



# The operational perspective in business process management: towards holistic task execution support

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## Abstract

This paper redefines the operational perspective in Business Process Management (BPM). While BPM inherently operates at the operational level, its traditional focus on automation, standardization, and software execution has historically overlooked a holistic understanding of task execution, particularly manual tasks and the tools and materials required for them. Our mixed-methods study, which combines a structured literature review and abductive reasoning, confirms this oversight, a gap also visible in modeling support. To address this, we introduce a novel classification scheme for process entities and propose a comprehensive vision for future operational support. Leveraging developments such as the Internet of Things (IoT), this vision encompasses enhanced modeling artifacts, intelligent planning, and real-time execution assistance. This paper bridges a critical abstraction gap between automated and manual tasks by redefining the operational perspective, introducing a novel classification of process entities, and proposing a framework for holistic support.

**Keywords** Business process management · Business process execution · Operational perspective · Internet of things · Tool support

## 1 Introduction

The convergence of Business Process Management (BPM) and the Internet of Things (IoT) has unlocked new frontiers for monitoring and optimizing business operations (Janiesch et al. 2020; Cherrier and Deshpande 2018). Recent work on IoT-BPM integration highlights ongoing challenges in extracting meaningful process events from

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low-level sensor data (Mangler et al. 2024; Schöning et al. 2020), confirming the need to bridge physical and digital domains. While organizations leverage a diverse ecosystem of technologies to achieve a holistic view of the process (Thong 1999; Buonanno et al. 2005), a significant portion of organizational work (particularly manual tasks (cf. OMG 2011)) remains unsupported by IT, creating an analytical blind spot. This is especially critical in sectors such as construction and manufacturing (Bazan and Estevez 2021), logistics (Grefen et al. 2019), and healthcare (Braun et al. 2016), where manual labor remains a key component of value creation despite increasing digitalization. This lack of digital visibility into manual work creates significant operational challenges. Specifically, process opacity prevents management from identifying physical bottlenecks; difficulties in quality assurance arise because the exact execution parameters of physical tasks cannot be systematically recorded and verified; and opportunities for data-driven optimization are missed because the absence of event logs for these manual activities prevents the application of advanced analytical techniques, such as process mining. The increasing ubiquity of mobile devices and sensors now offers a tangible opportunity to bridge this divide, motivating a re-evaluation of how we manage and support the full spectrum of business activities.

Traditionally, BPM has focused on modeling, automating, and optimizing IT-supported workflows (Dumas et al. 2018). This focus has cultivated a deep understanding of process perspectives, such as control flow (the *what* and *when*) and organizational structure (the *who*). However, it has historically neglected the **operational perspective** (the *how*). We define this perspective as the function of providing and supporting all resources required for a task's execution within a process model. This encompasses both the active resources that perform the work (e.g., human actors, automated services) and the passive resources they use (e.g., applications, tools, machinery). This oversight has created a critical gap: while the administrative tasks surrounding manual work (e.g., creating an order or sending an invoice) are often managed by BPM systems, the execution of the manual task itself remains unsupported and unmonitored (Muthusamy et al. 2021; Dumas et al. 2018, p. 372). The increasing automation of routine tasks raises concerns about organizational memory loss related to manual execution (Plattfaut et al. 2024), highlighting the need to maintain visibility into and support for non-automated work. Recent systematic analyses of BPM confirm that while Industry 4.0 technologies offer opportunities for process automation and innovation, significant challenges remain in scalability, interoperability, and human-centricity (Khider et al. 2025). This leaves a vast area of process reality outside the scope of traditional process management, hindering comprehensive optimization and support.

The core problem lies in the underdeveloped nature of the operational perspective within BPM theory and practice. To unlock holistic process improvement, we must integrate these non-automatable tasks as first-class citizens within our management frameworks. While recent advancements in IoT offer a promising path forward, their integration with BPM is not trivial. It presents its own set of challenges, including managing data heterogeneity and bridging the gap between low-level sensor events and high-level business process models (Janiesch et al. 2020; Schöning et al. 2020). Overcoming these hurdles is essential to enable the capture of real-time data from manual activities using sensors and wearable technology, and to address the need

to manage manually executed physical processes by leveraging mobile devices and sensors during physical tasks to "perform work in a natural way" (Janiesch et al. 2020, p. 38). This technological shift prompts a fundamental re-examination of the operational perspective. Therefore, this paper is guided by the following research questions:

**RQ1.** *What is the current state of the operational perspective in business process management?*

**RQ2.** *What IoT-enabled synergistic mechanisms can be developed to facilitate the integrated support of diverse process entities for enhanced organizational value creation?*

While various technological approaches can support manual task execution, we focus specifically on IoT because of its unique capabilities to bridge the physical and digital domains through ubiquitous sensing, real-time data capture, and context-aware actuation (see Sect. 2.3). Unlike traditional IT systems that require manual data entry, IoT enables passive, continuous monitoring of manual work, making it particularly well-suited to addressing the operational perspective gap identified above.

Building on this technological potential to address our RQs, our research employs a two-stage approach. First, we conduct a structured literature review to trace the historical development and establish the current state of the operational perspective in BPM. Second, using abductive reasoning informed by the identified gaps and opportunities, along with real-world observations, we develop a conceptual framework that refines the definition of the operational perspective and proposes novel mechanisms for integrating manual tasks with IoT technologies.

Our analysis reveals that the operational perspective has been largely confined to simple resource allocation, lacking the rich support structures found in other process perspectives. Our key findings include a novel classification scheme for process entities that goes beyond the traditional view of resources, as well as concrete pathways for leveraging IoT. These pathways enable enhanced modeling artifacts, intelligent task planning, and real-time execution assistance for manual work. This paper makes several important contributions. *Theoretically*, we provide a clear and coherent conceptualization of the operational perspective, bridging a significant gap in BPM literature. *Practically*, we offer actionable insights for managers and system designers on how to use IoT to support and optimize previously "invisible" manual processes. By elevating the operational perspective to a first-class citizen in BPM, our work paves the way for more comprehensive and effective process management.

The remainder of the paper is structured as follows: Sect. 2 provides the necessary background on BPM, the IoT, and their combined application in IoT-aware BPM. Following a detailed description of our methodology in Sect. 3, Sect. 4 offers an overview of the operational perspective in BPM, covering its historical development and current state, including its general understanding, the role of process entities, its application in the de facto standard process notation language, Business Process Model and Notation (BPMN) and future possibilities for supporting task execution, detailing enhanced modeling artifacts, intelligent planning, and real-time execution assistance. Section 5 then provides an interpretation of our findings and contribu-

tions, discusses challenges and limitations, and presents explicit research propositions. Finally, Sect. 6 concludes the paper and identifies opportunities for future work.

## 2 Background

To address the research gap identified in the introduction, it is essential to establish a shared understanding of the core concepts that underpin our analysis. This section provides the necessary theoretical and technological foundations. We begin by outlining the key principles of BPM, including its lifecycle and the various perspectives for analyzing processes. Subsequently, we introduce the IoT as a critical technological enabler for capturing data from the physical world. Finally, we discuss the convergence of these two fields in IoT-aware BPM, setting the stage for our detailed analysis of the operational perspective in the subsequent sections.

### 2.1 Business Process Management (BPM)

BPM represents a boundary-spanning discipline that harmonizes operational capabilities and technology to design, manage, and improve processes (Dumas et al. 2018; van der Aalst et al. 2016). The primary aim of businesses is to generate value through the effective execution of processes, a goal that can be facilitated by using Information Technology (IT). Business processes encompass a series of actions to achieve a specific business outcome (Weske 2007; Dumas et al. 2018). One or more business process models can represent these processes, comprising the activities and instructions, including their sequence and the decision points that govern their execution. These models serve as blueprints for real-world scenarios and cases, providing a structured representation (Weske 2007). BPM, as a research endeavor, encompasses different domains, which we will cover in the following sections. These include the BPM lifecycle that embraces the iterative nature of process improvement, BPM perspectives that are essential as they provide different views on processes (e.g., behavioral (*when?*) vs. organizational (*who?*)), the required background on participating entities in the form of resources, and the form of specific task types that separate automated from manual tasks.

To achieve its goals, BPM is conceptualized as an iterative cycle of continuous improvement, often referred to as the BPM lifecycle. While many different ways of approaching a lifecycle exist (de Morais et al. 2014), we will focus on the BPM lifecycle by Weske (2007) that can be divided into two broader phases: the first phase, where the current state is identified and modeled, and the second phase, with the use of said processes and the execution of included tasks and the goal of improving them. Any conceptual or practical approach must consider both phases, as only their combination enables the cycle to lead to the goal of business process improvement.

To analyze and manage processes comprehensively, BPM research employs several distinct *perspectives* that provide different views of a process. The main focus of research has been on the following perspectives (see Table 1): *function* (which process elements are being performed and what flows of information are relevant), *behavior* (when process elements are performed and how), *organization* (where and

**Table 1** Overview of perspectives on business processes in BPM (Curtis et al. 1992; Jablonski and Goetz 2007; Tinnilä 1995; Dumas et al. 2018)

| BPM dimension             | Goal                   | What?                                               |
|---------------------------|------------------------|-----------------------------------------------------|
| Functional                | What?                  | Processes, Process steps, Activities                |
| Behavioral (Control-flow) | When?                  | Sequence of activities, Workflow, legal regulations |
| Organizational            | Who?                   | User, Responsible party, System                     |
| Information/Data          | With what?             | Data, Documents, Parameters                         |
| <i>Operational</i>        | <i>How?</i>            | <i>Applications, Tools, Materials</i>               |
| Security                  | With which rights?     | Access control patterns for processes and tasks     |
| Data Quality              | With what quality?     | Quality of data used in processes                   |
| Time                      | With what constraints? | Temporal constraints and dependencies               |
| Location                  | Where?                 | The physical place where activities are performed   |

by whom process elements are performed), and *information* (informational entities produced or manipulated by a process) (Curtis et al. 1992). In addition to these perspectives, several others have emerged, including more focused approaches and combinations of existing ones. Among them are the *security perspective*, which describes the use of classical access control patterns for processes and tasks (Jablonski and Bussler 1996), the *data quality perspective*, which focuses on the quality of data used in processes (Rodríguez et al. 2012), or the *time perspective*, which extends BPM to focus on temporal constraints and dependencies far beyond the order (Gagne and Trudel 2009), the *location perspective*, which focuses on the place where activities are performed (Schönig et al. 2014; Poss et al. 2023), which can be necessary for the operational perspective, where the location specificity of tasks is one of the challenges. Finally Russell et al. (2015), which describes a *resource perspective* within its resource patterns, including both human and non-human resources, thus including parts of both the organizational and the operational perspectives)<sup>1</sup>. While the base perspectives should be viewed as perpendicular, focusing solely on one of them as a basis for business process management is insufficient; combining them yields a holistic approach to managing business processes.

From an organizational standpoint, all participants in a process commonly can be encompassed by the term *resource* ("anyone or anything involved in the execution of a process activity" (Dumas et al. 2018, p. 96)). These resources can be further categorized into *active* and *passive resources* (Ouyang et al. 2010). *Active resources* are resources capable of independently performing an activity, such as participating human actors but also possibly machines working on their own, actively changing and influencing the real world; on the other hand, *passive resources* are all resources involved in and needed for the process, such as data, documents, tools, and used applications (these resources are also a fundamental part of business processes, but cannot act autonomously). Consequently, we can assert that the existing organizational perspective primarily focuses on active resources. In contrast, the operational perspective uses passive resources to support the execution of tasks through active

<sup>1</sup> Depending on the strictness and use, one could conceptually argue that all of these perspectives are part of other perspectives, e.g., the time perspective is part of the control flow perspective, if we extend the standard understanding of control flow.

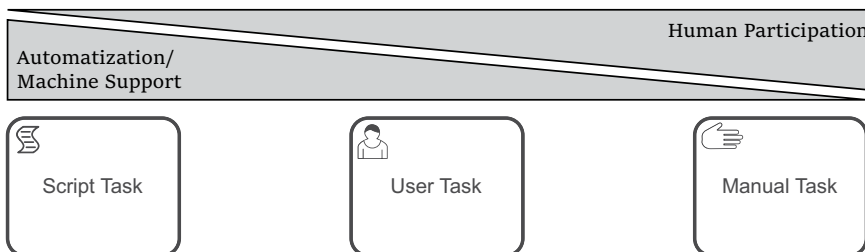
resources<sup>2</sup>. We will further specify this differentiation and provide a closer look and definition of process entities in Sect. 4.2.2.

Finally, within a process model, individual activities (tasks) can be categorized by their execution method and degree of human involvement. BPMN provides a possible categorization and naming, which we will adapt for presentation purposes. Figure 1 shows three different task types, the amount of inherent automatization or machine support, and the extent of human participation. Starting on the left, *Script Tasks* (but also, to some extent, *Service Tasks*) are tasks that are executed fully or mostly automatically by the used Business Process Management System (BPMS). Depending on the implementation or use of a BPMS, it can be programmed in any arbitrary programming language to access and work with any data. The following *User Tasks* in the center model require a human actor's attention.

Nevertheless, the BPMS can still support the creation of a specific task within the task list and a web-based user form. Different implementations also allow accessing and writing task-specific data during task execution. The last task type is *Manual Tasks*, which are used to model work not crucial to the engine or tasks with no known system or user interface<sup>3</sup>. This task type is typically used to model classic functions that are not easily automated or standardized, which we will focus on in this manuscript. Here, the automatization and machine support are low or even zero (The BPMS implementation Camunda<sup>4</sup>, for example, handles manual tasks as "a pass-through activity, automatically continuing the process when the process execution arrives at it" (Camunda 2025), on the other hand, the human participation is at its maximum.

## 2.2 Internet of Things (IoT)

The concept of ubiquitous computing, a world in which every object is connected and accessible via a network, was first proposed in the early 1990s (Weiser 1999). This vision is closely coupled with the Internet of Things (IoT), which is broadly



**Fig. 1** BPMN tasks with human participation and their grade of automation

<sup>2</sup> In Russell et al. (2015), different resource patterns are described focusing on the human resources (except for the *Additional resource* pattern where, next to the human actor, additionally the necessary resources are mentioned). In contrast, Ouyang et al. (2010) focuses on the difference between human and non-human resources in more detail.

<sup>3</sup> This is often also an issue with the granularity and chosen modeling approach for the specific application.

<sup>4</sup> <https://camunda.com/>

defined as the integration of physical objects with embedded sensors, software, and other digital technologies, enabling them to connect and exchange data over a network (Gershenfeld et al. 2004). A comprehensive survey defines IoT as a paradigm in which interconnected objects collect and share data about the physical world, enabled by the convergence of technologies such as RFID, wireless sensor networks, and cloud computing (Al-Fuqaha et al. 2015).

From a business perspective, the true impact of IoT lies in its ability to create a new "organizing logic for innovation," in which the digital and physical worlds are layered and intertwined, enabling novel products, services, and business models (Yoo et al. 2010). These connected objects can be categorized into two main groups: *sensors*, which gather data from the physical world (e.g., temperature, location), and *actuators*, which actively influence the physical world (e.g., adjusting a valve, turning on a light). This capability to both sense and act on the physical environment positions IoT as a core enabler for the advanced operational support discussed in this paper.

### 2.3 IoT-aware BPM

The IoT fundamentally transforms how organizations approach process management by creating networks of interconnected devices that generate continuous streams of contextual data. Rather than viewing IoT simply as a set of connected objects, this paradigm represents a shift toward intelligent operational environments in which physical activities become visible and manageable through digital infrastructure (Cherrier and Deshpande 2018). BPM systems excel at orchestrating IT-supported workflows but face significant limitations when addressing manual, location-dependent, or physically executed tasks. IoT technologies directly address this gap by providing real-time visibility into previously opaque operational activities (Janiesch et al. 2020; De Luzi et al. 2024) ("IoT can complete BPM" Janiesch et al. 2020, p. 35). Sensors, wearable devices, and embedded systems capture granular data about physical processes, worker activities, and environmental conditions that were historically beyond the reach of conventional BPM systems, as mentioned above. This technological convergence enables organizations to achieve comprehensive process visibility spanning both the digital and physical domains (Schönig et al. 2020). IoT-generated data streams provide contextual information that enhances process execution through real-time monitoring, predictive analytics, and adaptive workflow management (Friedow et al. 2018; Porter and Heppelmann 2015). Emerging concepts like digital twins of business processes promise affordable, comprehensive operational visibility by integrating IoT sensors with process models (Fornari et al. 2025).

A comprehensive systematic review of IoT-aware BPM reveals that most approaches focus on modeling and monitoring phases, with limited attention to operational execution support (Compagnucci et al. 2022). The architectural implications extend beyond simple data collection. Effective IoT-BPM integration requires sophisticated data processing capabilities to transform raw sensor inputs into actionable process insights. This involves developing middleware layers that aggregate data from heterogeneous sources, perform real-time analytics, and trigger appropriate process responses based on physical-world conditions. Furthermore, this integration

enables new forms of process intelligence that respond dynamically to operational realities (see the presented BPMN extensions below, which facilitate a new approach to incorporating this external data). Location-aware processes can optimize resource allocation based on real-time positioning data, while condition-monitoring systems can initiate maintenance workflows before equipment failures occur. Such capabilities represent fundamental advances in the complexity of process management, moving beyond static workflow definitions toward adaptive, context-aware operational systems (Schöning et al. 2020; Janiesch et al. 2020).

### 3 Methodology

Our research aims to advance the understanding and support of the operational perspective within BPM by detailing its current state and proposing IoT-enabled future possibilities. To achieve this, we use a mixed-methods approach (Venkatesh et al. 2013; Creswell 2018), integrating insights from a structured literature review with abductive reasoning informed by our ongoing research projects and real-world observations. The structured literature review (SLR) aims at mapping existing documented knowledge directly related to the topic (answering RQ1). However, to conceptualize future possibilities and organize the entities in a new way (answering RQ2), a purely deductive method is insufficient. Abductive reasoning allows us to move from observed gaps in the literature and real-world work environments to the most plausible new framework.

The foundational component of our methodology is a structured literature review conducted in accordance with the guidelines of Okoli (2015). This systematic review aimed to map the historical development and current conceptualization of the operational perspective in process management. The search strategy involved prominent digital libraries, including ACM Digital Library, IEEE Xplore, ScienceDirect, AIS eLibrary, and EBSCO. Specific search queries combined core BPM terms ("*BPM OR "process execution" OR "process modeling" OR "workflow management" OR "WfMS"*") with keywords central to the operational perspective (e.g., "*operational perspective*", "*task execution*", "*service selection*", "*execution support*")<sup>5</sup>. No temporal restrictions were imposed, and publications were limited to English.

Initially, our search yielded 2,978 records. After removing 83 duplicates, 2,895 unique records proceeded to the screening phase. During the screening of titles and abstracts, 2,766 records were excluded, primarily for being irrelevant based on their titles or abstracts. The majority of these exclusions stemmed from the broad nature of the term "*task execution*" in the search terms, which accounted for two-thirds of the initial search results. This left 129 records for full-text assessment. To ensure relevance, the following explicit non-exclusive exclusion criteria were applied to publications during the full-text review:

<sup>5</sup> The search term "BPM" was used as it is the standard acronym in the field and commonly indexed in databases. A complementary search using the full term "business process management" yielded no additional relevant papers, confirming the comprehensiveness of our initial search strategy.

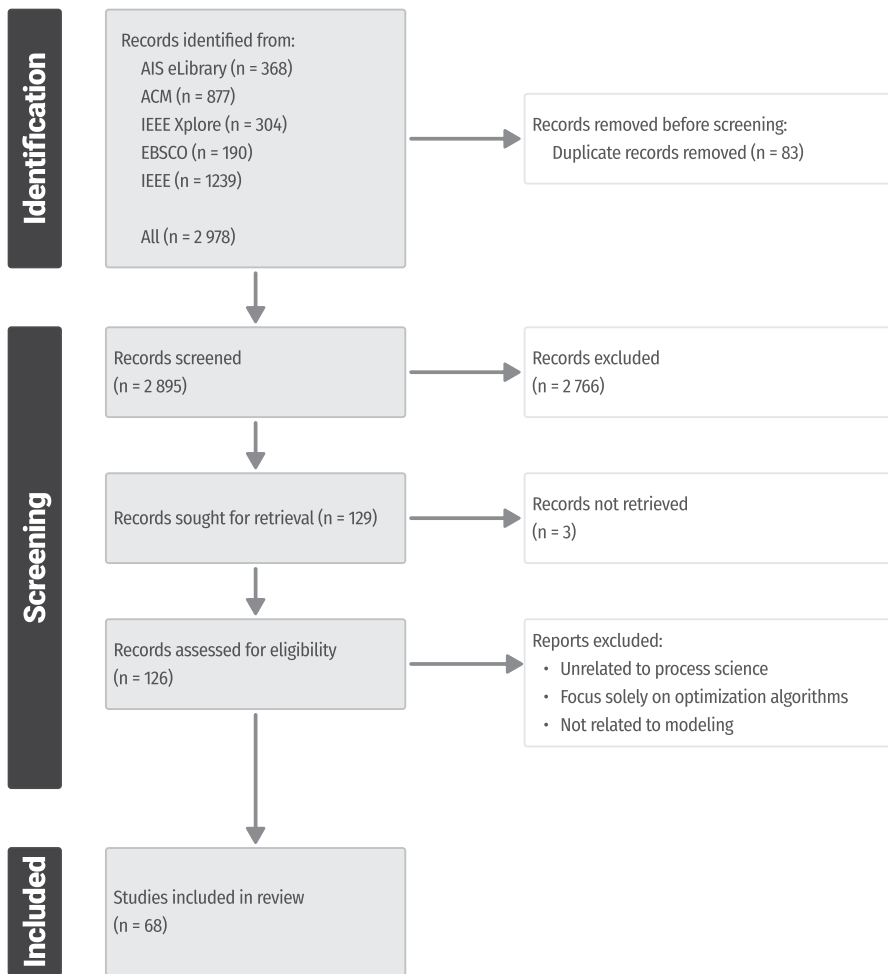
- **EC1 (Unrelated to process science):** Publications that did not focus on the core area of process management research (e.g., Ochoa et al. 2023).
- **EC2 (Focused solely on task execution optimization algorithms):** Papers that only presented algorithms for scheduling or allocation without exploring the conceptualization or broader support mechanisms for task execution (e.g., Feng et al. 2005).
- **EC3 (Not related to modeling):** Articles not related to process models or modeling, which are foundational to the BPM lifecycle (e.g., Boissier et al. 2019; Song et al. 2019).

The authors jointly defined the exclusion criteria following an initial review of 20 selected papers. The first author applied these criteria systematically, documenting justifications for exclusions that were discussed within the author team.

The detailed exclusion process is documented in the PRISMA diagram shown in Fig. 2, as adapted from Page et al. (2021). The review process, including screening and data extraction, was primarily conducted by one researcher, following a protocol jointly defined by the author team. Specifically, the data extraction protocol mandated capturing the following standardized fields for each included publication: (1) general metadata (e.g., publication year, venue), (2) the specific research domain or application area (e.g., IoT, healthcare, conceptual BPM), (3) explicit or implicit definitions of the operational perspective, (4) identified process entities (active and passive resources), and (5) proposed mechanisms for supporting task execution. To ensure reliability, unclear cases were discussed and resolved collaboratively among the researchers during the screening and eligibility phases. The extracted data were then analyzed using qualitative content analysis, following the inductive category formation approach of Mayring (2015). This method is designed to synthesize and structure material by moving from specific data to generalized, higher-order themes when a theoretical framework is emergent.

The analysis proceeded in several steps: *First*, we defined the research question guiding the analysis: *"How is the operational perspective defined, conceptualized, and supported within the BPM literature?"* *Second*, the 68 selected publications were analyzed to generate initial, low-inference codes directly from the text (e.g., "workflow logic," "resource allocation," "manual task", "tool support", "sensor"). In the *third* and central step of abstraction, these initial codes were iteratively refined, compared, and generalized into broader, higher-level categories (e.g., "Automated Services," "Conceptualization as Passive Resources," "Connection of Digital and Physical"). This process created a final, structured coding frame. This inductive method ensured that our analysis was grounded in the literature, allowing us to identify the evolution of the operational perspective and reveal the conceptual gaps that motivate our research.

Complementing the structured literature review, abductive reasoning (Tavory and Timmermans 2014) played a crucial role, particularly in identifying and conceptualizing future possibilities for operational support. We selected abductive reasoning over purely deductive or inductive approaches because the operational perspective lacks established theoretical frameworks for IoT integration, making pure deduction insufficient. Because our goal extends beyond describing existing phenomena



**Fig. 2** PRISMA statement following Page et al. (2021)

(induction) to proposing novel, theoretically grounded solutions, abduction allows systematic inference from observed gaps to plausible innovations. In practice, this process was guided by insights from an ongoing research project in the logistics and manufacturing sectors, which involves observing the daily workflows of field service technicians and assembly line workers, as well as a general analysis of modern work environments where mobile device use is ubiquitous. Yet, many tasks still have to be completed manually. The abductive process involved analyzing patterns, anomalies, and unmet needs in existing practices to infer plausible and innovative solutions for operational support. Specifically, observations regarding the widespread adoption of mobile devices, the capabilities of IoT technologies (e.g., sensors, actuators, mobile devices, and personal electronics for data streams), and the evolving needs for managing non-automatable tasks guided the conceptualization of novel support mechanisms. We structured this reasoning into an iterative cycle: *(i) Observation:*

Identify specific gap from SLR (e.g., lack of tool modeling); (ii) *Contextualization*: Examine this gap in real-world settings (e.g., observe how workers select tools); (iii) *Hypothesis generation*: Propose plausible explanation (e.g., tools require context-aware selection); (iv) *Mechanism design*: Develop support mechanism addressing both gap and observation (e.g., context-aware tool recommendation); and (v) *Validation*: Check consistency with both literature and practice. This cycle was repeated for each identified gap, with all authors participating in hypothesis generation and mechanism design. This iterative synthesis enabled a robust understanding of the operational perspective, moving beyond existing theoretical frameworks to propose practical, forward-looking solutions grounded in contemporary technological and organizational realities. The classification of process entities (Table 2) was derived by contrasting the limited resource definitions from the SLR (inductive) with the complex reality of physical tools and materials observed in our field research (abductive), thereby necessitating new categories to bridge the two.

## 4 The operational perspective in BPM

Returning to the definition of the operational perspective already provided in the introduction, we define it as the *function of providing and supporting all resources required for a task's execution within a process model*. This generic definition includes the earlier ways of incorporating the description of how exactly a task is executed while referencing the executing active resource, on the one hand, and the

**Table 2** Overview of different entities participating in business processes

| Type                  | Subtype                    | Example                   | Primary Citizen   |        |         | Interaction Type | Secondary Citizen |          |      |      |   |
|-----------------------|----------------------------|---------------------------|-------------------|--------|---------|------------------|-------------------|----------|------|------|---|
|                       |                            |                           | trigger execution | active | passive |                  | Physical          | Location | Data |      |   |
| Human                 |                            |                           | ●                 | ●      | ○       | ●                | ○                 | ○        | ○    | n.a. |   |
| Non-Human             | Self-operating systems     | Autonomous robots, Drones | ●                 | ●      | ○       | ●                | ○                 | ○        | ○    | n.a. |   |
| Non-Human             | Semi-autonomous systems    | CNC machines              | ○                 | ●      | ○       | ●                | ○                 | ○        | ●    | n.a. |   |
| Non-Human             | Automated software-systems | ERPs, Automated workflows | ●                 | ●      | ○       | ○                | ○                 | ●        | n.a. | n.a. |   |
| Operational Equipment |                            | Tools                     | ○                 | ○      | ●       | ●                | ○                 | ○        | ●    | ○    | ● |
| Material              |                            |                           | ○                 | ○      | ●       | ●                | ○                 | ○        | ●    | ●    | ○ |
| Physical Data         |                            | Documents                 | ○                 | ○      | ●       | ○                | ○                 | ○        | ●    | ●    | ○ |
| Digital Data          |                            | BPMS process variables    | ○                 | ○      | ●       | ○                | ○                 | ●        | n.a. | ●    | ○ |

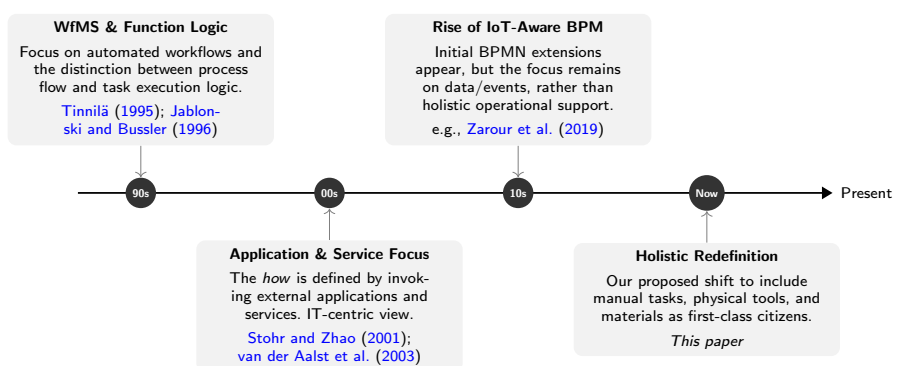
Legend ● : fulfilled, ○ : not fulfilled

used (passive) resources on the other<sup>6</sup>. In the following sections, we will outline the development of this definition, its current status, and future possibilities for its support within a holistic, human-centric BPM framework. This section presents our findings structured around our two research questions. **RQ1** (current state of operational perspective) is addressed through Sects. 4.1 and 4.2, which present findings from our structured literature review. **RQ2** (synergistic mechanisms for integrated support) is covered by Sects. 4.3 and 4.4, which combine SLR insights with abductive reasoning derived from real-world observations to propose novel support mechanisms Fig. 3.

#### 4.1 The evolving definition of the operational perspective

The first mentions of the operational perspective within a process context appeared in the late 1980s, when operational and organizational perspectives on executing processes using Workflow-Management Systems (WfMS) were defined (Tinnilä 1995). During this time, the term *operational perspective* referred to a broader understanding of business processes, encompassing the tasks required to achieve a business goal. The evolution of BPM from its origins in WfMS is a significant development in the field. Consequently, perspectives on processes were adapted to focus more on the full BPM lifecycle (Dumas et al. 2018), extending beyond execution alone. The introduction of Business Process Reengineering (BPR) (Hammer 1990) is quoted as the first real impact of BPM (Lee and Dale 1998; Klun and Trkman 2018), which led to a shift "from a functional organization to one which is business process-based" (Armistead 1996, p. 48) and "assessing ways in which their productivity, product quality and operations can be improved" (Elzinga et al. 1995, p. 119).

Jablonski and Bussler (1996) describe the operational perspective by including it as part of a potential workflow model. Their operational perspective encompasses three key resources: tools, devices, and computers, all of which are regarded within this perspective. In a later definition, the authors define the operational perspective



**Fig. 3** Overview of the historical development of the operational perspective

<sup>6</sup>Applications, services, machines, and even human-actors mentioned in earlier definitions can be both, passive resources, when they are used to execute a task, e.g., by a human actor or active resources, when they are fulfilling the task themselves (cf. Sect. 4.2.2).

as "how [...] a workflow operation is implemented." (Jablonski 1995, p.119) Based on this definition, Petkov et al. (2005) provide further details, emphasizing a strict separation between the Workflow-System (i.e., the logical execution of a process within the WfMS or BPMS) and the actual execution of tasks (flow logic vs. function logic Cardoso et al. 2004). Additionally, Meyer-Wegener and Böhm (1999) and Stohr and Zhao (2001) focus on the tools needed for executing tasks as the main component of the operational perspective. van Der Aalst et al. (2000), van der Aalst et al. (2003) and Rosa et al. (2011) all define the operational perspective as the basic steps required to complete a task, including the applications involved and the resources required in the form of business objects. Jablonski and Goetz (2007), on the other hand, focus more on the operational perspective, specifically on how services are invoked to complete a process step, without mentioning either active (executing) or passive (used) resources. Finally, Weske (2007) provides a possible operational perspective, including all the necessary information for a BPMS to efficiently utilize external applications to execute tasks, encompassing both functional and non-functional requirements. In contrast, other authors, such as Letsholo et al. (2014), include several definitions of the operational perspective, which is generally considered the organizational perspective, including active resources, the resource perspective (cf. Russell et al. 2015; Stroppi et al. 2015), and the location in their definition.

The literature review reveals a lack of a consistent, universally accepted definition of the operational perspective. Early conceptualizations, in particular, do not explicitly reference passive resources and focus primarily on the active (executing) entity. In addition, early BPM research often inferred that execution was performed by a machine, mentioning resources only as applications or generic services. Returning to the differentiation among various task types in BPMN, we note a significant gap identified at the outset. Most existing definitions and the bulk of current BPM research emphasize the standardization and support of tasks that can be automated, as well as those tasks facilitated by applications, services, and machines, which are typical user tasks within the BPMN classification.

## 4.2 Current state

Focusing on the current landscape of BPM research and tool support, beyond the task types discussed in Sect. 2, some processes involve activities that, by their nature, do not require human participation. These are distinct from the operational perspective's focus, which inherently examines how tasks are executed, often involving human actors and their tools. Contemporary BPM research increasingly emphasizes employee-aware approaches that prioritize worker experience and empowerment (Fehrer et al. 2024). This shift recognizes that manual tasks, while not automatable, can benefit from intelligent support systems that augment rather than replace human capabilities—a principle central to the operational perspective. Among tasks that involve human participation, there is significant variation in the degree of involvement. While BPMSs frequently support user tasks by providing supplementary information, such as digital forms or other technological guidance, manual tasks (which rely exclusively on human execution) typically receive no such direct support within BPM systems. Consequently, depending on the granularity of the process models,

there is often no explicit indication of how a manual task should be executed or of which specific equipment or tools are required for its successful completion.

Similar to other research areas that focus on a significant number of tasks that are standardizable, automatable, or work as expected every time, the human factor plays a crucial role in the remaining process executions by introducing various challenges and opportunities in managing business processes. To reiterate an essential distinction, the **organizational perspective** focuses on the *who* of a process, i.e., identifying the actors, their roles, and responsibilities for a task. In contrast, the **operational perspective**, which is the focus of this paper, addresses the *how* and *with what*, i.e., detailing the specific procedures, tools, and materials required for task execution.

#### 4.2.1 Operational perspective in general

Building on the previously established general definition of the operational perspective, this section explores various approaches to support it. We begin by examining its relevance in Enterprise Resource Planning (ERP) systems, a key starting point for understanding the specifics of task execution. Szelagowski et al. (2022, p. 326) define ERPs as systems "used to manage the organization's resources" and BPMS to "support [...] work or document flows". While the process is inherently embedded and explicitly implemented across various flows within ERP systems, process management provides the foundation for the process model and its associated flows. Next to two direct examples that could be transferred to BPM, Belli et al. (2019) that consider production planning and Bill of Materials (BOM) in an ERP System that could be regarded as part of future application areas in BPM or Kir and Erdogan (2021) that focus on knowledge-intensive processes in supply chain management, there are additional approaches that could benefit the operational perspective that are not directly tied to ERP Systems.

Examining existing approaches from an operational perspective, we can categorize them by complexity. Starting with simple annotations of contextual information (George and Ward 2008) and using smartwatches and other mobile interfaces to track the start and end of manual tasks (Schönig et al. 2020) that do not lift the black box around manual task execution, or Ihde et al. (2022), Xiao et al. (2010) and Chang et al. (2020) that all describe resources and their use at several different application areas, the main focus lies on the optimization of allocation. Here, primarily active resources in the organizational perspective are used, and the authors assume the existence of data and knowledge about the current state of entities that were not previously made explicit. The sole focus on improving business process and value creation (BPI) in BPM, as seen in Johannsen and Fill (2017), also skips the fundamentals of modeling the necessary passive resources as well as the support during execution and combined data collection, further motivating the need for a real systematic process-based support of the operational perspective.

Haddar et al. (2016), on the other hand, describe the collaboration between different actors on the same task, which also contains ideas that could be transferred to passive resources. Similarly, Bocciarelli et al. (2017, p. 601) describe modeling "non-functional properties," i.e., task resources, using a custom string-based notation and execution possibilities. Nevertheless, the authors also focus on automation,

stating that the "broker defines a set of resources capable of performing the required activity." Schmidt et al. (2010) focus on knowledge-intensive processes, where they describe the use of software as a tool to execute, but focuses on human actors (here the authors require human resources as well as applications for the execution of a task), on the other hand, Antunes et al. (2013) describe different canvases to specify further human-centric tasks, end-user-focused dialog lines, and scenes with specific descriptions of what is happening. Finally, Tietz et al. (2013) describe an approach closest to our definition of the operational perspective by providing an overview of hierarchy-based task modeling tools that enable a more specific, focused description of tasks and the tools they include. Similarly, Poss and Schöning (2025a) present a formalization of tool use, supporting execution and modeling based on an ontology and facilitating the use of RDF and SPARQL for managing tools. The presented tools and approaches are far from standardized and remain only a small, unstructured part of the operational perspective.

#### 4.2.2 Process entities and the operational perspective

After examining the historical development of the operational perspective and its current state in process models, we must also define and delineate the different entities that play a role within processes for structured development and overview. Building on the publications Jablonski and Bussler (1996), Bussler et al. (1996), van der Aalst (2018) and Russell et al. (2015) as a core, we can begin by defining basic concepts to distinguish the entities. As is universally done with the definitions and classifications of different perspectives in process management, a clear definition and selective criteria for differentiating process entities are necessary (Dumas et al. 2018). The traditional distinction between *active* and *passive* resources (Ouyang et al. 2010) is a starting point. However, it lacks the granularity necessary to model and support the complex realities of modern work, which often involves blending automated and manual tasks. Therefore, before we can meaningfully discuss how to support task execution, we must first establish robust vocabulary for what is involved and who is involved. The following classification, presented in Table 2, is a core contribution of this paper. It provides a structured framework for delineating process entities based on their capabilities, interaction modes, and physical properties (Davenport and Prusak 1998). This framework is a necessary foundation for developing the enhanced modeling artifacts and support mechanisms proposed later.

Table 2 represents a key contribution of this study. This classification scheme emerged from integrating three sources: (i) traditional active/passive resource distinctions identified in our literature review (Ouyang et al. 2010; Russell et al. 2015), (ii) gaps in existing categorizations revealed by the SLR, particularly regarding physical tools and materials, and (iii) abductive reasoning based on observed entities in real-world manufacturing and logistics processes from our ongoing research projects. The framework extends beyond binary active/passive distinctions to incorporate interaction types, physical properties, and data characteristics necessary for IoT-enabled operational support.

We distinguish process entities along two primary dimensions: Primary citizens are entities that can trigger or execute process tasks autonomously (organizational

perspective), while secondary citizens support task execution but cannot act independently (operational perspective). Within primary citizens, the first distinction concerns whether entities are *active* or *passive*, and whether they can *trigger the execution* of a task (organizational perspective). Active resources, including humans, robots, machines, and software systems, can execute tasks independently. In contrast, operational equipment, such as tools, materials, and data, can support task execution but cannot perform it autonomously (Dumas et al. 2018; Cabanillas et al. 2015). Next, the **interaction type** describes how an entity interacts with the process; here we have three types: *direct* interaction (active resources and operational equipment and material that directly influence the process and the entities), *mediated* interaction (these entities have to be used by other entities to influence the process<sup>7</sup>) and *indirect* interaction (entities that influence the process by providing information or resources that guide or support the process rather than engaging directly with the process operations).

Finally, the secondary citizens comprise classifications on the **physical** characteristics, the **location**, and further division of each **data** entity. Here, the term *tangible* describes entities that can be perceived by the senses. In contrast, entities such as software systems and data are considered *non-tangible*, implying a lack of physical presence in the real world (Amadi-Echendu et al. 2010). However, this does not prohibit tracking and using these entities for execution support. The distinction between *dynamic* and *static* entities is based on the ability of tangible entities to move. All entities with a location can either move independently or be moved by a third party (Küpper 2005; Poss and Schöning 2024). This includes human actors and autonomous entities. Ultimately, examining whether they are *consumable/producible*, *reusable*, or *transformable* during task execution allows us to draw a final distinction. Operational equipment, such as tools, is only worn down during task execution. In contrast, material is consumed and potentially transformed (Slack and Brandon-Jones 2019; Eversheim et al. 1991; Poss and Schöning 2025b)<sup>8</sup>.

### 4.2.3 Operational perspective in BPMN

Having established the conceptual foundation and classification of process entities, we now turn to how emerging IoT technologies can address the identified gaps in operational support. The following subsection examines current approaches to using IoT to enhance visibility and support manual tasks and their associated resources.

Leveraging BPMN as the de facto standard for process modeling and execution, we examine different existing approaches and extensions of the standard. Our primary goal is to investigate the extent to which these extensions address the operational perspective, specifically focusing on how they support the execution details of tasks, particularly manual activities, and the direct use of passive resources.

<sup>7</sup> This is even the case for automated software-systems, at some point, they have to be started by a human or a fully self-operating system.

<sup>8</sup> The classification of data depends on the definition of *transformable*, physical data like documents contain information that can be used and transformed, the documents themselves are not.

For this analysis, we drew upon BPMN extensions identified in two systematic reviews by Zarour et al. (2019) and Compagnucci et al. (2022). Table 3 illustrates the correlation between selected BPMN extensions, their corresponding perspectives, and the BPMN elements they affect. To streamline the table, we aggregated all contributions within the same extension family. We included additional relevant publications beyond the original review cutoffs, citing only the most recent publication for each extension family. The extensions are sorted by the publication year of their first appearance, followed by alphabetical order. Extended elements and affected perspectives are indicated when referenced papers explicitly expand or support the given component or perspective.

An analysis of the results reveals that the various BPMN extensions currently used in IoT encompass elements tailored to specific application areas that span several perspectives. While the connections between use cases are discernible, their application area is quite specific, and the perspectives they address are limited. Most of the identified extensions for IoT in BPM focus on supporting basic perspectives by extending events, changing how data is handled, or influencing the process flow. From the identified and combined extensions, only three focus on the operational perspective and explicitly try to support *how* activities are executed. Ardito et al. (2020) describe a use case of a chatbot, providing a selection of types for the bot, such as *notification*,

**Table 3** Overview of BPMN extension families, their application areas, affected BPMN elements and perspectives

|                            |                                  |             |                                 |   | Extended BPMN Elements |          |       |      |            | Affected Perspectives |            |      |              |             |
|----------------------------|----------------------------------|-------------|---------------------------------|---|------------------------|----------|-------|------|------------|-----------------------|------------|------|--------------|-------------|
|                            |                                  |             |                                 |   | Executable             | Activity | Event | Data | Pool/ Lane | Group                 | Functional | Data | Organization | Operational |
| Name of Extension(-family) | Reference(s)                     | Year(s)     | Application Area                |   |                        |          |       |      |            |                       |            |      |              |             |
| IAPM                       | Cheng et al. (2018)              | 2011 – 2018 | Generic IoT Devices             | ● | ●                      | ●        | ●     | ●    | ○          | ●                     | ●          | ●    | ○            | ●           |
| BPMN4WSN                   | Mottola et al. (2019)            | 2012 – 2019 | Sensor Networks                 | ● | ●                      | ○        | ○     | ●    | ○          | ●                     | ●          | ●    | ○            | ●           |
| –                          | Jankovic et al. (2015)           | 2015        | Cross Organizational Processes  | ● | ●                      | ○        | ○     | ●    | ○          | ○                     | ○          | ●    | ○            | ●           |
| uBPMN                      | Yousfi et al. (2019)             | 2015 – 2019 | Ubiquitous Computing            | ● | ●                      | ●        | ○     | ○    | ○          | ●                     | ●          | ○    | ○            | ●           |
| BPMN4CPS                   | Graja et al. (2016)              | 2016        | Cyberphysical Systems           | ● | ●                      | ○        | ○     | ○    | ○          | ○                     | ○          | ○    | ●            | ○           |
| BPMN4CP                    | Braun et al. (2016)              | 2016        | Healthcare                      | ● | ●                      | ○        | ●     | ○    | ○          | ●                     | ●          | ●    | ○            | ○           |
| OutyBPMN                   | Rekik et al. (2016)              | 2016        | Outsourcing                     | ● | ●                      | ○        | ○     | ○    | ○          | ○                     | ○          | ○    | ○            | ○           |
| BPMN4V                     | Ben Said et al. (2017)           | 2017        | Healthcare                      | ○ | ●                      | ●        | ○     | ○    | ○          | ○                     | ○          | ○    | ○            | ○           |
| elyBPMN                    | Domingos et al. (2016)           | 2017 –      |                                 | ○ | ●                      | ●        | ○     | ●    | ○          | ○                     | ●          | ○    | ○            | ○           |
| IoT-BPO                    | Suri et al. (2018)               | 2017 – 2018 | Smart Environments              | ○ | ○                      | ○        | ○     | ○    | ○          | ○                     | ●          | ●    | ○            | ●           |
| Context4BPMN               | Dörndorfer and Seel (2018)       | 2018        | Execution Context               | ○ | ○                      | ○        | ○     | ○    | ○          | ○                     | ●          | ●    | ○            | ●           |
| –                          | Dukaric and Juric (2018)         | 2018        | Cloud Environment for Execution | ● | ●                      | ○        | ○     | ○    | ○          | ○                     | ○          | ○    | ●            | ○           |
| BPMN4SGA                   | Vogel et al. (2018)              | 2018        | IoT                             | ○ | ○                      | ●        | ○     | ○    | ○          | ○                     | ○          | ○    | ○            | ○           |
| BPMN-E <sup>2</sup>        | Ramos-Merino et al. (2018, 2019) | 2018 – 2019 | Health Care                     | ○ | ○                      | ○        | ○     | ○    | ○          | ○                     | ●          | ●    | ○            | ●           |
| –                          | Grefen et al. (2019)             | 2019        | Delivery and Cross-Docking      | ○ | ○                      | ○        | ○     | ○    | ○          | ●                     | ○          | ○    | ○            | ○           |
| BPMN-X                     | Ardito et al. (2020)             | 2020        | Public Administration           | ○ | ○                      | ○        | ○     | ●    | ○          | ○                     | ○          | ○    | ○            | ○           |
| –                          | Zareen et al. (2020)             | 2020        | Security                        | ● | ○                      | ○        | ●     | ○    | ○          | ○                     | ○          | ○    | ○            | ○           |
| –                          | Bazan and Estevez (2021)         | 2021        | Industry 4.0                    | ○ | ○                      | ○        | ○     | ○    | ○          | ○                     | ○          | ○    | ○            | ○           |
| LABPMN                     | Poss et al. (2023)               | 2023        | Location Information            | ● | ●                      | ●        | ○     | ○    | ○          | ○                     | ●          | ●    | ○            | ●           |
| RBPMN                      | Skouti et al. (2024)             | 2024        | Cyberphysical Systems           | ● | ○                      | ○        | ○     | ○    | ○          | ○                     | ○          | ○    | ○            | ○           |
| PRIME                      | Poss and Schöning (2025b)        | 2025        | Passive Resources               | ● | ●                      | ○        | ○     | ○    | ○          | ○                     | ●          | ○    | ○            | ●           |

Legend ● : fully considered/fulfilled, ○ : partly considered/partly fulfilled, ○ : not considered/not fulfilled

Legend: ● : fully considered/fulfilled, ○ : partly considered/partly fulfilled, ○ : not considered/not fulfilled

*group or channel, commands, or inline*, explicitly modeling how specific tasks must be executed.

On the other hand, Grefen et al. (2019) focus on co-location for collaborative business processes, which involve specific tasks requiring spatial and temporal coordination. The authors motivate this by using the example of container logistics, in which the object to be moved (the container) has a specific spatial and temporal relationship with the active resource (a crane, possibly controlled by a human). Finally, Graja et al. (2016) explicitly model the real-world environment within the BPMN Metamodel, containing different physical entities, which are then used to support task execution. Generalizing IoT as a key enabler, other approaches also seek to extend process modeling to yield richer operational insights. For instance, Bocciarelli et al. (2017) outline a string-annotation-based approach that utilizes an external system to specify further task details, thereby aiming to enhance performance. In related research, Carvalho et al. (2018) propose breaking down end-to-end processes into smaller components and considering added artifacts that encompass both active and passive resources.

In summary, the analysis of the current state indicates that the operational perspective has been historically underexplored, a consequence of the field's dominant focus on process automation and IT support. However, active and passive resources are indispensable for effective process execution and require equal consideration. As highlighted in foundational process management literature (Dumas et al. 2018; van der Aalst 2018), this oversight has created a critical gap: while the administrative tasks surrounding manual work (e.g., creating an order or sending an invoice) are efficiently managed and logged by traditional BPM systems, the physical execution of the manual task itself remains largely unsupported and unmonitored. However, the operational perspective has evolved to consider these tasks. It provides a basis for process execution, focusing on the *how* that has not yet been considered. This perspective is less about redesigning processes and more about adapting support options for existing tasks that are not fully automatable or supportable. The operational perspective has implications across all lifecycle stages, emphasizing the importance of understanding how tasks are executed, which actors participate, which applications are used, and which tools and other resources are required to complete them successfully.

### 4.3 Future possibilities – new way of supporting task execution

The future possibilities presented in this section are derived through abductive reasoning, building upon the gaps identified in our SLR (Sects. 4.1 and 4.2) and based on observed needs in real-world work environments. This approach allows us to move from empirical observations to plausible, innovative solutions for operational support. The evolution of organizational systems and the proliferation of IoT-enabled devices provide new opportunities for gathering and processing contextual data streams (see Sect. 2.3). These technological advances, combined with the widespread use of companion devices (e.g., smartphones and tablets), enable several novel mechanisms to support the operational perspective, particularly for manual tasks. The following subsections present a framework of such possibilities, aligned with the BPM lifecycle.

The following sections present a non-exhaustive list of possibilities for supporting *how* process tasks are executed, aligning with the activity itself through abductive reasoning, and for synthesizing gaps identified in the literature with insights from modern work environments. These two parts, aligning artifacts along the BPM life-cycle and the perspective on the temporal ordering of a task, result in a descriptive framework that supports the operational perspective.

#### 4.3.1 Enhanced modeling artifacts for process design and configuration

To address the current limitations in supporting the operational perspective, particularly concerning manual tasks and passive resources, advancements in process design and configuration are imperative. Process modeling, analysis, and execution configuration, which make up large parts of the BPM lifecycle, offer critical junctures for introducing enhanced modeling artifacts. These artifacts aim to move beyond conventional flow-centric redesign, enabling a richer representation and management of tasks and their associated operational resources.

- **Integrated resource modeling:** New artifacts can be developed and incorporated for modeling resources directly within process models. As with existing data objects, necessary materials or tools can be attached and integrated into the process model.

*Use Case: Imagine a furniture assembly process where BPMN models could directly specify the input (e.g., four screws, four legs, one seat plate) and output (e.g., seat plate with attached legs) materials for an Assemble Chair task, along with the required tool (e.g., small screwdriver).*

- **Dynamic resource information:** These artifacts could include additional real-time information and parameters on (required) tools, such as their current battery level, time until next maintenance, current wear level, or maximum allowed wear for a specific task.

*Use Case: For a maintenance task that requires a specific drill, the process model or task list could display its current battery status or the last calibration date, preventing delays or incorrect execution, thus supporting task execution.*

- **Synergistic BPMS and ERP integration:** Promoting the benefit and overlap between BPMS and ERP systems, passive resources like necessary materials could be included in a separate flow diagram closely connected to the process model. Adapting a Material Flow Diagram in the form of a Sankey diagram (Schmidt 2008) to BPM is one example.

*Use Case: An integrated IoT-aware warehouse management system could provide real-time inventory data, eliminating the need for tasks like searching for materials or waiting for materials by informing the process model directly.*

- **Granular manual task classification:** Further categorization of manual tasks based on the level of human participation can significantly improve process efficiency by streamlining knowledge-intensive processes (current classifications often only present extremes, while manual tasks could be subdivided for better support).

*Use Case: Differentiating between a Customer Consultation task (high human*

*interaction, knowledge-intensive) and a Leaking Sink Repair task (manual dexterity, tool-dependent) allows for tailored operational support within the BPMN classification.*

### 4.3.2 Enhanced planning and post-execution evaluation

Beyond its direct application to real-time task execution, the operational perspective yields rich data critical to improving process planning and post-execution evaluation. This holistic integration facilitates more informed decision-making and continuous process improvement.

- **Instance-spanning planning and optimization:** With sufficient data on necessary and available resources, fulfillment locations, and personnel with specific skills, instance-spanning planning and optimization can be improved, influencing how tasks are executed.  
*Use Case: A field service management system, aware of a craftsman's location and the tools available in their company car via IoT, could prevent them from driving to a customer without the required specialized drill for a specific repair.*
- **Prioritization and organizational improvements:** IoT data and contextual information, such as customer details or task locations, can be used for further prioritization and organizational improvements at an instance-spanning level.  
*Use Case: For field maintenance, real-time IoT data on the wear level of a specific drill bit (tool) or the remaining quantity of a specialized adhesive (material) in a technician's inventory could dynamically influence the daily task queue. High-priority jobs that require insufficient or worn-out resources could be automatically rescheduled or reassigned to ensure operational readiness and prevent task failure.*
- **Real-time process monitoring for management:** The additional information gained through operational support can provide management with a real-time overview of active and passive resources involved in processes, including their current use and location. This data is invaluable for analysis and future process improvement.  
*Use Case: A dashboard could display the current utilization rate of specialized equipment across all ongoing projects, enabling the identification of bottlenecks or underutilized assets and making data-driven decisions for future resource procurement or allocation.*

### 4.3.3 Real-time execution assistance

Addressing the operational perspective's core question of *how* tasks are executed, real-time execution assistance plays a pivotal role. Moving beyond conventional machine- or application-driven approaches, this support mechanism integrates diverse contextual information to provide immediate and actionable guidance to human actors during task completion.

- **Contextual information delivery:** This information could include customer details, location-specific warnings about material characteristics, or information about tools needed for the task and their presence with the actor.  
*Use Case: A fieldworker wearing a smartwatch could receive real-time alerts about specific safety precautions for a hazardous material identified at a job site or a reminder that a specific tool required for the next step is still in their vehicle.*
- **Companion device integration:** Companion devices (e.g., smartphones, tablets) can be easily integrated, serving as a primary source of contextual information from various sources, a communication device for data transmission, and a display for specific execution information.  
*Use Case: During a complex machine repair, an augmented reality (AR) overlay on a tablet can guide the technician step-by-step, highlighting components, displaying correct torque settings for bolts, or indicating parts that require replacement.*
- **Adaptive guidance for disruptions:** If an execution deviates from the modeled task due to a disruptive event, different alternatives or guidance could be displayed to help the actor complete the task.  
*Use Case: If a sensor detects an unexpected reading during a medical procedure (a disruptive event), the system could immediately suggest alternative protocols or flag potential issues to the medical professional.*
- **Tool-specific support:** Support can even extend to providing additional information on tool usages, such as required angles, temperatures, or other conditions for proper operation.  
*Use Case: For precise carpentry cuts, a connected saw can provide real-time feedback on the blade angle or pressure, ensuring adherence to specifications.*

#### 4.4 Research propositions

Based on the gaps in supporting the operational perspective identified in our systematic literature review (Sects. 4.1 and 4.2) and the future possibilities derived through abductive reasoning (Sect. 4.3), we synthesize our findings into an actionable research agenda consisting of five distinct propositions. As illustrated in Table 4, these propositions aim to guide future investigations into developing and assessing a more holistic BPM approach that effectively integrates manual tasks and diverse process entities to enhance value creation. Specifically, they map directly to our proposed advancements in modeling, planning, and execution assistance:

- **P1** (Integrated Modeling Artifacts) addresses the gap identified in Sect. 4.2.3, where current BPMN extensions lack standardized modeling for passive resources (Ardito et al. 2020; Grefen et al. 2019; Graja et al. 2016). Building directly on the *Enhanced Modeling Artifacts* proposed, this proposition suggests that explicitly integrating physical tools and materials into process models will reduce execution errors and improve resource utilization.
- **P2** (Real-Time Contextual Delivery) responds to the finding of Sect. 4.2.1 that current IoT-BPM approaches do not lift the black box around manual task execu-

**Table 4** Research propositions for advancing the operational perspective

|    | Research proposition                                                                                                                                                                                                                                                                   |
|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P1 | The implementation of integrated modeling artifacts for passive resources (e.g., tools, materials) within BPM process models will reduce task execution errors and improve resource utilization efficiency in processes involving manual tasks.                                        |
| P2 | During manual task execution, delivering real-time contextual information to human actors via companion devices will increase task completion accuracy and reduce process cycle time.                                                                                                  |
| P3 | Dynamic, IoT-enabled planning and allocation systems that leverage data on active and passive resource availability and location can significantly optimize instance-spanning process execution and reduce operational overhead for processes with mobile or distributed manual tasks. |
| P4 | A refined classification scheme for manual tasks, extending beyond binary automation levels, can enable more granular and effective operational support strategies, leading to improved adaptability and resilience in process management.                                             |
| P5 | Overcoming challenges in data integration and interoperability between IoT systems, ERP, and BPMS is a prerequisite for achieving the full potential of a holistic operational perspective in Business Process Management.                                                             |

tion (Schöning et al. 2020; George and Ward 2008). Connected to the Real-time *Execution Assistance* mechanisms outlined, we posit that leveraging companion devices to deliver contextual guidance will directly increase task accuracy and reduce cycle times.

- **P3** (Dynamic Planning) builds on the observation that current allocation approaches assume the pre-existence of explicit entity data (Ihde et al. 2022; Chang et al. 2020). Rooted in the *Enhanced Planning and Post-Execution Evaluation* possibilities, this proposition asserts that instance-spanning optimization using dynamic IoT data will significantly reduce operational overhead.
- **P4** (Refined Task Classification) emerges from our entity classification framework (Table 2). Driven by the need for *Granular Manual Task Classification* identified, we propose that moving beyond binary automation levels to categorize manual tasks will enable more tailored and resilient operational support strategies.
- **P5** (Data Integration Prerequisites) acknowledges the technical challenges documented in Sect. 2.3 (Schöning et al. 2018; Janiesch et al. 2020). As a foundational requirement for successfully implementing the Synergistic BPMS and ERP Integration discussed above, overcoming these challenges is essential to realize the operational perspective fully.

## 5 Discussion

Our analysis revealed a critical oversight in traditional BPM: the historical emphasis on automating and IT-supporting workflows has cultivated a deep understanding of the control flow (the *what* and *when*) and organizational (the *who*) perspectives, but has largely neglected the operational perspective (the *how*). This has led to a significant abstraction gap, leaving manual and non-automatable tasks largely unaddressed and unsupported within process models and systems. This gap is particularly visible in current BPMN implementations, where manual tasks are predominantly treated as unmonitored pass-through activities. Furthermore, our review of BPMN extensions

underscores this oversight, revealing that only a limited number explicitly address the execution details and operational support of physical activities.

This work contributes to the existing literature by directly addressing these modeling and analytical blind spots. Theoretically, we extend prior research by redefining the operational perspective and expanding its scope beyond the traditional IT-centric view of software-aided execution and service invocation. While previous foundational studies have differentiated between active and passive resources, our findings extend this work by introducing a novel, granular classification scheme for process entities (Table 2). This scheme addresses the limitations of binary resource classifications by explicitly integrating interaction types (direct, mediated, indirect) and physical characteristics (tangible, dynamic, consumable). The primary theoretical implication of this research is that it elevates manual tasks and physical resources to first-class citizens within BPM frameworks. By providing this structured vocabulary, our granular classification enhances the conceptual foundation of BPM. It allows researchers to theoretically model and evaluate processes beyond the digital black box, enabling a more precise and comprehensive representation of real-world, IoT-aware operations that seamlessly bridge the physical and digital domains. From a practical standpoint, we outline a concrete vision for future operational support that leverages emerging technologies, such as the IoT. We propose tangible mechanisms, including enhanced modeling artifacts for resource integration, intelligent instance-spanning planning, and real-time execution assistance delivered via companion devices. These pathways offer managers and system designers actionable insights on how to support and optimize previously 'invisible' manual processes, ultimately enabling more informed decision-making and continuous process improvement.

Despite its potential, implementing a holistic operational perspective presents several challenges. Integrating data from diverse sources, such as IoT devices, ERP systems, and manual inputs, raises significant technical hurdles related to interoperability, communication protocols, and data heterogeneity (cf. Schöning et al. 2018; Janiesch et al. 2020). Furthermore, the collection of real-time operational data, especially when involving human actors, raises critical concerns about data privacy, security, and ethics, necessitating robust anonymization and access control mechanisms (cf. Kern et al. 2024; van der Aalst 2017). The resulting systemic complexity demands sophisticated architectural designs and scalable solutions (cf. Rahmani et al. 2020; He et al. 2019). Finally, user adoption remains a key barrier; the success of these new tools hinges on their user-friendliness and the ability to overcome potential resistance to changes in established work processes (Mettler and Stepanovic 2023).

The research propositions derived in Sect. 4.4 outline a clear agenda for future investigation. Empirical validation is the crucial next step. Future work should focus on quantifying the impact of integrated modeling artifacts on resource utilization and error rates (**P1**) and measuring how real-time contextual information affects task completion accuracy and cycle time (**P2**). Investigating the optimization potential of dynamic, IoT-enabled planning systems for mobile and distributed tasks (**P3**) is another vital area. Further research is also needed to assess how a refined classification of manual tasks enables more effective and resilient support strategies (**P4**). Ultimately, addressing the foundational challenge of data integration and interoperability

between diverse enterprise systems remains a critical prerequisite for realizing the full potential of this holistic operational perspective (**P5**).

## 6 Conclusion

This paper redefines the operational perspective in BPM, shifting the focus from automation to the full scope of organizational work, including previously unsupported manual tasks. We demonstrate that organizations can bridge the critical abstraction gap between automated functions and manual labor by integrating a deeper understanding of how work is done, supported by a novel classification of process entities and a clear vision for leveraging the IoT.

Our structured literature review of 68 publications reveals that while BPM has developed sophisticated support for control flow, organizational, and information perspectives, the operational perspective has remained underdeveloped, confined primarily to service invocation and simple resource allocation. This gap is particularly noticeable in current BPMN implementations, where manual tasks are treated as pass-through activities without explicit representation of required tools, materials, or execution procedures. To address this, we propose a novel classification scheme for process entities (Table 2) that extends beyond traditional active/passive distinctions to encompass interaction types, physical characteristics, and resource properties, which are essential for comprehensive operational support.

From a practical standpoint, we propose concrete mechanisms across the BPM lifecycle: enhanced modeling artifacts for integrated resource representation, intelligent instance-spanning planning based on real-time IoT data, and context-aware execution assistance via companion devices. These pathways are particularly relevant for sectors such as construction, logistics, and healthcare, where manual labor accounts for a significant share of value creation yet remains largely invisible to traditional process management systems. The five research propositions presented in Table 4 establish a clear agenda for empirical validation, addressing critical questions about modeling impact (**P1**), real-time support effectiveness (**P2**), dynamic planning optimization (**P3**), the benefits of refined task classification (**P4**), and the prerequisites for general data integration (**P5**).

We argue that the future of BPM depends not only on automation but also on creating a comprehensive support ecosystem for all tasks, regardless of who performs them. This approach enhances overall process efficiency and effectiveness. By elevating the operational perspective, we establish a more comprehensive, adaptable, and effective foundation for process management that reflects the true complexity of modern work environments.

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