation for further artifact design and development.

Second, despite the high expectations, research on BPI has not yet provided a comprehensive range of data-driven methods and tools for PII. To address this gap, this thesis seeks to demonstrate the potential of process data as a catalyst for PII by providing several concrete artifacts. Specifically focusing on BPI, it introduces an approach for interactively exploring process event logs as groups of similar cases, facilitating their use in PII. A PIIS is presented to support BPI by recommending, simulating, and semi-automatically implementing best practices through improvement best practices. Moreover, this thesis proposes a method artifact that aids in the search for improvement options within process event logs by using matching rules to validate the suitability of improvement best practices, translating and assessing BPI patterns within these rules. Also, this thesis a takes customer-centric perspective on BPI and aims to improve meal delivery processes by employing multi-criteria decision analysis to optimize delivery routes based on process and historical customer data.

Third, this dissertation seeks to advance human-centric PII by proposing patterns for resource allocation that enhance the effective use of human resources in business processes. Additionally, it aims to introduce a structured method for human-centric BPI that incorporates the voice of employees into the process, ensuring that their perspectives are integrated into the improvement initiatives.

This thesis analyzes technological advancements to structure existing work and knowledge, offering prescriptive insights for PIISs. Further, it presents artifacts for data-driven PII. It also provides practical method guidance for considering people and culture topics and demands in BPI. Mostly following the design science research (DSR) principles, the research objectives are achieved through the design and evaluation of multiple artifacts, including reference architectures, methods, and instantiations. Ultimately, this thesis aims to contribute theoretically to existing research streams and to offer BPM stakeholders practical guidance, assistance, and decision support in the PII lifecycle stage.

1.3 Structure of the Dissertation and Embedding of the Research Papers

This thesis consists of eight research papers that collectively address the outlined research objectives. Table 1.1 provides an overview of the thesis structure and the integration of these papers. The contributions of these papers advance the current research on PII at the system level, data-driven BPI, as well as methods and tools for human-centric BPI.

After motivating the scope of this thesis and defining the research objectives (chapter 1), chapter 2 (which includes research papers P1 and P2) presents research that explores the nature and design of PIISs. Research Paper P1 offers an overview of existing PIISs as documented in the literature. The paper presents a taxonomy that examines how PIISs develop new process designs depending on their objective, input, data processing, and output. Additionally, the paper identifies archetypes of existing PIISs. Building on the literature, Research Paper P2 proposes principles for designing novel PIISs. In addition to the known artifacts, input from subject matter experts was solicited to assess the future development of these systems. The taxonomy and the design principles were evaluated through multiple internal and external evaluation activities.

Chapter 3 (including Research Papers P3, P4, P5, and P6) presents research artifacts that address the topic of data-driven BPI. First, Research Paper P3 introduces an approach for exploring PM event log data interactively by progressively splitting groups of similar process cases, thereby constructing a tree structure of process data. This approach is implemented as a tool and subsequently evaluated. Research Paper P4 presents a PIIS designed to assist in BPI. The assisted business process redesign (ABPR) concept guides users in enhancing business processes based on BPI best practices in the form of patterns. Depending on the available data, the ABPR concept classifies four types of recommendations, each varying in their level of automation. Additionally, this paper proposes a reference architecture that offers operational support for implementing ABPR tools. The reference architecture has been instantiated as a prototype and evaluated in interviews and a case study. Research Paper P5 presents a method artifact designed to identify BPI options within event log data. This structured approach is based on BPI patterns and aids users in discovering the application potential of these patterns in historical trace data. The method was applied to translate an initial set of BPI patterns and to assess data from historical traces. Research Paper P6 aims at adaptive process improvement in last-mile food delivery processes. It employs multi-criteria decision analysis to include a customer-centric perspective in vehicle routing. This approach utilizes process and historical customer data, along with the concept of customer satisfaction to optimize delivery routes accordingly.

Table 1.1: Structure of this thesis and embedding of the research papers.

1	**Introduction**
2	**Process Improvement and Innovation Systems**
P1	**A Taxonomy for Process Improvement and Innovation Systems**
	T. Fehrer, L. Moder, and M. Röglinger
P2	**Design Principles for Process Improvement and Innovation Systems**
	L. Moder, T. Fehrer, and M. Röglinger
3	**Data-Driven Process Improvement**
P3	**Interactively Exploring Case Groups and Their Characteristics**
	T. Fehrer, L. Moder, and M. Röglinger
P4	**An Assisted Approach to Business Process Redesign**
	T. Fehrer, D. A. Fischer, S. J. Leemans, M. Röglinger, and M. T. Wynn
P5	**The FLAC Method: Data-Facilitated Discovery of Business Process Improvement Options**
	T. Fehrer, L. Marcus, M. Röglinger, U. Smalei, and F. Zetzsche
P6	**Customers Like It Hot and Fast – Incorporating Customer Effects into the Meal Delivery Process**
	C. van Dun, T. Fehrer, W. Kratsch, and N. Wolf
4	**Human Centricity in Business Process Improvement**
P7	**Not Here, But There: Human Resource Allocation Patterns**
	K. Goel, T. Fehrer, M. Röglinger, and M. T. Wynn
P8	**With People, for People: A Method for Employee-Aware Business Process Improvement**
	T. Fehrer, A. García González, M. Röglinger, M. Wynn, and F. Zetzsche
5	**Conclusion**

Chapter 4 (including Research Papers P7 and P8) presents two artifacts for human-centric BPI. Research Paper P7 proposes patterns for human-centric resource allocation, serving as a reference for the task of enhancing the allocation of human resources in business processes. These patterns are derived from existing literature and distilled to facilitate understanding and support allocation strategies for human actors. Research Paper P8 introduces a method to enhance business processes focusing on human actors. The method encompasses multiple project phases to develop and innovate business processes promoting human engagement. Its application is exemplified through a case study conducted at a German state agency.

Chapter 5 concludes this dissertation with a summary, outlining limitations and suggesting potential avenues for future research. Appendix A contains an index of the research papers, details my contributions to each paper, and provides an overview of each paper.

2 Process Improvement and Innovation Systems

An understanding of how ISs can operationally support PII is needed to guide research in developing systems to support this crucial stage in the BPM lifecycle. Activities in this phase involve tasks such as envisioning and initiating process changes, analyzing current ("as-is") processes, and, central to PII, generating, evaluating, and selecting future ("to-be") process design options (Malinova et al., 2022). These steps are followed by the implementation, monitoring, and evaluation of the process changes (Dumas et al., 2018; Malinova et al., 2022).

Given its inherent complexity and the demands for creativity and knowledge (Figl & Recker, 2016; Groß et al., 2021; Malinova et al., 2022), PII, has traditionally been a human-led endeavor, making its automation and scalability a significant challenge for academia (Beerepoot et al., 2023). However, at the time of writing, AI—with its ability to emulate and enhance human creativity and extract insights from large datasets—is increasingly being adopted across organizations and their business processes. This development is driven by the groundbreaking results in generative AI research (Feuerriegel et al., 2023; Vidgof et al., 2023), highlighting the importance and showcasing the potential of understanding and developing ISs that support PII.

PIISs, i.e., tools "provid[ing] (semi-)automated support for the generation of improved business processes" (Rosemann and vom Brocke, 2014, p. 117) focus on design-time changes (i.e., changes to the process design instead of manipulations in running process instances). PIISs are socio-technical systems that integrate social and technical components (Grashoff & Recker, 2023) and align with established system classes within and surrounding BPM: At the broadest level, PAISs are defined as ISs that support the execution and management of business processes, such as enterprise resource planning systems and BPM systems (BPMSs) (Dumas et al., 2018; van der Aalst, 2013). PIISs can be viewed as a specialized subset of BPMSs. Alignment with related system classes further helps to understand PIISs (figure 2.1). Given the decision support required for PII, PIISs possess characteristics found in decision support systems. Furthermore, since PIISs aim to assist human process designers in the creative task of PII, creativity support systems are also considered.

The automation of PII is in its infancy, as displayed by the lack of tool availability and adop-

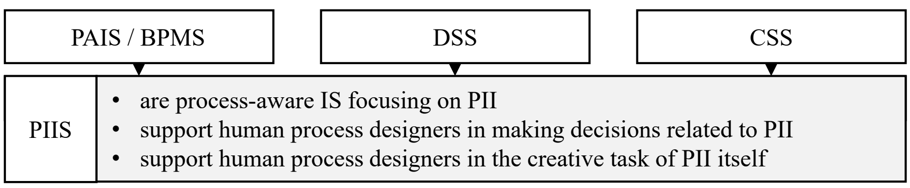


Figure 2.1: Embedding of PIISs in related system classes.

tion in practice, compared to other BPM activities where data-driven approaches are on the rise (Beerepoot et al., 2023; van der Aalst & Carmona, 2022; vom Brocke et al., 2024). Today, data and technology are primarily employed for generating ex-post insights, ad-hoc improvements, and to lever automation potentials within process execution rather than focusing on fundamentally enhancing PII (Beerepoot et al., 2023). Given demand, competition, and technological advances, research on systems that computationally support PII is highly relevant (Beerepoot et al., 2023).

Therefore, this chapter presents research that structures existing research and conceptual knowledge to understand the function of PIISs (Section 2.1; Research Paper P1). Further, and building on these insights, this chapter presents design principles for the design of novel PIISs (Section 2.2; Research Paper P2).

2.1 Understanding Process Improvement and Innovation Systems

Although academia has systematically explored human-led PII methods (Malinova et al., 2022; vom Brocke et al., 2021) and approaches for prescriptive process monitoring, particularly through run-time adaptations (Kubrak et al., 2022), a comprehensive understanding of PIISs remains undeveloped. Despite existing approaches that warrant interim evaluation, there is no systematic overview of how PIISs generate improved process designs. This gap hinders transparent evaluation, comparison, and the identification of research opportunities while also limiting guidance for vendors (Kerpedzhiev et al., 2021). This research gap is framed by two research questions (RQs):

How do PIISs create improved process designs?, and
What is the state of the art of how PIISs create improved process designs?

To address these research questions, a classification scheme was developed in Research Paper P1 to structure existing research on PIISs and provide an overview of current approaches, guiding future research directions (Recker & Mendling, 2016). A taxonomy of PIISs was created based on the guidance in Nickerson et al. (2013) and Kundisch et al. (2022), drawing on conceptual and empirical knowledge from 44 artifacts identified through an extensive systematic literature review, supplemented by interviews with five leading PM vendors. During the design and development of the taxonomy, three iterations were conducted, employing both empirical-to-conceptual (E2C) and conceptual-to-empirical (C2E) approaches. In each iteration, the taxonomy was challenged and refined. Subsequently, the fulfillment of objective ending conditions (OECs) and subjective ending conditions (SECs) was assessed and demonstrated (Kundisch et al., 2022). The taxonomy was evaluated through eleven interviews with academics, a survey with twelve BPM practitioners, a demonstrative classification of exemplary objects, and via the Q-sort method with input from seven ISs researchers (Nickerson et al., 2013). Additionally, four archetypes of PIISs were derived and evaluated, reflecting the current state of PIISs research.

Table 2.1 presents the developed and evaluated taxonomy, classifying PIISs along four layers and eight dimensions. The first layer, consisting of two dimensions, outlines the scope of PIISs

Table 2.1: Final taxonomy of how PIISs create improved process designs.

Layer/Dimension		Guiding Question	Characteristic						Excl.
Scope	Focus of changes	*What is the primary focus of changes when designing new processes?*	Control flow		Resource		Data		NE
	Ambition	*To what extent is the existing process transformed?*	Incremental		Radical		Both		E
Input		*What kind of data is fed into the PIIS?*	Process design data	Process execution data	Process goal	Business rules	Process context	Improvement objective	NE
Throughput	Design generation	*What sparks the generation of new process designs?*	Randomness-based		Rule-based		Both		E
	Knowledge acquisition	*How is knowledge in the given input data gathered and interpreted?*	Explicit		Implicit		Both		E
	Design evaluation	*Which evaluation criteria are evaluated or ensured?*	Feasibility		Performance		Both	None	E
	Level of human involvement	*What is human process designers' level of active involvement in generating new process designs?*	Human in the loop		Human on the loop		Human out of the loop		E
Output		*What kind of outcome is produced by the PIIS?*	Formalised process design		Non-formalised process design		Both		E

Excl: Exclusivity of Characteristics, E: Mutually Exclusive Criteria, NE: Non-Exclusive Criteria

(Malinova et al., 2022). The remaining three dimensions are conceptually aligned with the system model approach, an established framework in system theory and information processing, which includes input, throughput, and output (Orr, 1998; Stefani & Zschech, 2018)

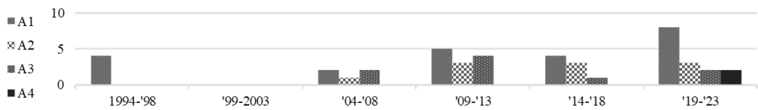
The *scope* layer defines the predetermined focus and ambition of the PIIS and consists of two dimensions: what aspects of the process are to be changed and to what extent. This layer, aligned with the research question, helps contextualize system design elements based on their intended purpose. The *input* layer in PIISs defines the data that shapes the solution space and foundational information. It includes six *non-exclusive* characteristics: *Process design data*, i.e., process blueprints in the form of models or descriptions; *Process execution data*, i.e., captured real or simulated process trace data; *Process goals*, describing the processes' desired outcomes; *Business rules*, i.e., statements governing process behavior; *Process context*, i.e., factors and characteristics describing the processes' surrounding and environment; and *Improvement objectives*, specifying enhancement targets like cost, time, quality, or specific performance objectives such as sustainability or compliance. The *throughput* layer in PIISs covers four key dimensions: the method of design generation, knowledge acquisition, design evaluation objectives, and the level of human involvement. Design generation can be randomness-based, rule-based, or a combination. Knowledge acquisition may involve explicit, implicit, or combined forms of knowledge. Evaluation objectives focus on the feasibility of the redesign, its performance, both aspects in combination, or none if no evaluation is conducted. Human involvement ranges from co-creation (human in the loop) to feedback and evaluation (human on the loop) to full automation (human out of the loop).

The *output* layer describes the outcomes of PIISs, categorized into three *mutually exclusive* characteristics: *Formalized process design*, which offers structured process models like Petri nets; *Non-formalized process design*, which provides less structured outcomes like written instructions; and *Both*, where PIISs generate both formalized and non-formalized designs.

Table 2.2 details the distribution of characteristics across four archetypes of PIISs generated from 44 artifacts identified in the literature review. To determine the significance of individual characteristics for cluster assignment and to define the archetypes, a random forest model was trained on the expression 'archetype ~ .', with feature importance assessed (Cutler & Breiman, 1994; Shi & Horvath, 2006). Key factors include the objects' ambition, design generation, and evaluation type. The four archetypes are labeled as follows: *Algorithmic Solution Engines (A1), Dynamic Process Integrators (A2), Innovative Process Refiners (A3), and Co-Creators Learning from Event Data (A4)*, each highlighting the central focus of the archetype. These archetypes guide system designers in identifying relevant traits and developing strategies tailored to specific challenges.

Distinctive contrasts emerge among the archetypes. *Algorithmic Solution Engines* (A1) function in a structured and deterministic way, relying on rule-based solution algorithms (100% of objects) to find incremental process improvements (87% of objects), mostly without human intervention (57% of objects). With the static nature of the systems' processing and output, the system input relies on static data that must be manually put together. Most objects represent this archetype. In contrast, *Dynamic Process Integrators* (A2) seek to create process improvements (100% of approaches) by fusing various process elements in a chaotic, random manner (90% of objects), re-

Table 2.2: Cluster analysis outcomes detailing the distribution of characteristics across four clusters.

Archetype			**A1**	**A2**	**A3**	**A4**
Label			Algorithmic Solution Engines	Dynamic Process Integrators	Innovative Process Refiners	Co-Creators Learning from Event Data
Group Size			23	10	9	2
Occurrence of artifact representatives over time						
Scope	Focus of changes	Control flow	100%	90%	100%	100%
		Resource	35%	60%		50%
		Data				
	Ambition	Incremental	87%	100%	22%	50%
		Radical	13%		78%	50%
		Both				
Input		Process execution data	22%	10%	11%	100%
		Process design data	87%	100%	89%	
		Process context	22%	20%	44%	
		Business rules	48%	70%	11%	
		Process goal	48%	90%	22%	
		Improvement objective	30%	70%	22%	
Throughput	Design generation	Randomness-based		90%	33%	100%
		Rule-based	100%	10%	67%	
		Both				
	Knowledge acquisition	Explicit	96%	100%	89%	
		Implicit			11%	100%
		Both	4%			
	Design evaluation	Feasibility	4%		78%	
		Performance	9%			
		Both	70%	90%	22%	
		None	17%	10%		100%
	Level of human involvement	In the Loop	22%		44%	100%
		On the Loop	13%			
		Out of the Loop	57%	100%	56%	
Output		Formalized process design	91%	100%	100%	
		Non-formalized process design	17%			100%
		Both				

sulting in unanticipated improvements. *Innovative Process Refiners* (A3) take a more audacious approach, radically redesigning processes (78% of objects) and instead using rule-based approaches (67% of objects). The objects under consideration only focus on the control flow (100% of objects). Archetypes A1-A3 output formalized process designs, most without human intervention. The *Co-Creators Learning from Event Data* (A4), which are only represented by two recent objects (published in 2022 and 2023), acquire process knowledge implicitly (100%) from process execution data, i.e., event logs (100% of objects). Their recommendations are served to users, who pick up on this non-formalized output (100% of objects) to evaluate the findings and assemble complete process designs (100% of objects).

P1 reveals, few mature, systems are described in the literature today, highlighting the field's emerging nature. It can be observed that significant potential remains, such as automating process innovation by leveraging more process execution data, incorporating improvement objectives and context information for targeted designs, and utilizing implicit knowledge through AI to reduce human effort.

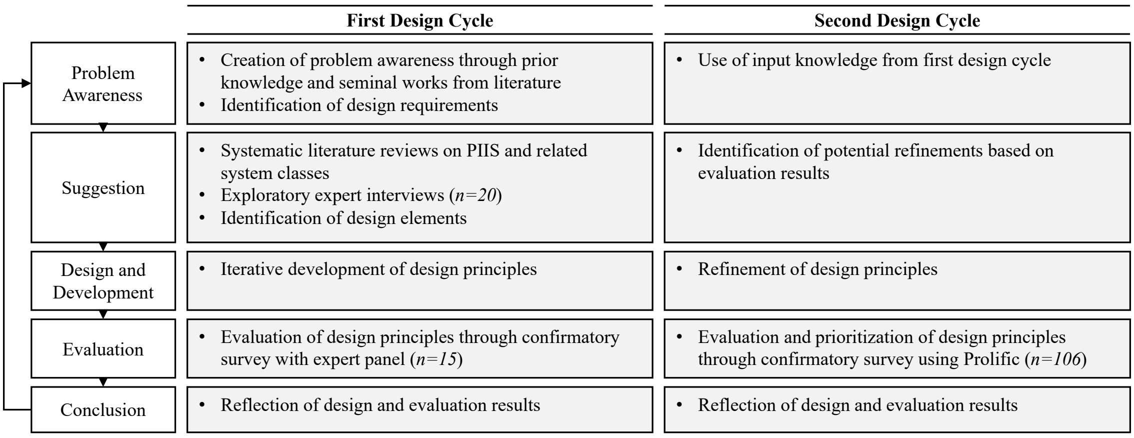


Figure 2.2: Research approach.

2.2 Design Principles for Process Improvement and Innovation Systems

Research on PIISs is limited, with contributions mainly in the form of problem statements (Beerepoot et al., 2023) and software engineering projects exploring expository approaches (e.g., Mahammed et al., 2021; van Dun et al., 2023). While P1 offers an initial framework for structuring and analyzing PIISs, there remains a lack of systematically captured prescriptive design knowledge. Consequently, both researchers and practitioners, lack comprehensive guidance on relevant design choices, increasing inefficiencies and risks in system development, implementation, and adoption. This gap leads to the research question:

How should PIISs be designed?

To address this research question, the DSR paradigm is adopted to derive and formulate design principles for PIISs (Gregor, 2006; Gregor et al., 2020; Kruse et al., 2022; Kuechler & Vaishnavi, 2012). Design principles are essential elements of emerging design theory (Jones & Gregor, 2007) and are formulated to meet specific design requirements. Design requirements refer to general goals or conditions that any system instantiation must satisfy to achieve its intended purpose (Jones & Gregor, 2007; Meth et al., 2015). Design principles, which are prescriptive in nature, outline the necessary capabilities of a system to meet these requirements, serving as an abstract guide for the system's design and development (Gregor et al., 2020; Jones & Gregor, 2007; Meth et al., 2015). DSR involves iterative design cycles (Kuechler & Vaishnavi, 2012). Following the approach of Kuechler and Vaishnavi (2012), similar to Meth et al. (2015) and Herm et al. (2022), this research is conducted in two design cycles (see figure 2.2). The first design cycle combined two systematic literature reviews on PIISs (building on P1) and related system classes with insights from 20 exploratory expert interviews to generate an initial set of design principles, which were evaluated through confirmatory surveys with a panel of 15 experts (Survey 1). In the second cycle, these design principles were refined based on the evaluation results and further evaluated and prioritized through a confirmatory survey with 106 participants (Survey 2).

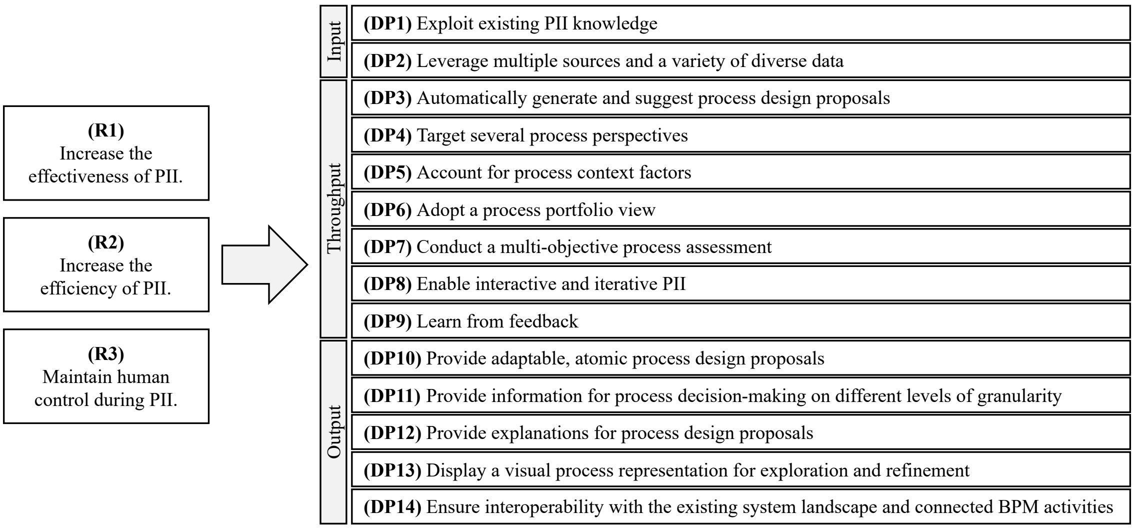


Figure 2.3: Overview of fourteen design principles for PIISs.

The focus of this research is on the application of PIISs, excluding upstream and downstream elements such as system triggers, preprocessing pipelines, data storage, and implementation, as well as usage contexts like individual or collaboration modes. Based on literature and prior knowledge, three design requirements were identified. PIISs must enhance the effectiveness, efficiency, or both in PII activities, improving both the outcome (the new process design) and the process of achieving it, while ensuring human control due to the significant implications of process design and automated decision-making, particularly from legal or ethical perspectives. R 1 addresses the outcome of PII, while R 2 and R 3 focus on the PII process.

R 1 (Increase the effectiveness of PII) *PIISs should produce new or improved process designs that are more effective and efficient in achieving the process goal, or that restore the feasibility of the process (Havur et al., 2019; Zellner, 2011). By doing so, they enhance decision quality (Meth et al., 2015).*

R 2 (Increase the efficiency of PII) *PIISs should offer computational support for both generating and evaluating process designs while maintaining ease of use (van Dun et al., 2023). This reduces the cognitive load on human process designers (Meth et al., 2015).*

R 3 (Maintain human control during PII) *PIISs should allow human process designers to actively influence the outcome of PII while being easy to understand (Fehrer, Fischer, Leemans, et al., 2022). This means reducing system restrictiveness by offering more decision-making choices and enhancing explainability and transparency to foster informed decisions and trust (Afflerbach et al., 2017; Bode et al., 2022; Herm et al., 2022; Meth et al., 2015). Such features are crucial in high-stakes decision settings, given the significant implications of PII (Bellandi et al., 2012; Zschech et al., 2020).*

Fourteen design principles are proposed within an input-throughput-output structure to guide the design and development of PIISs, based on Gregor et al. (2020) (figure 2.3).

Seven exemplary artifacts were analyzed to illustrate the implementation of these design principles. The analysis indicates that several artifacts partially or fully implement the design principles. These artifacts, for example, integrate existing PII knowledge, process data, and support multi-objective assessments but often lack in areas such as process portfolio views, explainability, and adaptability. The analysis concludes that while most design principles can be partially implemented, significant gaps remain, highlighting areas for improvement in future PIIS development. The overall feedback from Survey 1 was very positive. Although one expert noted that "14 principles are a lot" and "too many to recall from the top of one's head" the set was considered comprehensive and relevant. Quantitative results showed high ratings for *accessibility*, *importance*, *effectiveness*, and *completeness*. Survey 2 provided fewer qualitative comments, mostly focusing on future research directions. The ratings were slightly lower than *Survey 1*. In summary, the evaluation suggests that the principles are both *reusable* and *complete*.

In summary, this chapter offers two key contributions to the understanding of PIISs. First, it presents a structured overview of how existing PIISs function, developed through a taxonomy informed by literature, expert insights, and the author's conceptual analysis. Second, it derives design principles for the future creation of new artifacts. Together, these contributions provide guidance for both understanding and designing PIISs.

3 Data-Driven Process Improvement

Following the motivation in chapter 2 for systems that enhance PII by increasing effectiveness and efficiency through automation and data utilization while ensuring human control at key points, this chapter introduces approaches for data-driven BPI. Repeating from above, BPI activities involve analyzing current processes, generating, evaluating, and selecting "to-be" process design options (Malinova et al., 2022). The first research article, presents an approach that applies the principles of visual analytics (VA) to assist analysts in discovering and understanding current "as-is" process trace data in a novel way, thereby establishing a basis for PII and other PM projects (Section 3.1; Research Paper P3). PM encompasses data-driven techniques designed to offer analytical support for BPM by utilizing process execution data from event logs (Dumas et al., 2018; van der Aalst & Carmona, 2022; vom Brocke et al., 2024). A primary objective of PM is to analyze this process data to gain insights into the nature of the business process and identify potential areas for improvement (van der Aalst & Carmona, 2022; van Eck et al., 2015). Another article introduces a conceptualization of a PIIS that focuses on incremental improvements through redesign operations inspired by best practices embedded in BPI patterns (Section 3.2; Research Paper P4). Patterns capture best practices and assumptions from the field and are commonly used to provide methodological support for BPI (Gamma et al., 1995; Zellner, 2013). They are advantageous because they are specific enough to address current problems yet generic enough to apply to future issues (Gamma et al., 1995). Patterns offer a straightforward entry point into BPI as they are easy to understand, describe clear redesign ideas, and stimulate creative thinking about BPI options in both generic and specific contexts (Fehrer, 2023; Limam Mansar & Reijers, 2007). The third article in this chapter leverages the significant potential and broad applicability of BPI patterns by identifying improvement opportunities in historical process execution data. It introduces a method artifact that translates BPI patterns into rules, ultimately generating query code for analyzing PM event logs (Section 3.3; Research Paper P5). The final article in this chapter presents a data-driven approach to BPI for adaptive process execution, specifically enhancing the meal delivery process. It integrates the principles of value-oriented BPM into route generation, aiming to optimize both efficiency and customer satisfaction (Section 3.4; Research Paper P6).

3.1 Interactively Exploring Case Groups and Characteristics

In the exploration phase, a constitutional part of most PM projects, process analysts familiarize themselves with the process data (van Eck et al., 2015; Zerbato et al., 2022). Even when only essential data is carefully prepared, event logs retain complexity and variability that reflect real-world processes (Dumas et al., 2018; van der Aalst, 2011). Seven key tasks are executed in this phase: analyzing the control flow, identifying relevant context data attributes, forming and classifying groups of cases, drilling down into data, comparing groups, and testing hypotheses while documenting findings (Zerbato et al., 2022). These tasks help analysts understand the process structure and behavior, ultimately guiding in-depth analysis and validation of findings.

An examination of common work practices reveals that analysts repeatedly devote substantial time and effort to an open-minded, exploratory, and relatively unstructured investigation of process data, which is highly knowledge-intensive (de Weerdt et al., 2013; Di Ciccio et al., 2015; Kubrak et al., 2023). Hence, tool support is essential to support and simplify this phase (Di Ciccio et al., 2024; Zuhaira & Ahmad, 2021). Visual analytics (VA) has gained significant attention for its ability to employ interactive visualization, aiding human assessment in data-driven analyses (Cui, 2019; van der Aalst, de Leoni, & Ter, 2012). VA integrates automated analysis, domain knowledge, and human judgment through interactive tools that leverage both human and computational strengths (Di Ciccio et al., 2024; Gschwandtner, 2017). However, our literature review reveals that while some complexity reduction is achieved through automated clustering and partitioning methods (Bolt et al., 2018; Leemans et al., 2020; Seeliger et al., 2019; Vidgof et al., 2022), they lack interactive exploration capabilities for process groups, despite its widespread application in PM analysis (Martin et al., 2020). Therefore, an open research question remains:

How can process analysts be best supported in interactively exploring groups of process cases within event log data?

Research Paper P3 addresses the gap by conceptualizing the interactive generation and analysis of process case groups through the artifact *Case Group Explorer*, following the DSR paradigm (Gregor & Hevner, 2013). The study demonstrates how VA enhances event log grouping techniques via interaction and visualization. The approach is evaluated using the Framework for Evaluation in Design Science Research (FEDS) (Venable et al., 2016): validating the design specification by comparing it with competing artifacts, implementing a prototype to assess feasibility with three public event logs, and evaluating its usefulness and ease of use through a user study.

An event log is necessary for PM analysis. On a granular level, *events* are specific occurrences of *activities* at a particular timestamp. Activities are labels that describe what has happened in an event. Events can have additional context data in the form of named attributes of various types, such as customer information, the resource executing the event, or the cost associated with a single event. A *case* is a sequence of events belonging to one process instance (e.g., a sales order). Therefore, a case identifier is considered a must. An *event log* is a collection of cases. In process analysis, the *control-flow* perspective is concerned with case identifiers and the chronology of events. Supplementary attributes, such as resources, customers, or cost, are additional context. Cases with the same sequence of activities are represented by a *control-flow variant*.

To support PM analysts in exploring event logs, three design objectives (DOs) are formulated. Following the seven key tasks, PM analysts want to *analyze*, *form*, and *annotate* the groups of process data they are currently interested in. Typically, they switch between these modes, so the complete workflow should be embedded in an interactive tool environment (Ribarsky et al., 2014; Zimmermann et al., 2023). The first DOs emphasizes the need for visual analysis of case data to enable the detection, aggregation, and visualization of process properties and characteristics,

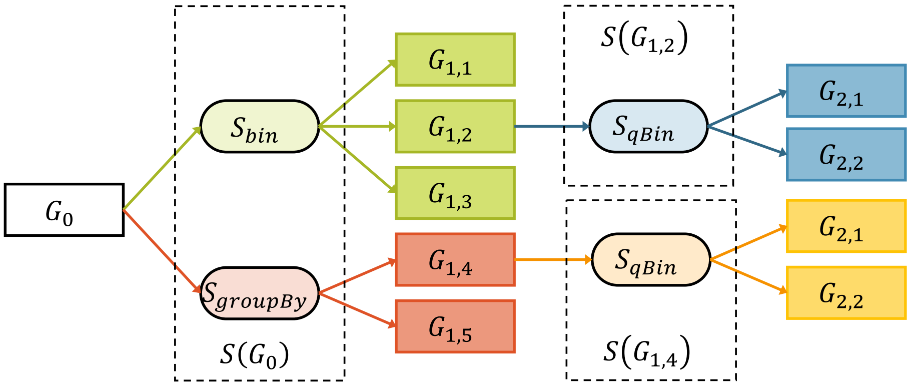


Figure 3.1: Gradual group tree construction with splits applied to groups

as known from typical PM tools (Kerremans et al., 2024; Stierle et al., 2021; van der Aalst & Carmona, 2022). In the second DO, the requirement for gradual case grouping is addressed, allowing analysts to form and refine groups based on their dynamic needs (Zerbato et al., 2022; Zimmermann et al., 2023). In a third DO, the importance of comparing and analyzing these groups is highlighted, facilitating the identification of similarities, differences, and insights across the event log.

To effectively achieve the DOs, a tight integration of the three VA aspects, interaction, visualization, and computational support, is essential (Keim et al., 2008; Knoblich et al., 2024). Interaction patterns are defined to facilitate event log exploration, subgroup formation, and group difference analysis. Interaction also enables hypothesis testing by varying split attributes and values. Additionally, computational support is necessary for preparing analyses and assisting users in grouping event logs. The *Case Group Explorer* enables analysts to interactively explore and form event log groups in a tree structure, facilitating the separation of the event log into groups and subgroups in three major activities (1-3)

The (1) *manage and explore features* activity supports analysts in analyzing the control flow and exploring contextual process features. Predominantly, the control flow is explored via diagrams that visualize the flow of activities, annotated with performance data. Different descriptive visualizations, tables, and charts provide an overview of context dimensions. A VA approach should support this exploration by aggregating event log attributes and providing statistics that help determine interesting features. To reduce complexity, the paper abstracts from the notion of cases and their related events into a flat and unified representation. Each case is represented as a tuple of features, aggregating the attributes of its constituent events. Aggregation functions (e.g., sum, count, min, max, average, first, and last) transform event-level attributes to the case level, resulting in aggregated cases. Advanced aggregation functions derive additional features like variant, throughput, waiting_time, conformance, and rework. Custom functions allow further features (e.g., automation rate, boolean flags for matches of activities, sequences, and patterns).

Once the features are designed and converted to explain important characteristics at the case level, analysts can begin to (2) *gradually form groups* of aggregated cases. A manual, top-down partitioning approach allows analysts to apply domain knowledge while forming groups. Start-

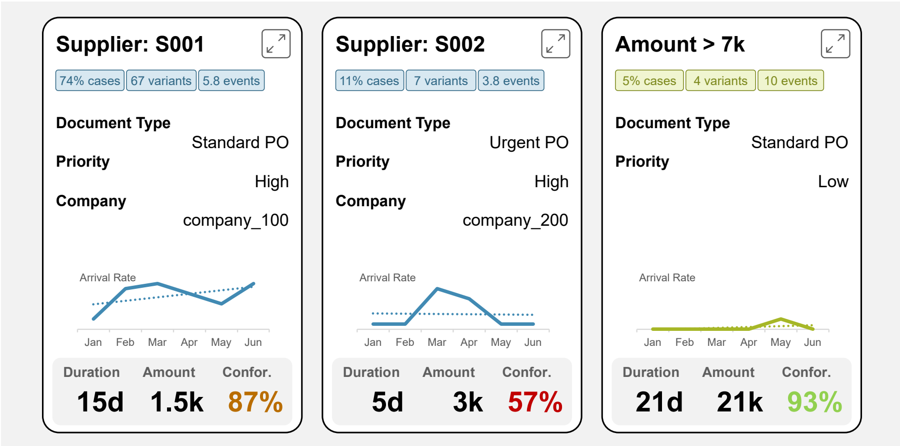


Figure 3.2: Comparison of trace groups via card UI components.

ing with all cases in one group G_0, analysts perform split operations to create subgroups, forming a nested tree structure (see figure 3.1). After iterative grouping, analysts can *analyze and compare groups* using group profiles, configurable names, summaries, and card views for direct comparison (see figure 3.2). Insights can be highlighted, annotated, and documented collaboratively.

While the activities are initially presented in a natural sequence, the *Case Group Explorer* being an interactive VA approach allows these three activities to be executed repeatedly, accommodating flexible and evolving analysis requirements. A software prototype demonstrates the applicability of the conceptualized approach (see figure 3.3) and was used to evaluate its usefulness in a user study.

Research Paper P3 investigates how process analysts can be best supported to interactively explore groups of process instances in event log data and extends the landscape of existing PM tools via a novel instantiation. The *Case Group Explorer* is characterized by the interplay of visualization and computational support enacted by task-level interaction patterns so that domain experts can bring in their knowledge and gain new understanding interactively (Gschwandtner, 2017). The artifact was evaluated in three episodes, transitioning from artificial to more naturalistic settings and involving prospective users. This evaluation shaped and assessed the artifact's functionality, ensuring rigor in deriving theoretical and practical contributions (Venable et al., 2016). In an artificial evaluation, existing artifacts were assessed against the DOs and discussed compared to the technique's characteristics. Other techniques for group exploration mostly build on automatic grouping techniques but provide limited support for interactively exploring distinct criteria for group behavior. The *Case Group Explorer* prototype was implemented and tested on various event logs with differing characteristics, demonstrating its effectiveness across diverse scenarios. Additionally, a study with PM experts evaluated the prototype's perceived usefulness and ease of use. The experts acknowledged the relevance of the research gap and confirmed the presence of an exploratory grouping phase in their work practices, finding the overall concept appealing. Positive feedback led to the conclusion that *Case Group Explorer* is feasible, perceived as being useful, and easy to use for PM analyst purposes.

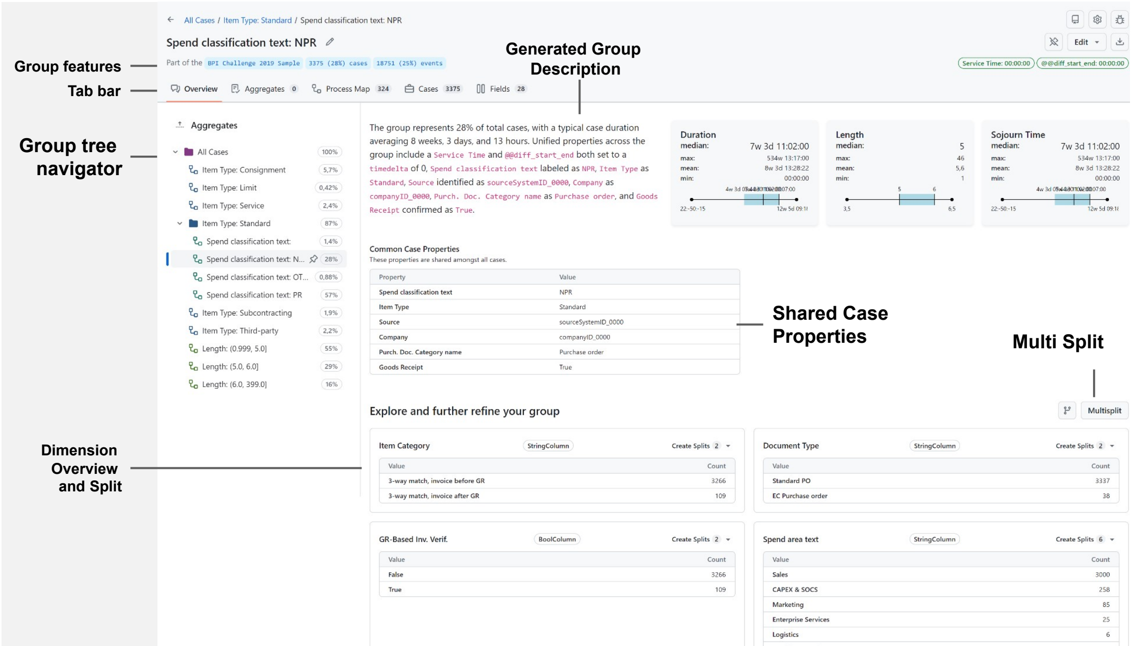


Figure 3.3: UI of the interactive group-based event log exploration tool according to proposed group visualization.

3.2 Assisted Business Process Redesign

PIISs aim to support and automate PII. In this research article, the incremental improvement of business processes (BPI) is in focus and also referred to as business process redesign (BPR). The explorative and innovative approach is not considered. As introduced, BPI patterns are widely recognized as practical method tools for documenting and communicating best practices. Inspired by such best practices, organizations aim to analyze challenges and opportunities and manually generate BPR options (Zellner, 2011) in workshops with consultants and various process stakeholders. In this context, the quality and effectiveness of BPI depend on the creativity and expertise of the project team in finding valuable solutions (Essam & Limam Mansar, 2012). While most BPR methods in the literature lack tool support, some approaches use BPI patterns to generate application suggestions (Fellmann et al., 2019; Netjes et al., 2010; Zuhaira & Ahmad, 2021). However, these approaches have limitations: (1) they rely on hard-to-obtain data, (2) they are inflexible due to hard-coded assumptions, and (3) few approaches incorporate a variety of redesign patterns (Essam & Limam Mansar, 2012). Therefore, it is uncertain to what extent these tool-based approaches can manage the complexity and richness of business process information while providing actionable BPR suggestions without human intervention (Essam & Limam Mansar, 2012). Although this gap is recognized in the literature, no interactive approach combines automated tool support with domain expertise in a guided process (Beerepoot et al., 2023; Essam & Limam Mansar, 2012). Thus, Research Paper P4 addresses the research question:

How can assistive tools improve BPR?

Adopting the DSR paradigm (Hevner et al., 2004; Peffers et al., 2007) alongside reference architec-

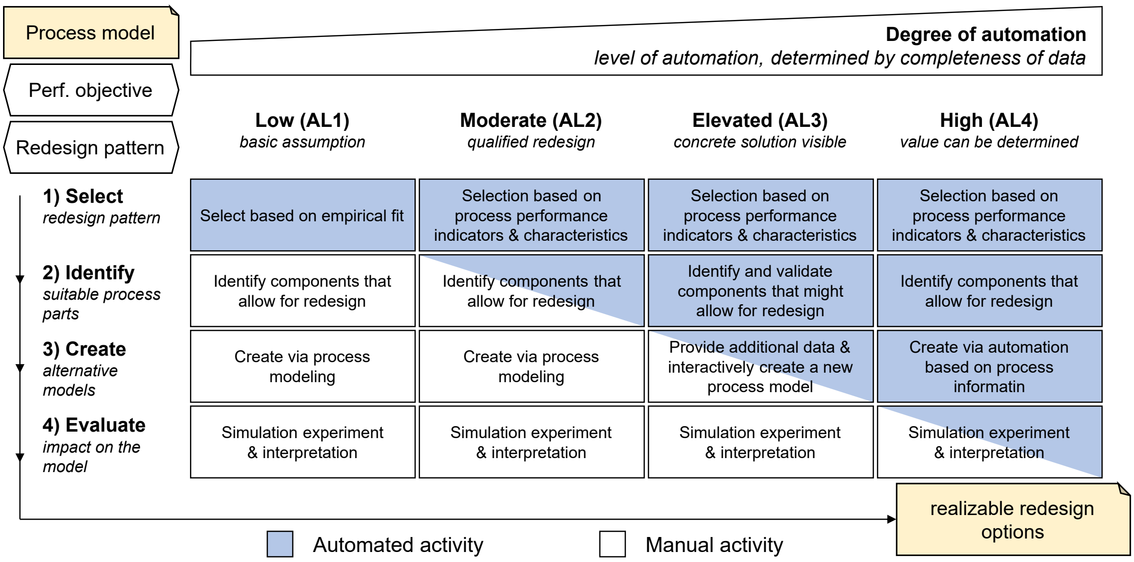


Figure 3.4: Conceptualization of assisted business process redesign.

ture (RA) development principles (Galster & Avgeriou, 2011), Research Paper P4 introduces the ABPR concept, an RA design specification, and a prototypical instantiation. The development of BPI options is guided by four activities derived from related work (Jansen-Vullers & Reijers, 2005), enabling a step-by-step approach, as illustrated in figure 3.4: Step 1) select promising redesign patterns, Step 2) identify suitable process parts, Step 3) create alternative models, and Step 4) evaluate the performance of these alternative models. The completion of these four steps yields redesign options that, depending on the outcomes of evaluation supported by simulation experiments, can enhance the process under review. PIISs following the ABPR approach, deeply integrate these steps and interactively guide users through their structured application. Leveraging automation potential, the instantiations aim to perform these steps in the background, presenting the results as redesign recommendations. Users then manually complete the remaining steps, using their expertise to transform these recommendations into actionable BPI options. This blend of (semi-)automated and manual steps results in varying levels of automation for individual steps, leading to increasingly automated recommendations. In figure 3.4, four types of recommendation are defined in increasing automation level (AL) following Parasuraman et al. (2000).

The generated recommendations are presented in a diverse and ranked selection, initially filtering out less valuable or overly similar suggestions. To assess their potential and similarity, a scoring function within the ABPR tools estimates the impact of each recommendation based on the chosen performance objective. Notably, the impact of recommendations is not directly comparable across recommendation types, as those at higher ALs are more specific than those at lower ALs. When specific impacts cannot be measured, the scoring function uses empirical data to estimate potential impact. Similarity is calculated by integrating information about the underlying BPI pattern (e.g., process aspect) and the specific recommendation (e.g., affected elements).

To guide the implementation of PIISs following the ABPR approach, the component diagram in

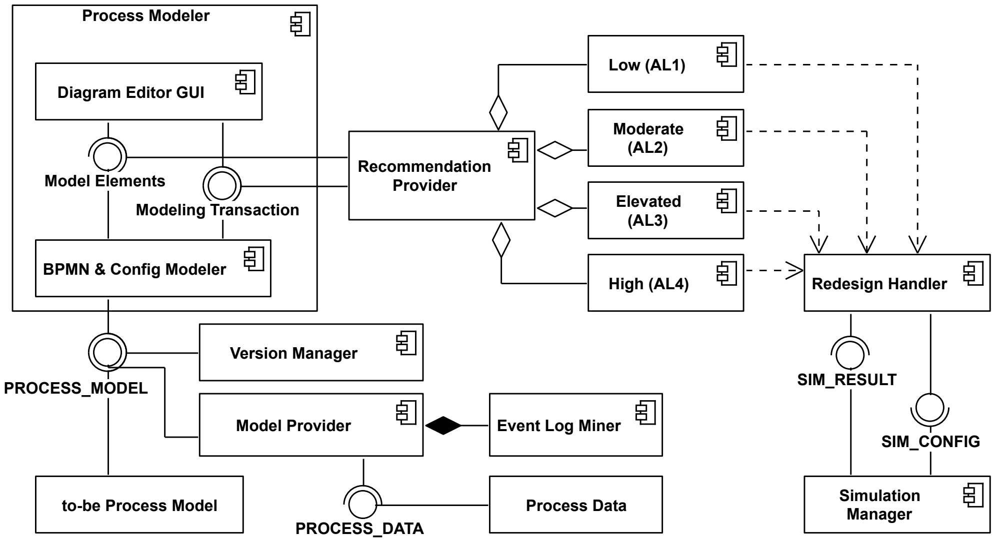


Figure 3.5: Assisted business process redesign reference architecture.

figure 3.5 shows the ABPR RA. The model provider component serves as an external interface for data. The model provider component acts as an external interface for data, while the process modeler component offers user interaction and modeling capabilities. The simulation manager handles process models and executes simulation experiments according to the configuration. The redesign handler ensures the sequential execution of the four steps outlined in figure 3.4 for each redesign option. Triggered by changes in the process model, the recommendation provider evaluates and diversifies redesign handlers, fostering user creativity. The version manager tracks the evolution of all redesign options and model changes.

The PIIS approach was implemented as a software prototype of the ABPR RA (Galster & Avgeriou, 2011). The project's source code and technical documentation are in Fehrer, Fischer, Leemans, et al. (2022). The prototype is developed as a desktop application containing all components except for the optional event log miner. The simulation manager can both be used within the desktop application or outsourced to a cloud service. Figure 3.6 illustrates the UI. The prototype supports the BPI patterns in Reijers and Limam Mansar (2005). The application begins with an empty canvas or an existing business process modeling notation (BPMN) diagram, allowing users to edit the process model. After selecting a performance objective such as time, cost, flexibility, or quality, the application generates redesign recommendations displayed in a list. Each recommendation includes details about the process aspect, heuristic category, description, and potential impact. Users can accept or reject these recommendations and evaluate their impact through simulations and expert judgment. This iterative process continues until the user is satisfied, and the improved process model is then exported.

In line with the design principles of DSR and RA development, several evaluation activities were integrated into the design process (Galster & Avgeriou, 2011; Peffers et al., 2007). The DSR evaluation framework by Sonnenberg and vom Brocke (2012) (EVAL1 to EVAL4) was applied. For EVAL1, a literature scan justified the research problem, gap, and derivation of DOs. For EVAL2

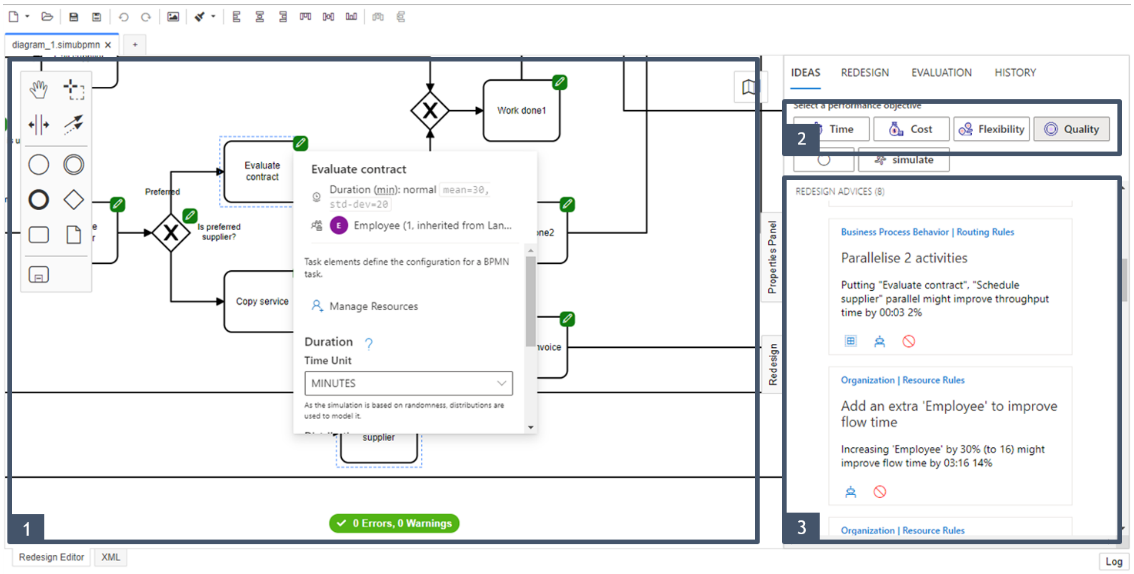


Figure 3.6: Software prototype – general overview with UI elements (1) diagram editor, (2) performance objective selection, and (3) list of recommendations.

and EVAL3, the ABPR concept's design specification was validated through expert interviews, and BPM experts evaluated a prototype. EVAL4 assessed the artifact's usefulness in a naturalistic setting via a case study at KUKA, a global automation company.

P4 demonstrates a PIIS focusing on BPI and introduces a conceptual framework for ABPR. This approach utilizes process data to iteratively guide users in improving business processes to meet specific performance objectives. By extending existing methods, ABPR offers a novel way to apply redesign recommendations with varying levels of automation and interactivity.

3.3 Data-Facilitated Discovery of Business Process Improvement Options

Knowledge about methods is an important asset in BPI projects. Collaboration between BPM method specialists with BPI expertise and business representatives with process context expertise is essential for identifying actionable BPI options (Zellner, 2013). However, the scarcity of these experts limits BPI scalability across organizations. This gap is recognized in current research, which highlights the complexity of BPI and calls for novel tools and methods to address these scalability challenges (Beerepoot et al., 2023; Zuhaira & Ahmad, 2021).

Automating BPI has the potential to enable BPI at scale (Beerepoot et al., 2023). While textual descriptions of BPI patterns, based on field experience, can help identify potential improvement options (Fehrer, 2023), they are often abstract and require specific knowledge of process behavior to prescribe fit to a particular process. Research as presented in Research Paper P4 supports the (semi-)automatic application of BPI patterns to static process models. However, significant untapped potential exists in incorporating process execution data into BPI to enhance these applications as described in chapter 2. PM is a leading technique in process science, offering evidence-based insights from business process execution data. While primarily analytical, PM holds significant potential for BPI (vom Brocke et al., 2024). However, traditional BPI patterns, which are often abstract, pose challenges for automation and scalability. To overcome this, there is a need to convert BPI patterns into specific, data-driven rules that can be automatically applied within processes. Research Paper P5 investigates the development of such rules, ensuring they align with BPI patterns while being programmable and executable within BPI projects, following the research question:

How can BPI patterns be transformed into programmed rulesets that might facilitate the automated development of redesign options in a BPI project?

To address this research question, *FLAC* is proposed as a method for translating BPI patterns into programmable rulesets. For example, the abstract BPI pattern "Empower", defined as "give workers most of the decision-making authority and reduce middle management" (Reijers & Limam Mansar, 2005, p. 301), can be transformed into a specific programmable rule: "select pairs of activities executed in sequence where the latter is performed by a resource from a higher hierarchy level". The proposed method artifact, *FLAC*, identifies *F*itness, *L*ocation, *A*ttribute, and *C*onstraint rules to apply BPI patterns to business processes. The research design is following the design science research methodology (DSRM), and situational method engineering (SME) as a specific method (Bucher et al., 2007; Gregor & Hevner, 2013; Peffers et al., 2007) The approach alters the value proposition of traditional BPI patterns by dividing the extraction of best practices from their application (see figure 3.7). First, the *FLAC* method guides the translation of BPI patterns into intermediate programmable and final programmed rulesets (see table 3.1). Second, these programmed rulesets are repeatedly applied in BPI projects to automatically generate BPI options. This separation allows the manual, expertise-intensive extraction to be done once, enabling automated application across multiple BPI projects, thus optimizing resource allocation.

The user converts a BPI pattern into a programmable ruleset by progressing through four perspectives, as outlined in table 3.1. Once the programmable ruleset is attained, the next step involves coding the rules in any suitable software environment, such as PM tools or process query languages. The finalized programmed ruleset is then stored in the collection, ready for application to appropriate process event logs (see figure 3.7).

A BPI project that builds on the generated rulesets can be performed in five consecutive activities:

1. *Select business process:* First, the project team selects a core or support process with medium to high variability, which is repetitive and captured in event logs. The method is applicable regardless of process scope or industry as long as process execution data is available.
2. *Select BPI pattern from the collection:* The team then selects a BPI pattern from the collection based on descriptions and estimated impact. The pattern may need to be translated into a programmed ruleset tailored to the process.
3. *Customise programmed ruleset:* The programmed ruleset is customized to align with the specific data structures and context of the BPI project, addressing both conceptual and implementation perspectives.

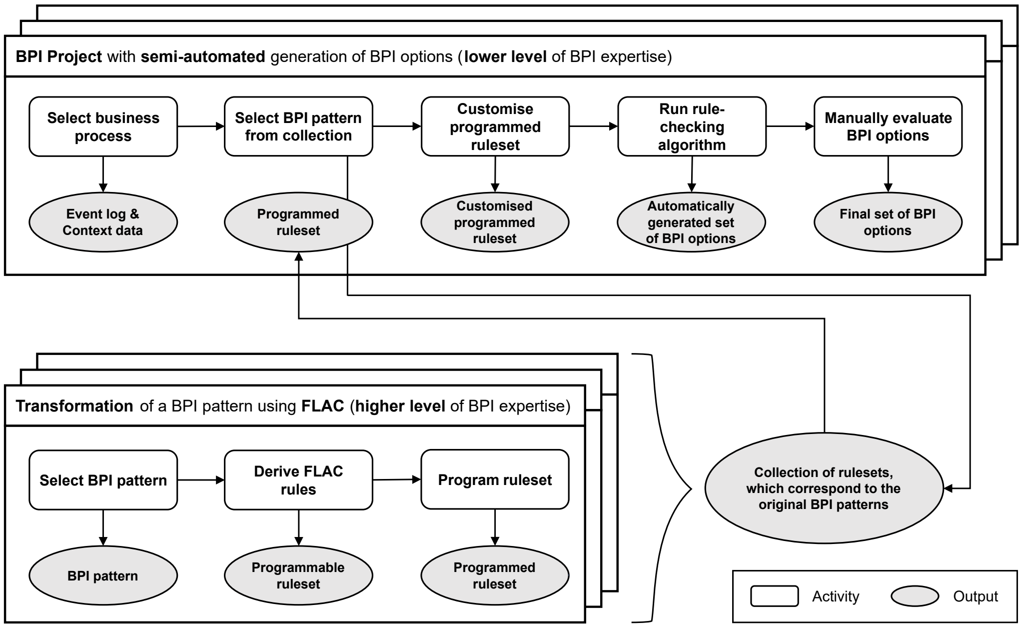


Figure 3.7: Schematic overview of the transformation projects and BPI projects.

Table 3.1: The FLAC method for transformation of BPI patterns into programmed rulesets.

Activities *tasks of the method*	**Techniques** *detailed instructions on how to execute activities*	**Tools** *means supporting the execution of activities*	**Roles** *users executing activities*	**Outputs** *results of activities*
Derive *FLAC* rules	• Find specific rules that are hidden behind the vague description of the BPI pattern • Possible formats: brainstorming, brainwriting, case studies, etc. • Guidance and facilitation: Purpose, Guiding question, Possible answers	• BPI pattern catalogues with natural language descriptions of best practices • BPI case study reports	• Senior BPM expert (method expertise) • Process owner (subject matter expertise) • BPM researcher	**A programmable ruleset** that corresponds to the specific BPI pattern
1. Fitness perspective	**Purpose:** Understand whether applying this BPI pattern is relevant or has already been sufficiently explored. **Guiding question:** Which **process-level indicators** show if the BPI pattern is already sufficiently applied? **Possible answers:** process-level nominal values (e.g., number of gateways), process-level ratios (e.g., level of idle time).			
2. Location perspective	**Purpose:** Understand in which areas of the process it makes sense to apply this BPI pattern. **Guiding question: Where precisely** within the process can the BPI pattern be applied? **Possible answers:** specific activity (e.g., every activity that gets input from two others), sequence of activities (e.g., two consecutive gateways), process variant (e.g., process variants that include more than ten activities), resource.			
3. Attribute perspective	**Purpose:** Understand which attributes define whether applying the BPI pattern at a specific location is reasonable. **Guiding question:** Which **specific attributes** show how sensible the application of the BPI pattern at the specific location is? **Possible answers:** attributes of activities (e.g., duration of an activity), relations between activities (e.g., the same set of resources executes both activities), attributes of instances (e.g., the average number of resources involved in one instance).			
4. Constraint perspective	**Purpose:** Understand which constraints should be considered when applying this BPI pattern. **Guiding question:** Which **constraints and possible limitations** should be considered before/during applying the BPI pattern? **Possible answers:** DOs during redesign (e.g., DO consider required merging time), DON'Ts during redesign (e.g., DO NOT violate data dependencies).			
Program ruleset	Implement and test the ruleset using the modular structure (each rule as a function, method, etc.)	PM tools and libraries (e.g., PM4Py, Celonis PQL query language)	• Software engineer • Process owner	**A programmed ruleset** that corresponds to the specific BPI pattern

4. *Run rule-checking algorithm:* The customized ruleset is automatically applied to event data to automatically generate BPI options. A defined sequence and rule types ensure efficient processing, starting with a fit check before generating, ranking, and filtering options.
5. *Manually evaluate BPI options:* The project team reviews and filters the ranked BPI options, identifying those suitable for implementation. The process is iterative, allowing for repeated application and continuous improvement tracking.

Research Paper P5 focuses on transforming BPI patterns into programmed rulesets to enable automated development of redesign options in BPI projects. The proposed *FLAC* method is a structured, data-driven approach that aids researchers and practitioners in systematically identifying BPI options. By combining DSR as a research paradigm with SMEs as a research method, this approach facilitates the conversion of BPI patterns into rulesets that encapsulate the pattern's knowledge content while being formatted in code. The *FLAC* method effectively addresses key attributes of method artifacts (Braun et al., 2005): (1) goal orientation by transforming BPI patterns into programmable rulesets, (2) a systematic approach with well-defined activities and outputs (Denner et al., 2018), (3) principles orientation aligned with three DOs from BPM literature, and (4) repeatability across various contexts through clear activity descriptions and modular design.

The *FLAC* method was evaluated and refined through five case study workshops and demonstrated with a software prototype featuring several BPI patterns. Experts validated the research's relevance, recognizing *FLAC* as a valuable decision-support tool that can reduce time-to-insight when scaled. By pioneering the translation of BPI patterns into programmable rulesets, the *FLAC* method contributes to the prescriptive knowledge in BPI and advances toward full automation of BPI.

3.4 Data-Driven Business Process Improvement in Adaptive Process Execution

Research Paper P6 examines last mile food delivery, a crucial customer-facing process in the food delivery industry, a billion-dollar market (Statista, 2019). In the dominant "platform-to-consumer delivery" business model, logistics are managed by a service provider, while restaurants act as third-party suppliers. Companies face the dual challenge of balancing cost pressure and enhancing service quality to sustain in a competitive and consolidating market (Deliveryhero, 2018). Achieving operational excellence and focusing on customer relationships are essential for sustaining growth in the service sector (Statista, 2019; Vakulenko et al., 2019). As a result, operating meal delivery businesses is complex. The literature proposes various approaches for approaching the meal delivery routing problem (MDRP), typically involving the delivery of meals from one or multiple depots to customers in diverse locations using a set number of couriers (Ahmadi-Javid et al., 2018; Reyes et al., 2018; Xiang et al., 2008). These solutions generally aim to minimize delivery costs and efforts. The challenge of assigning couriers to routes is well-addressed

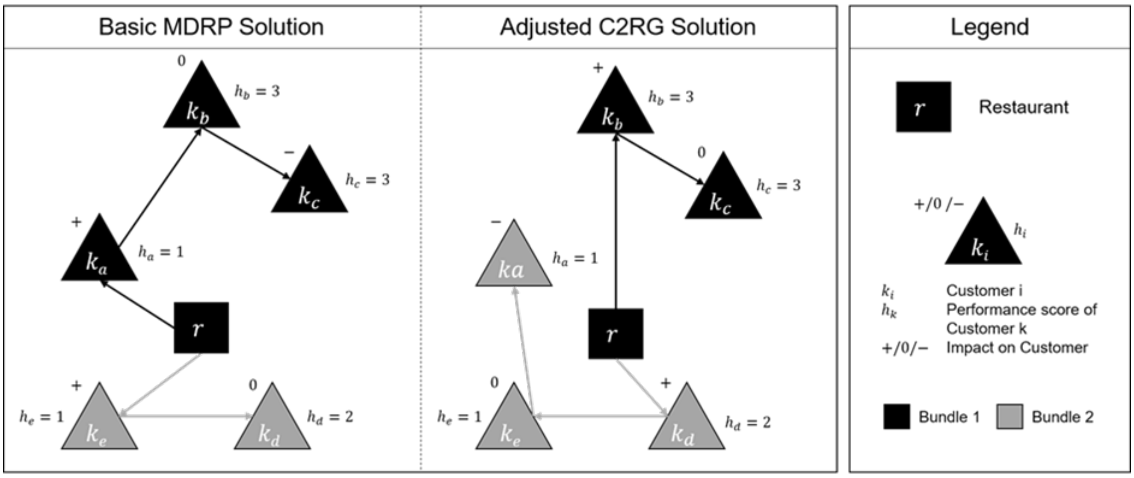


Figure 3.8: Schematic comparison of the basic MDRP solution to our proposed C2RG solution.

from a logistics perspective (Ioannou et al., 2001). However, by focusing on cost minimization, many algorithms take a short-term, efficiency-driven approach, leading to repetitive decision-making that negatively impacts long-term customer satisfaction, particularly for those with unfavorable characteristics, such as long distances or high traffic density. Organizations unaware of maladjusted process designs risk losing customers to competitors. Incorporating a long-term, customer-centric perspective in process decision-making is essential to prevent this. Such an approach helps establish a sustainable competitive advantage (van den Hemel & Rademakers, 2016). In consideration of this, this research question is formulated:

How can the meal delivery routing process be enhanced by incorporating long-term customer-centricity?

To address the research question, the Customer-Centric Route Generation (C2RG) model is developed which integrates a long-term perspective into route bundling. A decision-making algorithm is proposed for short-term route assignments that dynamically considers a long-term, customer-centric view of the delivery process. The model addresses systematic location-based discrimination by considering customers' historical perceptions, detecting disadvantaged customers, and prioritizing specific orders during optimization to improve overall customer experience. In designing the C2RG as a valid design artifact (March & Smith, 1995), the DSR paradigm outlined by Gregor and Hevner (2013) is adapted, following the DSR reference process proposed by Peffers et al. (2007).

The C2RG is designed to support platform-to-consumer organizations by grouping orders into "bundles" and recommending an optimal delivery sequence that balances customer waiting times. At a high level, C2RG introduces a customer-centric approach to route allocation, enhancing satisfaction by reducing delivery times for disadvantaged customers while maintaining route efficiency, particularly during peak periods.

Considering an exemplary scenario, C2RG is demonstrated by comparing a basic bundle generation to the C2RG approach and highlighting differences (see figure 3.8). Five customers k_a, k_b, k_c, k_d, k_e, place an order at restaurant r. The customers are known with their previous orders and

Table 3.2: Impact of the C2RG on overall ready-to-door times.

Segment	Share of Orders	Measure	MDRP	C2RG	ΔMDRP
All customers	100.0 %	mean	0:15:09	0:15:24	+0:00:15
		std.	0:03:24	0:03:19	-0:00:05
Recurring customers more than one order	86.6 %	mean	0:15:00	0:15:03	+0:00:03
		std.	0:03:54	0:03:48	-0:00:06
Customers with direct impact experienced a change in delivery	59.1 %	mean	0:15:54	0:15:58	+0:00:04
		std.	0:04:21	0:04:10	-0:00:11

delivery times. The historic customer experience can be estimated as h_k using delivery time as a proxy. This indicates that k_a and k_e have enjoyed the best customer experience to date. Customers k_b and k_c have the worst experiences $h_b = h_c = 3$. The baseline MDRP optimization algorithm is focused solely on efficiency, disregarding historical customer experiences (h_k). As a result, it generates the most efficient route for the given set of orders without considering past interactions or customer satisfaction. From a customer-centric perspective, the execution of this strategy would repeatedly impair the experiences of k_b and k_c. In contrast, the C2RG algorithm incorporates long-term effects into its decision-making process. It identifies the urgency to prioritize customers k_b and k_c, aiming to generate bundles that improve these customers' experiences. Consequently, the orders for k_b and k_c are given precedence in this solution strategy, ensuring that their deliveries are expedited.

To demonstrate the applicability of the C2RG and its software prototype in realistic scenarios, a case study was conducted using pseudonymized event data from a platform-to-consumer delivery service. The delivery process aligns with the structural assumptions of the MDRP. Table 3.2 illustrates the C2RG's impact across various customer segments. Overall, the C2RG achieves a slight but desirable reduction in standard deviation, particularly within the subset of customers directly affected by the algorithm. While the average delivery duration for all customers increases by 15 seconds, only 59.1% of orders are impacted by the C2RG.

P6 examines the last-mile meal delivery process, emphasizing the need for integrating customer satisfaction into traditionally efficiency-focused scheduling and routing models. Through the DSR paradigm, a customizable planning model, the C2RG, was developed to balance operational efficiency with long-term customer satisfaction. The model instantiation, validated using real-world data, reduces delivery time variation and allows organizations to customize their approach based on specific goals.

This chapter provides four contributions to advancing BPI using data-driven techniques. All research articles proposed novel design science artifacts and were thoroughly evaluated. First, it presents an approach for event log exploration. Second, it presents a PIIS that aims to assist BPI by proposing recommendations and guiding the redesign process. Third, a method artifact is presented that supports the formalization of BPI best practices into rulesets for application to event logs. Last, this chapter presents an approach for incorporating long-term aspects of customer-centricity into route bundling in last-mile delivery services. Together, they address the call for methods and tools in research and practice.

4 Human Centricity in Business Process Improvement

Organizations face increasing pressure to adapt to trends in a hyper-connected, fast-moving world (Beverungen et al., 2021). Factors such as a changing workforce, shortage of skilled labor, and increasing automation significantly impact work organization, making efficient and effective work allocation more crucial than ever. Research shows that assigning the right people to the right tasks enhances process efficiency, income, and customer satisfaction (Arias et al., 2018; Djedovic et al., 2018; Yeon et al., 2022). To make resource allocation strategies available for BPI the first research article concerns patterns for optimized human resource allocation (Section 4.1; Research Paper P7). Successful BPM, boundary spanning, encompasses capabilities to incorporate people and culture consideration into BPI. The second artifact presents a BPI method artifact that aims to focus on the human factor both in the act of BPI and the process under investigation (Section 4.2; Research Paper P8).

4.1 Human Resource Allocation Patterns

Business processes can be analyzed and improved from control-flow, data, and resource perspectives (Dumas et al., 2018). The resource perspective involves all actors, human and non-human, in a business process (Dumas et al., 2018). Human resource allocation is a significant challenge in BPM (Arias et al., 2016, 2018; Pereira et al., 2020), with growing research interest in this area. Early work by Russell et al. (2005) explored workflow resource patterns, while other studies have developed methods using machine learning or Markov models (Talib et al., 2010). However, understanding of human resource allocation in BPI remains limited. This study investigates the optimal assignment of people to process tasks, guided by the research question:

How can human resources be best allocated to tasks when redesigning business processes?

After the use of BPI patterns has already been demonstrated in chapter 3, a human resource allocation patterns (HRAPs) catalogue is proposed to address this research question. A two-phase research approach is used to synthesize the patterns. First, existing literature is analyzed to develop HRAPs. A narrative literature review was conducted to collect BPR patterns related to human resources. From an initial pool of 848 papers, 63 patterns were identified, and 24 were selected based on criteria such as relevance to human resources and potential to improve process performance. These 24 patterns were further refined and grouped, resulting in an initial catalogue of 15 patterns. For instance, similar patterns like "specialist" and "capability-based distribution" were merged into a single expertise-based task assignment pattern. Next, these patterns are evaluated and refined through ten expert interviews with BPM professionals experienced in BPI. The semi-structured interviews aimed to assess the perceived usefulness, pervasiveness,

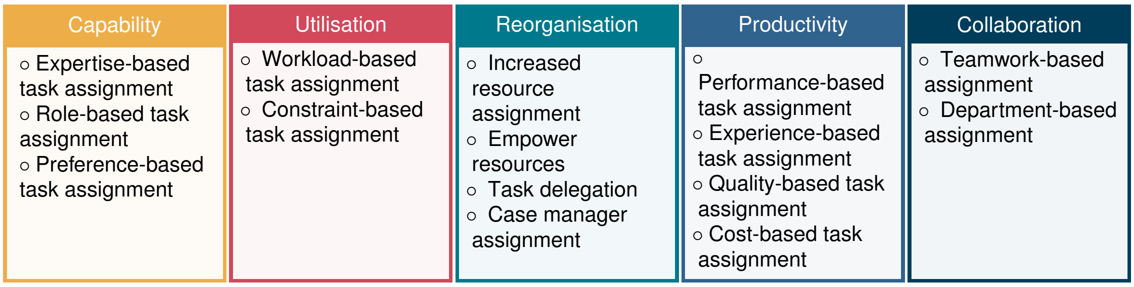


Figure 4.1: Overview of human resource allocation patterns in five categories.

and impact of the HRAPs on process performance. Each pattern was presented, explained, and then evaluated by the experts, who provided ratings and qualitative feedback. The data were analyzed using a hybrid approach, combining quantitative assessments with qualitative insights, leading to the refinement of the patterns based on expert feedback.

Fifteen HRAPs were developed and organized into five categories: *Capability*, focusing on allocating resources based on their ability to complete tasks (i.e., their expertise, role, and preference); *Utilisation*, considering the effective use of resources (i.e., based on workload and execution constraints within a process); *Reorganisation*, involving allocation based on strategic and tactical decisions (i.e., the need for resource expansion, task delegation, empowering people to make decisions, and assigning an accountable person to the process); *Productivity*, using historical data to allocate resources efficiently (i.e., based on past performance, experience, quality, and cost); and *Collaboration*, which allocates resources based on their interactions with others (i.e, within a team and with different functional units within an organisation). The patterns are listed in figure 4.1.

Ten BPI experts were interviewed to share their opinions. Table 4.1 presents the results obtained from expert feedback on the perceived usefulness and pervasiveness of the HRAPs. Similarly, expert comments related to certain patterns were analyzed and three main types have been identified: (a) Comments reinforcing the value of a pattern and its rank among others, which served as a consistency check for the quantified ratings of perceived usefulness and pervasiveness. (b) Comments seeking clarification of a pattern's description, which were utilised to improve the wording and naming of the patterns. (c) Comments sharing practical examples or further experiences related to pattern usage, which were incorporated into the patterns. The results demonstrate that all patterns are perceived to be at least useful: expertise-based task assignment, case manager assignment, and increased resource assignment were considered very useful. In a similar vein, the perceived pervasiveness of the patterns was also agreed by experts, with expertise-based task assignment, workload-based task assignment, role-based task assignment, and cost-based task assignment being used often. For example, "we often use expertise-based assignment. It is very useful" (INT8).

The expert discussions yielded further interesting results. Preference-based task assignment often scored lower when experts considered fit for high-volume processes and higher where the experts assessed affinity to knowledge-intensive processes. Experts emphasize the value of the selected prioritization in case handling for the patterns in the productivity category, especially

Table 4.1: Evaluation results across the HRAPs.

		p. usefulness[1]		p. pervasiveness[2]	
Category	Pattern	Mean	Std.Dev	Mean	Std.Dev
Capability	Expertise-based task assignment	2.6	0.49	2.7	0.46
	Role-based task assignment	2.4	0.66	2.7	0.64
	Preference-based task assignment	2.1	0.83	2.0	0.63
Utilisation	Workload-based task assignment	2.5	0.50	2.7	0.46
	Constraint-based task assignment	2.5	0.50	2.5	0.50
Re-organisation	Increased resource assignment	2.6	0.66	2.3	1.00
	Empower resources	2.5	0.50	2.1	0.70
	Task delegation	2.5	0.67	2.6	0.66
	Case manager assignment	2.8	0.40	2.6	0.49
Productivity	Performance-based task assignment	2.1	0.83	1.7	0.46
	Experience-based task assignment	2.1	0.70	2.3	0.64
	Quality-based task assignment	2.5	0.67	2.1	0.83
	Cost-based task assignment	2.5	0.50	2.7	0.46
Collaboration	Teamwork-based assignment	2.4	0.66	2.3	0.64
	Department-based assignment	2.1	0.70	2.5	0.50

[1] Responses from each interviewee for perceived usefulness were mapped as follows: not useful (0), somewhat useful (1), useful (2), and very useful (3).
[2] Responses from each interviewee for perceived pervasiveness were mapped as follows: not at all (0), rarely (1), sometimes (2), and often (3).

experience-based task assignment and quality-based task assignment. Yet, on performance-based task assignment, three experts noted that it could lead to disorder, resource overload, and imbalanced workloads. Although "cost-based task assignment is highly prevalent" (INT1), four experts commented that while the pattern may result in lower cost, it may compromise the quality of outcome if the people do not have adequate skills to perform the task (e.g., "Cost-based task assignment is used often but we need to ensure that quality and time involved remain good" (INT3)) This indicates that in some situations, patterns might need to be used in pairs to allocate resources optimally: one could use both the empower resources and experience-based task assignment patterns together to identify and empower experienced persons to handle activity without the involvement of a supervisor.

In addition, new people-specific considerations were raised in the interviews, which have less impact on the classic process performance dimensions but may have longer-term implications for the organization. Two experts commented on the need to assign tasks to contribute to building an employee's capabilities. Organizations are facing a paradigm shift in the management of employees from simple recruiting and terminating to managing the well-being and retention of employees (Agarwal et al., 2022). Up-skilling employees is recognized as a major factor for retention as is meaningful work (Chitra & Vanitha, 2022; Rombaut & Guerry, 2020). The ability to switch tasks and feel a sense of purpose is also associated with employee mental health and well-being (Achor et al., 2018). Henceforth, while P7 proposes fifteen literature-based HRAPs that were considered useful, the interviews suggest a new theme in considering human resources in BPM that should be further explored in future research: employee well-being.

4.2 A Method for Employee-Aware Process Improvement

Challenges for BPM are not solely from an external nature; they often stem from within organisations and thus require internal solutions. Human resources will remain crucial for BPM and, at the same time, (organizational) culture shifts towards the demand for active involvement and and emphasises on work-life harmony, physical and mental well-being, ongoing development, and alignment of jobs with individual goals and values (Börsch-Supan, 2003; Nguyen Ngoc et al., 2022). Hence, people and culture (P&C) emerges as an umbrella term in response to the abovementioned challenges and to emphasise the focus on employees in addition to classic human resource management (HRM) (Peiker, 2023). BPM has historically placed more focus on the control-flow perspective (i.e., how a process is/should be executed) as opposed to paying particular attention to the needs of employees who are involved in the execution of these processes (van der Aalst et al., 2016). However, the challenge for BPM to account for "the effects of business processes on people's work lives" (Kerpedzhiev et al., 2021, p. 89) has been acknowledged in BPM research, especially stressed by industry experts (Kerpedzhiev et al., 2021). To respond to the challenges mentioned above, organisations should align their BPM and HRM activities to achieve strategic goals, uplifting their workforce (Ahmad et al., 2023; Shafagatova & van Looy, 2021). Moreover, the HRM paradigm of realising *mutual gains*, i.e., implementing employee-oriented initiatives that benefit both the organisation and employees (i.e., win-win solutions) (Beer et al., 1985), further motivates employee awareness in the BPM domain. To the best of our knowledge, a gap exists in the implementation of the theory of mutual gains in the context of BPM.

As knowledge-centric roles become increasingly prevalent, it has become advantageous to develop methods that actively engage individuals in the field of BPM, particularly in the context of BPI (Davenport, 2015). BPM and BPI initiatives should be designed and implemented *by* and *for* employees to appropriately address relevant themes. However, there is a significant gap in employee-centered approaches to BPI (P7). These projects should consider the specific context of the processes and resources involved, the broader organizational strategy, and employee engagement (P7). To fill this gap, this research aims to develop a method that unifies the distinct and shared characteristics of BPM and P&C, providing value-adding benefits to organizations and their employees. This leads to the following research question:

How can organizations systematically improve business processes in an employee-aware manner?

To address this question, a method is developed to support employee-aware BPI, incorporating employees' needs into process improvements. The method integrates employee awareness within the organization's strategic framework, offering adaptable, context-aware steps for achieving employee-focused BPI. It fosters the involvement of the right employees with the necessary knowledge, emphasizing that BPI projects should be carried out *by* and *for* employees.

The method is named the *Employee-Aware BPI Navigator*. An overview is shown in figure 4.2. It consists of three subsequent phases, each consisting of specific activities. The first phase, *Orientation & Vision Setting*, seeks to zoom out from the process level to understand its broader con-

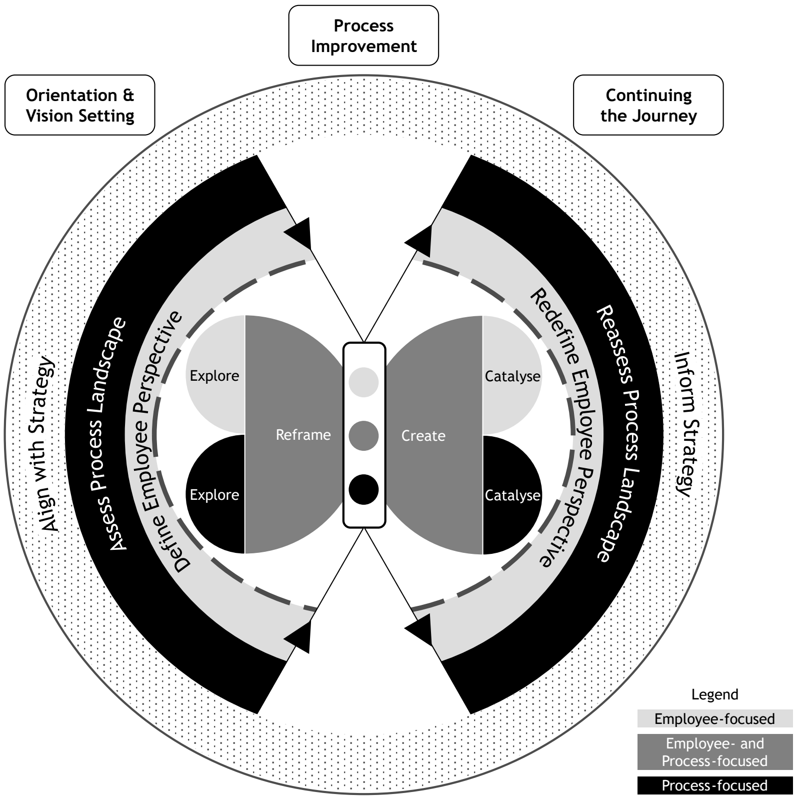


Figure 4.2: Overview of the Employee-Aware BPI Navigator.

text, align with the organizational strategy, the process landscape, and P&C themes, and create a shared understanding and language for collaboration. The orientation and vision are assessed from three perspectives, i.e., organizational strategy, BPM, and P&C. The importance of all perspectives and their interplay should, if possible, be emphasized via senior management signaling and sponsorship.

The second phase, *Process Improvement*, zooms into the selected process. It concerns the search for improvement options utilizing method components from BPM and P&C and fostering collaboration between stakeholders from these diverse backgrounds. This phase is conducted in a joint (multi-)workshop setting within the project team. The team applies their gained understanding and collaborates in the search for employee-aware BPI options. This phase is structured along convergent and divergent elements of the Systemic Design Framework (SDF) Double Diamond (Design Council, 2021).

The third phase, *Continuing the Journey*, zooms out of the process again to connect with the organization, transfer learnings, and continue work on high-level organizational topics. This phase feeds learning back into the organization. This step contributes to a method capable of producing tangible improvements adaptable to the organization's reality. It is crucial to maintain this perspective, particularly in the dynamic systems of BPM and P&C, where people and their needs continually evolve. This ongoing assessment allows team members to track changes and evolution in these two dynamic systems and their alignment with the organization's strategic landscape. Improvements in the *Process Improvement* are communicated to the organization. Moreover, the realigned vision is an updated starting point for future process improvement initiatives.

The project team comprises an interdisciplinary group of individuals from the perspectives of the BPM and the P&C. They bear the responsibility for executing the project. However, the method encourages the involvement of additional perspectives and expertise outside of the project team.

The method, created in a DSR approach, was evaluated using the framework proposed in Sonnenberg and vom Brocke (2012) with evaluation activities before (EVAL-1 and 2) and after (EVAL-3 and 4) artifact design and development. The literature review conducted before artifact construction (EVAL-1) established the relevance of the research problem in the BPM field and underscored the potential of multidisciplinary collaboration. Despite complementary research in these domains, EVAL-2 compared related artifacts and identified the lack of a method that integrates P&C in BPI for employee-focused design. This highlights the need for a unified approach that leverages synergies across these fields. Semi-structured interviews were conducted in an artificial setting (EVAL-3) to evaluate the artifact. The interview panel, selected through purposive sampling, included eight researchers from Germany with an average of three years of experience in BPM, innovation management (IM), and P&C in both research and practice. The feedback highlighted the value of integrating P&C in BPI for employee-centric design, emphasizing process-oriented thinking and the importance of short- and long-term changes. However, the initial method representation and activity sequence were noted as unintuitive, leading to a redesign. Quantitative feedback was generally positive, especially on the method's generality, with BPM experts rating it higher, likely due to their familiarity with BPI methods.

The case study with *byte*, a Bavarian state-owned agency for digital transformation, validated the artifact in a naturalistic setting (EVAL-4). Participants provided positive feedback, highlighting the method's effectiveness in combining perspectives, defining context, and involving employees as process experts. They noted the method's ability to generate specific BPI options and facilitate awareness of latent issues. However, they suggested the inclusion of a summary canvas to better organize interim outcomes. Overall, the method was seen as promising and effective for long-term process improvement.

In summary, this chapter offers two contributions to advancing BPI with a focus on people and culture. The first is a collection of human process resource allocation patterns that provides decision support in BPI. The second is a method for conducting BPI projects with a focus on people and culture topics that actively seeks to involve employees. Therefore, this thesis provides novel work addressing the demand for people and culture orientation in BPM.

5 Conclusion

5.1 Summary

Over the last decades, BPM has undergone several waves of attention, the latest being driven by the manifold challenges of organizations and society and the opportunities offered through novel data-driven technologies. BPM, both organizationally institutionalized and in academia, covers a broad scope of elements at its core: strategic alignment, governance, methods & IT, people, and culture. Applying comprehensive process-oriented thinking can, hence, positively impact many aspects of (business) life, as "all work is process work" (Hammer, 2015, p. 11). Recent developments urge advancing the research in PII. This dissertation and the eight embedded research articles contribute to the identified gaps in research and aim to enable practice to improve and innovate their business processes. First, this thesis provides an understanding of PIISs, a system class that aims to comprehensively support the act of PII and outlines design knowledge for future implementations (Chapter 2). Second, this thesis provides four approaches for data-driven support of BPI (chapter 3). Third, this thesis presents two artifacts that focus the role of human process resources, employees, both in their allocation within the process and in the act of BPI (Chapter 4).

The literature field provided few approaches demonstrating comprehensive computational support in PII but lacks structure and overview of PIISs and specific design knowledge. Chapter 2 presents two research papers that address this need. Research Paper P1 provides structured overview of the literature and conceptual knowledge on the functioning of existing PIISs in the form of an taxonomy. The taxonomy examines their objectives, input, data processing, and output stages. The paper also provides insights regarding four archetypes of PIISs that unite shared characteristics of 44 examined artifacts discovered in the literature. The contribution of P1 is twofold. First, it introduces a novel taxonomy for PIISs, offering a framework for analysis and classification in a research field with limited theoretical foundations (Gregor, 2006). This taxonomy aids in understanding PIISs. Second, the extensive literature review and archetype analysis provide new descriptive knowledge on the current state of PIISs. This work guides research and practice, helping to structure development efforts and inform design decisions for PIISs. Recognizing PIISs as an emerging phenomenon is crucial for practitioners. Practitioners can use the taxonomy to deepen their understanding of PIISs. Research Paper P2 contributes a set of fourteen design principles, offering design knowledge for PIISs and advancing the field from specific instances and descriptive research to a nascent design theory (Gregor & Hevner, 2013; Gregor et al., 2020). This research builds upon two literature reviews and expert interviews through two design cycles and presents principles assorted to the system dimensions of input, throughput and output. The theoretical implications include providing explicit guidance for PIIS design, enhancing conceptual understanding, and laying a foundation for future research on additional theory components since design requirements and design principles belong to the essential elements of an IS design theory (Jones & Gregor, 2007). Building upon P1, this work fosters the development of a comprehensive design theory for PIISs, enabling further exploration of artifact mutability, testable propositions, and expository instantiations (Jones & Gregor, 2007). The practical implications of this work support future vendors in designing PIISs by providing guidelines that narrow the solution space, increasing the likelihood of meeting customer needs and aiding in feature selection (Meth et al., 2015).

At an artifact level, data-driven opportunities enable novel ways to address prevalent challenges in BPI. Chapter 3 introduces four DSR-based artifacts that leverage data-driven methods to address these challenges. Developed as DSR artifacts, these contributions to BPM literature respond to the call for new tools and methods for BPI (Zuhaira & Ahmad, 2021). Research Paper P3 proposes a novel technique for analysing PM trace data by repeatedly dividing data into groups. This research advances process analysis by emphasizing the documented importance of case-level grouping in PM projects and offering a conceptual understanding. It fills a gap in the literature on event log exploration and process group analysis. It creates design knowledge that supports the visual analysis of case data, the gradual formation of groups, and their subsequent comparison. The approach is perceived as useful and easy to use by prospective users. Research Paper P4 proposes an PIIS that semi-automates BPI guided by the research question of how assistive tools can improve BPR. The aBPR concept uses process data to help users iteratively improve business processes toward specific performance goals. It offers recommendations at four levels of automation, progressively incorporating domain and use case knowledge to assist the user. The aBPR RA serves as a template for creating new instantiations, addressing the current lack of effective BPI tools. The paper provides evidence of the novelty of the approach and demonstrates functionalities on artificial process data using the prototypical instantiation. Furthermore, the design specification and the prototype were discussed with experts from academia and industry to demonstrate their applicability. Finally, a case study was conducted in a naturalistic setting to demonstrate the utility of aBPR. Classified within the taxonomy in P4, this approach focuses on incremental improvements to control-flow and resources. aBPR uses process design data, process goals, business rules, and improvement objectives as inputs, assisting users in iteratively refining the business process. It employs a rule-based method, leveraging explicit knowledge from input data and BPI patterns. New process designs are evaluated for feasibility and performance, with human involvement in refining and approving recommendations. The output is a formalized BPMN diagram representing the improved process design. By building on and extending existing approaches, the research adds to the prescriptive knowledge on PII (Gregor & Hevner, 2013). It categorizes and integrates existing BPI pattern application approaches into a structured process, providing a framework to guide their implementation. Research Paper P5 contributes to data-driven BPI by proposing a method for translating BPI best practices into programmed rulesets for automatic application to event log data. The proposed *FLAC* method is a structured, data-driven approach that supports systematically identifying the options of BPI. The method emphasizes goal orientation, systematic approach, principles orientation, and repeatability (Bucher et al., 2007). By translating BPI patterns into rulesets, the *FLAC* method contributes to advancing prescriptive knowledge in BPI, aiming to move towards full automation. Research Paper P6 focuses on customer-centric process design within last-mile food delivery by employing data-driven BPI. The research contributes to prescriptive knowledge by introducing C2RG, a decision model that balances efficiency with customer satisfaction. C2RG extends traditional vehicle routing problems by integrating a customer-centric perspective, using multi-criteria decision analysis. It draws on descriptive knowledge from BPM and customer relationship management (CRM). It appears to be the first model addressing a MDRP that balances efficiency and customer-centricity.

Culture and people are two foundational elements in BPM and must not be neglected in BPI. Chapter 4 introduces two artifacts that aim to shed light on the human process component. Research Paper P7 introduces fifteen human resource allocation patterns, derived from literature synthesis and expert evaluation, which offer guidance on effective human resource allocation. The patterns serve as a reference for academics and practitioners, emphasizing the need for the correct data to inform these decisions at design time. Additionally, mental health and well-being emerged as significant themes, suggesting further exploration in future research. Research Paper P8 contributes to the literature by introducing the *Employee-Aware BPI Navigator*, a novel method for conducting BPI that systematically incorporates employee perspectives, integrating concepts from BPM, HRM, and IM. The research fills a gap by providing structural guidance for interdisciplinary BPI, emphasizing collaboration across departmental boundaries. The core assumptions of this interdisciplinary research are grounded in the theory of mutual gains, the theory of ability, motivation, and opportunity (Pagán-Castaño et al., 2020), and BPM's capacity to implement an inclusive conceptual and methodological framework that promotes cross-departmental collaboration (Beer et al., 1985; Davenport, 2015; vom Brocke et al., 2021). The method has been validated through expert feedback and a public sector case study, proving its effectiveness in enhancing organizational performance and fostering a deeper understanding of organizational dynamics. The study also offers practical resources for wider application.

In conclusion, the presented articles contribute to the existing knowledge base of BPM, particularly by addressing the need for methods and tools that support BPI. However, challenges and limitations must be explored in future research to advance the field.

5.2 Limitations and Outlook

The results of this thesis need to be reflected against some limitations that also stimulate future research. Instead of discussing each paper's limitations and future research opportunities, the following offers an overarching view of the limitations and potential areas for further exploration in this doctoral thesis. Detailed information regarding the limitations of each specific research paper is available in the supplementary material.

Several limitations are inherent to the research designs and methodologies used throughout this thesis. DSR is used as the guiding principle for most papers (except for P7). DSR faces the inherent difficulty in balancing the creation of innovative, practical artifacts with the development of rigorous theoretical contributions (Gregor & Hevner, 2013). Artifacts designed in DSR are often highly context-specific, which limits their generalizability and broader applicability. Extensive evaluations were integrated into the research process to mitigate these challenges, ensuring that the artifacts provide utility to specific user groups while also contributing to theoretical development (Gregor & Hevner, 2013; Hevner et al., 2004). Evaluation frameworks, such as those by Sonnenberg and vom Brocke (2012) and the FEDS framework (Venable et al., 2016), have been employed to structure evaluation efforts.

In exploring PIISs, this research delved into an emerging and dynamic field characterized by rapid technological advancements. Developing a taxonomy, as detailed in Research Paper P1, required a focus that may have left out other important perspectives, such as data ingestion. Further, given the field's fast pace, especially with innovations in AI and process science, the current taxonomy may not fully account for upcoming artifacts and developments (Janssen et al., 2020; Nickerson et al., 2013). While P2 partially addresses these shortcomings through exploratory expert surveys on future PIISs designs, there remains a need for ongoing refinement. Future research should focus on updating the taxonomy as PIISs mature and technological advancements unfold. This will ensure the artifact remains relevant and comprehensive, allowing for continued analysis of PIIS instantiations and deriving actionable, prescriptive knowledge for their effective design and use. Future research should also focus on further instantiations of PIISs to validate their feasibility and broaden their practical applications. These instantiations can help develop specific use cases and generate prescriptive knowledge for their design and utilization.

Given the increasing trend towards real-time process data analysis, aligning design-time and run-time process improvement is crucial for future development. Exploring the conceptual gap between prescriptive process monitoring systems and PIISs offers valuable insights into enhancing these systems. Considering their broader application context, future research should adopt a design-oriented approach to develop principles for constructing PIISs. This includes analyzing how data should be organized, how these systems integrate into organizational structures, and how they interact with the humans who engage with them.

The papers in chapter 3 adopt a design-oriented approach to BPI, contributing methods and tools to the existing landscape. A fundamental limitation of this research is the assumption that high-quality data is readily accessible for applying the proposed BPI methods. The literature suggests that obtaining such data can be resource-intensive, potentially undermining the efficiency of data-driven approaches (Fischer et al., 2022). This concern is somewhat mitigated by the evaluation episodes and case studies that were conducted, which found valid data for assessment. Moreover, the artifact in P4 was purposefully designed to allow for the subsequent addition of data, addressing this issue dynamically. Further, while the individual research artifacts contribute valuable methods and tools to the field of data-driven BPI, a general limitation for design-science research lies in the need to explore further and explicate the practical requirements of practitioners. Although the presented artifacts address research gaps, their widespread application could benefit from a deeper understanding of practitioner needs and tasks. Similar to the practice-driven gaps addressed in P3 for PM tasks and identified in Zerbato et al. (2022), such analyses can enhance the relevance and usability of proposed artifacts in real-world settings.

Focusing on people and cultural factors in BPM broadens contextual awareness for effective BPI. Business processes significantly impact daily life, and their effects on individuals should be carefully considered at every stage of the BPM lifecycle. However, the BPM literature often overlooks this human dimension, resulting in a gap where the integration of people-centric considerations is insufficiently addressed. While P7 and P8 explore aspects such as well-being and participation, they also expose the lack of a common language and framework between BPM and HRM literature. This disconnect makes it challenging to integrate people and culture factors into process management fully. Future research should focus on bridging this gap by developing a shared language and methodologies that connect BPM and HRM. Doing so will facilitate a more complete understanding and management of the human elements in business processes, ensuring that BPI drives efficiency and enhances the well-being and engagement of those involved.

Overall, I am confident that this dissertation will contribute significantly to the current body of knowledge and pave the way for future research in improving business processes by leveraging data and incorporating the human perspective within BPM.

Use of writing assistance Please note that I have utilized various writing assistance software programs (e.g., ChatGPT, DeepL, and Grammarly) to enhance the language and readability of this work. Nevertheless, I take full responsibility for its content and have thoroughly reviewed and edited the material as necessary.

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A Overview of Research Papers

A.1 Research Papers Included in This Dissertation

Research Paper P1: A Taxonomy for Process Improvement and Innovation Systems
Fehrer, T., Moder, L., & Röglinger, M. (n.d.-b). A taxonomy for process improvement and innovation systems [Submitted 1st Round of Revision]. *Outlet hidden due to the double-blind review process of the journal* (VHB-JQ3[1]: B, VHB PMR[2]: B, ABDC[3]: A, SJR[4]: Q1, IF[5]: 7.4)

Research Paper P2: Design Principles for Process Improvement and Innovation Systems
Moder, L., Fehrer, T., & Röglinger, M. (n.d.). Design principles for process improvement and innovation systems [Submitted]. *Outlet hidden due to the double-blind review process of the journal* (VHB-JQ3: C, VHB PMR: C, ABDC: B, SJR: Q1)

Research Paper P3: Interactively Exploring Case Groups and Their Characteristics
Fehrer, T., Moder, L., & Röglinger, M. (n.d.-a). Interactively exploring case groups and their characteristics [Under Revision]. *Information Systems* (VHB-JQ3: B, VHB PMR: B, ABDC: -, SJR: Q1, IF: 3.0)

Research Paper P4: An Assisted Approach to Business Process Redesign
Fehrer, T., Fischer, D. A., Leemans, S. J., Röglinger, M., & Wynn, M. T. (2022). An assisted approach to business process redesign. *Decision Support Systems*, *156*, 113749. https://doi.org/10.1016/j.dss.2022.113749 (VHB-JQ3: B, VHB PMR: B, ABDC: A*, SJR: Q1, IF: 6.4, listed in the AIS Senior Scholars' List of Premier Journals)

Research Paper P5: The FLAC Method: Data-Facilitated Discovery of Business Process Improvement Options
Fehrer, T., Marcus, L., Röglinger, M., Smalei, U., & Zetzsche, F. (2024). The FLAC method: Data-facilitated discovery of business process improvement options. In *ECIS 2024 Proceedings*. https://aisel.aisnet.org/ecis2024/track08_bpm_di/track08_bpm_di/4/ (VHB-JQ3: B, VHB PMR: A)

Research Paper P6: Customers Like It Hot and Fast – Incorporating Customer Effects into the Meal Delivery Process
van Dun, C., Fehrer, T., Kratsch, W., & Wolf, N. (2020). Customers like it hot and fast – incorporating customer effects into the meal delivery process. *ECIS 2020 Proceedings*. https://aisel.aisnet.org/ecis2020_rp/31/ (VHB-JQ3: B, VHB PMR: A)

Research Paper P7: Not Here, But There: Human Resource Allocation Patterns
Goel, K., Fehrer, T., Röglinger, M., & Wynn, M. T. (2023, September). Not here, but there: Human resource allocation patterns. In C. Di Francescomarino, A. Burattin, C. Janiesch, & S. Sadiq (Eds.),

[1] VHB-JQ3: VHB-JOURQUAL3
[2] VHB PMR: VHB Publication Media Rating 2024
[3] ABDC: Australian Business Deans Council Journal Quality List
[4] SJR: Scimago Journal & Country Rank, 2023
[5] IF: Impact Factor, 2023

BPM 2023 Proceedings (pp. 377–394). https://doi.org/10.1007/978-3-031-41620-0_22 (VHB-JQ3: C, VHB PMR: B)

Research Paper P8: With People, for People: A Method for Employee-Aware Business Process Improvement

Fehrer, T., García González, A., Röglinger, M., Wynn, M., & Zetzsche, F. (2024). With people, for people: A method for employee-aware business process improvement. In *ECIS 2024 Proceedings*. https://aisel.aisnet.org/ecis2024/track08_bpm_di/track08_bpm_di/2/ (VHB-JQ3: B, VHB PMR: A)

A.2 Index of Further Papers

Over the course of the dissertation, I also authored and co-authored the following research papers, studies, and reports. These papers are not part of this dissertation.

Röglinger, M., van Dun, C., Fehrer, T., Fischer, D. A., Moder, L., & Kratsch, W. (2021). Automated process (re-)design. *Proceedings of the International Workshop on BPM Problems to Solve Before We Die (PROBLEMS 2021)*, *2938*, 28–33. https://ceur-ws.org/Vol-2938/paper-PROBLEMS-28.pdf

The following paper presents the software prototype developed for P4. It received the "Best Demo and Resources Award" at BPM 2022[6].

Fehrer, T., Fischer, D. A., Leemans, S. J. J., Röglinger, M., & Wynn, M. T. (2022). A tool for assisted business process redesign. In *Proceedings of the Best Dissertation Award, Doctoral Consortium, and Demonstration & Resources Track at BPM 2022* (pp. 97–101). CEUR-WS.org. http://ceur-ws.org/Vol-3216/

Fehrer, T., Jonas, C., Krause, F., & Kreuzer, T. (2023). Der Kunde im Fokus: Eine mit Hilti entwickelte Methode für kundenzentriertes Prozessredesign. *Wirtschaftsinformatik & Management*, *15*, 195–202. https://doi.org/10.1365/s35764-023-00474-2

Beerepoot, I., Di Ciccio, C., Reijers, H. A., Rinderle-Ma, S., Bandara, W., Burattin, A., Calvanese, D., Chen, T., Cohen, I., Depaire, B., Di Federico, G., Dumas, M., van Dun, C., Fehrer, T., Fischer, D. A., Gal, A., Indulska, M., Isahagian, V., Klinkmüller, C., … Zerbato, F. (2023). The biggest business process management problems to solve before we die. *Computers in Industry*, *146*, 103837. https://doi.org/10.1016/j.compind.2022.103837

Fehrer, T. (2023). Process-pattern.app: A collection of business process redesign patterns. In *Proceedings of the Best Dissertation Award, Doctoral Consortium, and Demonstration & Resources Track at BPM 2023* (pp. 117–121). CEUR-WS.org. https://ceur-ws.org/Vol-3469/

Röglinger, M., Fehrer, T., Meyer-Hollatz, T., & Luippold, C. (2024). Prädiktive Prozessüberwachung in der Batterieproduktion. http://nbn-resolving.org/urn:nbn:de:bvb:703-epub-7519-4

Kratsch, W., Stengel, G., Egger, A., & Fehrer, T. (2024). Unstrukturierte Daten aus der Serienproduktion mit Process Mining zur Fehleranalyse und Prozessoptimierung nutzen. *VDI Mechatron-*

[6] https://bpm-conference.org/awards/#bpm-2022-münster-germany

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Chvirova, D., Egger, A., Fehrer, T., Kratsch, W., Röglinger, M., Wittmann, J., & Wördehoff, N. (2024). A multimedia dataset for object-centric business process mining in it asset management. *Data in Brief*, *55*, 110716. https://doi.org/10.1016/j.dib.2024.110716

A.3 Individual Contribution to the Included Research Papers

This cumulative dissertation comprises eight research papers, all co-authored with multiple collaborators. This section details the context and outlines my contributions to the eight papers. The descriptions adhere to the Contributor Roles Taxonomy (CRediT) (Allen et al., 2019).

Research Paper P1 entitled "A Taxonomy for Process Improvement and Innovation Systems" (Fehrer et al., n.d.-b, Appendix A.4) was written by a team of three authors. My contributions were substantial in the areas of conceptualization, methodology, investigation, data curation, and the formal analysis of research data. Alongside a co-author, I took responsibility for writing the original draft. Additionally, I played a key role in reviewing and editing the entire manuscript. As a team, we have agreed that all authors contributed equally to this research paper.

Research Paper P2 entitled "Design Principles for Process Improvement and Innovation Systems" (Moder et al., n.d., Appendix A.5) was written by a team of three. I contributed to the conceptualization, methodology, data investigation, and curation. I reviewed and edited the paper on the basis of an initial manuscript. One co-author served as the lead author, managing the project, while the other co-author and I served as subordinate authors.

Research Paper P3 entitled "Interactively Exploring Case Groups and Their Characteristics" (Fehrer et al., n.d.-a, Appendix A.6), was authored by a team of three. As the leading author, I played a crucial role in all aspects of the project, including administering the research. I conceptualized the research objectives and designed the methodology. I also led the iterative investigation and validation process of the DSR project and developed the associated software prototype. Additionally, I was responsible for creating meaningful visualizations based on the data. I drafted the paper and was actively involved in reviewing and editing it.

Research Paper P4 entitled "An Assisted Approach to Business Process Redesign" (Fehrer, Fischer, Leemans, et al., 2022, Appendix A.7) was written by a team of five authors. I played a crucial role in most aspects of administering the research project. I made significant contributions to conceptualizing the overarching research aims and designing the research methodology. Additionally, I developed the associated software prototype and led the iterative investigation and validation process of the DSR project. I was responsible for the original drafting of most sections and for reviewing and editing the entire paper. Two senior scholars provided valuable supervision throughout the project. As a team, we agreed that all authors contributed equally to this research paper.

Research Paper P5 entitled "The FLAC Method: Data-Facilitated Discovery of Business Process Improvement Options" (Fehrer, Marcus, et al., 2024, Appendix A.8) was written by a team of five authors. I contributed to the conceptualization, design of the methodology, validation of the software prototype, and investigation. I also took part in writing the initial draft and in reviewing and editing the manuscript. Together with one co-author, I managed the project and provided supervision for junior authors. As a team, we agreed that all authors contributed equally to this research paper.

Research Paper P6 entitled "Customers Like It Hot and Fast – Incorporating Customer Effects into the Meal Delivery Process" (van Dun et al., 2020, Appendix A.9) was written by a team of four authors. I implemented the prototype, curated the data, performed the formal analysis of output data, and conducted validation. My contributions also included conceptualization and contributing to the methodology. Additionally, I was responsible for visualization and investigation. I mutually contributed to the original draft and participated in reviewing and editing the manuscript. As a team, we agreed that all authors contributed equally to this research paper.

Research Paper P7 entitled "Not Here, But There: Human Resource Allocation Patterns" (Goel et al., 2023, Appendix A.10) was written by a team of four authors. I contributed to the method design, data curation, and investigation. Additionally, I made minor contributions to the conceptualization. I played a key role in writing the initial draft and in reviewing and editing the manuscript. As a team, we agreed that all authors contributed equally to this research paper.

Research Paper P8 entitled "With People, for People: A Method for Employee-Aware Business Process Improvement" (Fehrer, García González, et al., 2024, Appendix A.11) was written by a team of five authors. I contributed to the conceptualization, method design, data curation, and validation of the evaluation activities. I also wrote parts of the initial draft and participated in reviewing and editing the manuscript. Additionally, I served as a supervisor to junior authors on the team. As a team, we agreed that all authors contributed equally to this research paper.

A.4 Research Paper P1: A Taxonomy for Process Improvement and Innovation Systems

Authors:
T. Fehrer, L. Moder, and M. Röglinger

Submitted to:
Outlet hidden due to the double-blind review process of the journal.

Extended abstract[7]:
Business processes are a critical element of organizational success, ensuring effective management of information, resources, and decisions (vom Brocke et al., 2021). Properly managed, they offer strategic agility and competitiveness in the market (Recker & Mendling, 2016; Reijers, 2021). To maintain agility, process improvement and innovation (PII) is essential, involving tasks such as analyzing current processes, generating alternative designs, and implementing changes (Malinova et al., 2022). These activities are paramount for adapting to changing environments, enhancing process designs, and ensuring sustained competitiveness (Beverungen et al., 2021; Groß et al., 2019; Kerpedzhiev et al., 2021).

Despite its importance, automating PII remains a complex challenge due to the need for creativity and deep knowledge (Groß et al., 2021; Malinova et al., 2022). While process improvement activities, including design generation and evaluation, have traditionally been human-led, advances in artificial intelligence (AI) present new opportunities for computational support in PII (Feuerriegel et al., 2023; Vidgof et al., 2023). To address this gap, Process Improvement and Innovation Systems (PIISs) have been proposed, which offer semi-automated support for improving business processes (Rosemann & vom Brocke, 2014). Unlike traditional Business Process Management Systems (BPMSs), PIISs focus on redesigning process models rather than operational instances.

Despite their potential, PIISs remain underdeveloped in both academia and industry, as highlighted by the limited availability and adoption of tools in practice (Beerepoot et al., 2023; van der Aalst & Carmona, 2022). This contrasts with the growth of process mining tools, which focus on analyzing event data but do not emphasize redesigning processes (van der Aalst, 2020). The limited research on PIISs calls for a systematic understanding of how these systems generate improved process designs. Such a framework would benefit both researchers and practitioners by providing design guidance and identifying gaps in current approaches.

To fill this research gap, this work proposes a classification scheme and taxonomy for PIISs. Using the methodology outlined by Nickerson et al. (2013) and Kundisch et al. (2022), a systematic literature review was conducted to identify key design dimensions and characteristics of existing PIISs. This effort was complemented by expert interviews with leading vendors in the process mining industry. The resulting taxonomy provides a comprehensive framework for understand-

[7] At the time of writing, this research paper is under review for publication in a scientific journal. Therefore, an extended abstract is provided here.

ing how PIISs generate improved process designs. It was evaluated through multiple stages of expert validation, including interviews with academics and a survey with BPM practitioners.

The taxonomy consists of eight dimensions organized into four layers: scope, input, throughput, and output. These dimensions capture key aspects such as the focus of process changes (e.g., control flow, resources, data), the ambition of changes (incremental vs. radical), the data used for design generation (process design data, process execution data, improvement objectives), and the evaluation of generated designs (feasibility, performance). The taxonomy's evaluation showed that it effectively supports the identification, analysis, and classification of PIISs.

Further analysis revealed the emergence of four archetypes of PIISs, each representing different approaches to computational process improvement. These archetypes include: (1) Algorithmic Solution Engines, which rely on rule-based algorithms for incremental improvements; (2) Dynamic Process Integrators, which generate process designs through randomness-based methods; (3) Innovative Process Refiners, which apply radical redesign techniques; and (4) Co-Creators Learning from Event Data, which leverage process execution data to co-create process designs with human involvement. These archetypes provide a foundation for understanding current approaches and guide future research and tool development.

In conclusion, this work addresses the research gap on how PIISs create improved process designs. The taxonomy and archetypes offer insights for both researchers and practitioners, highlighting opportunities for advancing the field of computational process improvement. Future research should focus on further developing PIISs that integrate data from process mining and employ advanced techniques to enhance process redesign capabilities (Beerepoot et al., 2023).

Keywords:
Process Improvement; Process Innovation; Prescriptive Business Process Management; Computational Support; Taxonomy Development

References:

Beerepoot, I., Di Ciccio, C., Reijers, H. A., Rinderle-Ma, S., Bandara, W., Burattin, A., Calvanese, D., Chen, T., Cohen, I., Depaire, B., Di Federico, G., Dumas, M., van Dun, C., Fehrer, T., Fischer, D. A., Gal, A., Indulska, M., Isahagian, V., Klinkmüller, C., … Zerbato, F. (2023). The biggest business process management problems to solve before we die. *Computers in Industry*, *146*, 103837. https://doi.org/10.1016/j.compind.2022.103837

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A.5 Research Paper P2: Design Principles for Process Improvement and Innovation Systems

Authors:
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Submitted to:
Outlet hidden due to the double-blind review process of the journal.

Extended abstract[8]**:**
In a rapidly changing world marked by technological advancements, intense competition, and multiple crises (Röglinger et al., 2022), organizations must adapt quickly to survive. The orchestration and execution of business processes are essential for organizational success (Malinova et al., 2022). Process improvement and innovation (PII) has become a vital capability in business process management (BPM), directly impacting customer satisfaction and overall organizational performance (Kerpedzhiev et al., 2021). Despite the growth of process mining technologies, computational support for PII remains limited (Beerepoot et al., 2023), often relying heavily on human cognitive effort and creativity (Mustansir et al., 2022; van Dun et al., 2023). This gap presents opportunities for process improvement and innovation systems (PIIS), defined as software tools that support the (re)design of business processes by automating the generation of process improvements (Rosemann & vom Brocke, 2014). Recent advances in artificial intelligence suggest that cognitive tasks like PII could benefit significantly from increased automation, reducing manual effort and improving decision-making (Benbya et al., 2024; Feuerriegel et al., 2023; Maedche et al., 2019).

The complexity of PII, which stems from its multidimensional, context-sensitive, and socio-technical nature, makes it one of the most challenging problems in BPM (Röglinger et al., 2021). Despite initial research efforts, PIIS remains an underdeveloped area with few practical applications and no comprehensive design knowledge (Beerepoot et al., 2023). This lack of guidance hampers both researchers and practitioners, as they often struggle to identify relevant design choices, which leads to inefficiencies and higher risks during system development and adoption. To address this, the design of PIIS must be systematically captured and guided by well-founded design principles.

The presented research follows a design science research (DSR) paradigm, aiming to establish design principles for PIIS (Gregor, 2006; Kruse et al., 2022). This is accomplished through two systematic literature reviews combined with insights from 20 exploratory expert interviews. Additionally, the design principles are evaluated through two confirmatory surveys, involving 15 and 106 participants, respectively. In total, 14 design principles are derived, offering comprehensive guidance for the development of PIIS in both research and practice.

To ground the research, a literature review of PII and related system classes, such as process-aware information systems (PAIS), decision support systems (DSS), and creative support systems

[8]At the time of writing, this research paper is under review for publication in a scientific journal. Therefore, an extended abstract is provided here.

(CSS), was conducted. PIIS are conceptualized as a subclass of PAIS and BPM systems, designed specifically to assist human process designers by offering computational support during the generation and evaluation of process redesign proposals. In addition, PIIS leverages knowledge from related systems to enhance the design of PII processes, ensuring that the system can handle the complexity and context-dependence of modern business processes.

The study also integrates perspectives from practice through expert interviews, drawing on the experiences of professionals in BPM, PII, and process mining. These interviews revealed significant gaps in current process improvement systems, particularly the need for systems that not only provide process visibility but also offer actionable suggestions for process redesign. The experts emphasized the importance of reducing cognitive load, enabling human control, and ensuring process design proposals are grounded in context-specific knowledge.

The resulting design principles for PIIS focus on several key areas: exploiting existing PII knowledge, leveraging multiple sources of diverse data, automatically generating process design proposals, targeting multiple process perspectives, and accounting for process context factors. Additional principles emphasize the importance of a process portfolio view, conducting multi-objective process assessments, enabling interactive and iterative PII, and learning from feedback to refine system suggestions. Moreover, the system must provide adaptable, atomic process design proposals, offer multi-level decision-making information, and ensure explanations are given for process design choices to foster user trust and understanding. Finally, the system should visually represent process designs and integrate seamlessly with existing systems.

The evaluation of the design principles through expert surveys confirmed their relevance, accessibility, and potential for practical application. The results indicate that while PIIS is technically feasible, its complexity presents challenges, particularly in ensuring that the system is comprehensible and actionable for users. However, the proposed design principles provide a solid foundation for future research and development of PIIS.

In conclusion, this research advances the conceptual understanding of PIIS by providing concrete design principles that support the creation of systems capable of automating PII activities. This contribution moves beyond descriptive research to provide actionable guidance for both the design and implementation of PIIS. Future research should focus on the practical instantiation of these principles, addressing challenges related to system development, adoption, and ethical considerations in automating creative and strategic tasks like process innovation.

Keywords:
Process Improvement; Process Innovation; Process Redesign; Business Process Management; Process Mining; Generative Artificial Intelligence

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A.6 Research Paper P3: Interactively Exploring Case Groups and Their Characteristics

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Under revision for:
Information Systems

Extended abstract[9]**:**
Process mining (PM) consists of data-driven techniques that aim to provide analytical support for business process management (BPM) through the analysis of process execution data, commonly from event logs (Dumas et al., 2018; van der Aalst & Carmona, 2022). A central objective in PM is to gain insights into the nature of business processes to identify potential improvements (van der Aalst & Carmona, 2022; van Eck et al., 2015). The exploration phase, a crucial part of many PM projects, requires process analysts to familiarize themselves with event logs (van Eck et al., 2015; Zerbato et al., 2022). Despite careful data preparation, event logs retain complexity due to the variability inherent in real-world processes (Dumas et al., 2018; van der Aalst, 2011). This complexity complicates analysis, requiring advanced comprehension of event logs' intricacies (van der Aalst, 2016; Zimmermann et al., 2023).

Analysts often use a divide-and-conquer approach, splitting event logs into smaller, more manageable groups (Kubrak et al., 2022; van der Aalst, 2016; Zerbato et al., 2021, 2022). These groups allow for focused analysis, where patterns and issues identified in one group may be generalizable across similar instances. Techniques such as clustering, filtering, and slicing/dicing are used to separate event logs into process instances with shared properties, facilitating interpretation and analysis (van der Aalst, 2016; Weinzierl et al., 2024; Zandkarimi et al., 2020). In addition to control-flow analysis, contextual data can significantly impact process behavior and should also be considered during analysis (Ghahfarokhi et al., 2021; IEEE, 2023; Klinkmüller et al., 2019). Contextual attributes further aid in separating event logs into distinct, interpretable groups.

A review of existing practices reveals that analysts dedicate significant time and effort to an open-ended, exploratory investigation of process data (de Weerdt et al., 2013; Di Ciccio et al., 2015; Kubrak et al., 2023). This knowledge-intensive task is often unstructured and must be repeated for each new dataset, requiring analysts to continually explore new event logs and reapply their expertise to understand and document process structures. Tools designed to support this task must enable analysts to manage complexity efficiently (Di Ciccio et al., 2024; Zuhaira & Ahmad, 2021).

In response to the challenges posed by the growing complexity of business processes, visual analytics (VA) has emerged as an important research area. VA integrates interactive visualizations with automated analysis, enhancing human cognitive capabilities in data analysis (Cui, 2019; van

[9]At the time of writing, this research paper is under revision for publication in a scientific journal. Therefore, an extended abstract is provided here.

der Aalst et al., 2012). VA leverages both computational and human strengths to facilitate process analysis, providing a framework for interactive exploration (Cui, 2019; Di Ciccio et al., 2024; Gschwandtner, 2017; Kerremans et al., 2024; Zerbato et al., 2021). Despite the potential benefits of VA, existing approaches in the field of PM do not sufficiently support group-based exploration of event logs. While automated clustering techniques exist (Bolt et al., 2018; Seeliger et al., 2019), there is a lack of support for interactive exploration of process groups.

This paper aims to address this gap by conceptualizing and implementing an artifact that supports the interactive generation and analysis of process case groups, following a design science research (DSR) approach (Gregor & Hevner, 2013). The proposed solution enhances existing event log grouping techniques with VA methods, using interaction and visualization to guide group exploration. The artifact is evaluated according to the FEDS framework (Venable et al., 2016), comparing it with competing artifacts and demonstrating its applicability through prototype implementation and testing on publicly available event logs. Finally, the approach is evaluated for its usefulness and ease of use through a user study.

The proposed artifact addresses research challenges by allowing analysts to interactively form and explore process groups. By incorporating human judgment and domain knowledge into the group generation process, the artifact helps analysts navigate the complexities of event logs. The approach combines automated grouping techniques with interactive visualizations, providing flexibility in how groups are generated and analyzed. Groups are explored using tree structures, which can be manipulated and refined according to the analyst's needs. The ability to compare groups and analyze their differences is also a key feature, supporting iterative refinement and deeper understanding of process behaviors.

Evaluation of the artifact includes a prototype implementation, which is applied to publicly available event logs. This demonstrates the feasibility and scalability of the approach, as the prototype successfully supports group-based event log exploration across multiple datasets. The evaluation also involves a user study with PM experts, assessing the artifact for perceived usefulness and ease of use. The results indicate that the artifact effectively supports the interactive exploration of process groups, providing both flexibility and efficiency in managing complex event logs.

The proposed solution contributes to the literature by filling a gap in existing PM tools, offering a comprehensive approach to group-based event log exploration that integrates visual analytics and interaction. Future research could extend this work by incorporating additional group analysis techniques, improving user guidance, and exploring applications in different PM contexts.

Keywords:
Process Mining; Visual Analytics; Variant Analysis; Event Log Exploration

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A.7 Research Paper P4: An Assisted Approach to Business Process Redesign

Authors:
T. Fehrer, D. A. Fischer, S. J. Leemans, M. Röglinger, and M. T. Wynn

Published as:
Fehrer, T., Fischer, D. A., Leemans, S. J., Röglinger, M., & Wynn, M. T. (2022). An assisted approach to business process redesign. *Decision Support Systems*, *156*, 113749. https://doi.org/10.1016/j.dss.2022.113749

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 ra 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

A.8 Research Paper P5: The FLAC Method: Data-Facilitated Discovery of Business Process Improvement Options

Authors:
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Fehrer, T., Marcus, L., Röglinger, M., Smalei, U., & Zetzsche, F. (2024). The FLAC method: Data-facilitated discovery of business process improvement options. In *ECIS 2024 Proceedings*. https://aisel.aisnet.org/ecis2024/track08_bpm_di/track08_bpm_di/4/

Abstract:
Business process improvement (BPI) is crucial to every business, as inefficiencies jeopardise an organisation's success. Predominant methods for BPI build on static process models, which are often incomplete, outdated, and lack execution-related insights. Process mining bears the potential to add execution-related insights into the process. However, organisations often lack the methodological expertise to apply process mining systematically to find process improvement options. Automating parts of BPI thus holds the potential to assist users without BPI expertise and enables data-driven BPI at scale. We introduce the FLAC method, which guides users in transforming conceptual BPI patterns into specific rulesets. Once transformed, they can be repeatedly applied to event logs to generate options for process improvement. An instantiation of the FLAC method on several BPI patterns and evaluation of its subsequent application to an event log confirmed its applicability and high relevance to practice by significantly reducing the time-to-insight.

Keywords:
Business Process Improvement; Business Process Redesign; Redesign Pattern; Situational Method Engineering

A.9 Research Paper P6: Customers Like It Hot and Fast – Incorporating Customer Effects into the Meal Delivery Process

Authors:
C. van Dun, T. Fehrer, W. Kratsch, and N. Wolf

Published as:
van Dun, C., Fehrer, T., Kratsch, W., & Wolf, N. (2020). Customers like it hot and fast – incorporating customer effects into the meal delivery process. *ECIS 2020 Proceedings*. https://aisel.aisnet.org/ecis2020_rp/31/

Abstract:
Delivering meal orders as fast as possible and the meal itself as hot as possible are the most important factorsin the meal delivery process as they drive customer satisfaction. High customer satisfaction leads to loyal customers, implying a higher rate of recurring orders, in return. Existing approaches tackle the meal delivery process by taking a short-term perspective on a single optimization criterion (e.g. minimizing delivery costs). Still missing is an alternative perspective that also incorporates the long-term value contribution of individual customers. By neglecting this customer-centric perspective, frequent out-of-town located ordering customers might be disadvantaged as they are repeatedly served at the end of the route. To close this research gap, we propose a decision model (C2RG) that incorporates a long-term customer-centric view. Depending on different short- and long-term preferences, the model can be appropriately customized. We observe a significant increase in a long-term factor, such as customer fairness by only slightly reducing short-term route performance. We instantiated a software prototype of the C2RG and evaluated it with real-world data of a local platform-to-consumer delivery service located in Germany. The results show the importance of considering a customer-centric long-term perspective in the meal delivery process.

Keywords:
Vehicle Routing Problem; Meal Delivery Routing Process; Customer-Centricity; Decision Model; Routing Optimization

A.10 Research Paper P7: Not Here, But There: Human Resource Allocation Patterns

Authors:
K. Goel, T. Fehrer, M. Röglinger, and M. T. Wynn

Published as:
Goel, K., Fehrer, T., Röglinger, M., & Wynn, M. T. (2023, September). Not here, but there: Human resource allocation patterns. In C. Di Francescomarino, A. Burattin, C. Janiesch, & S. Sadiq (Eds.), *BPM 2023 Proceedings* (pp. 377–394). https://doi.org/10.1007/978-3-031-41620-0_22

Abstract:
The digital age entails challenges that pressure organisations to redesign their business processes for improved performance. A significant aspect of this effort is the appropriate assignment of human resources – or people – to tasks. Despite the importance, there is a lack of structured guidance on allocating people to tasks considering various performance considerations such as time, cost, quality and flexibility. This paper presents 15 human resource allocation patterns organised into five categories: resource capability, utilisation, reorganisation, productivity and collaboration. The pattern collection is designed to offer guidance on diverse strategies for human resource allocation, focusing on process redesign for performance improvement from a resource perspective. The research was conducted in a two-phase approach. In the first phase, a literature review was conducted to identify existing resource patterns and practices, synthesised into an initial catalogue of human resource allocation patterns. In the second phase, this catalogue was evaluated through expert interviews with ten practitioners. The patterns provide a repository of knowledge guiding academics and practitioners on different ways a person can be assigned to a task for improved process efficiency. These patterns form a strong foundation for future research in the area of human-centred business process redesign.

Keywords:
Process Improvement; Allocation Patterns; Human Resource; BPM

A.11 Research Paper P8: With People, for People: A Method for Employee-Aware Business Process Improvement

Authors:
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Published as:
Fehrer, T., García González, A., Röglinger, M., Wynn, M., & Zetzsche, F. (2024). With people, for people: A method for employee-aware business process improvement. In *ECIS 2024 Proceedings*. https://aisel.aisnet.org/ecis2024/track08_bpm_di/track08_bpm_di/2/

Abstract:
In the evolving business landscape, where organisations are coping not only with external pressures and complexities but simultaneously with substantial transformations within their workforces, this paper underscores the necessity to adopt an employee-aware focus within business process management (BPM). By employing situational method engineering, this design science research proposes a method for employee-aware business process improvement (BPI). Design objectives derived from BPM, human resource management, and innovation management guide the development of the method. Expert interviews were conducted to evaluate the method. Method instantiation with an agency for digital transformation in the German public sector was conducted to assess the applicability and usefulness of the method. This research incorporates two main facets. Firstly, it interweaves employee awareness into the organisation's strategic framework, simultaneously providing practical guidance for concrete BPI initiatives. Additionally, it involves the right decision-makers and expertise to facilitate meaningful transformations for employees executing concrete processes.

Keywords:
Human Centricity; Human Resource Management; Business Process Management; Employee Awareness; Situational Method Engineering