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Laying the ground for future cross-organizational process mining research and application: a literature review

Julian Rott
Technical University of Munich, Munich, Germany
Markus Böhm
University of Applied Sciences Landshut, Landshut, Germany, and
Helmut Krcmar
Technical University of Munich, Munich, Germany

Abstract

Purpose – Process mining (PM) has emerged as a leading technology for gaining data-based insights into organizations' business processes. As processes increasingly cross-organizational boundaries, firms need to conduct PM jointly with multiple organizations to optimize their operations. However, current knowledge on cross-organizational process mining (coPM) is widely dispersed. Therefore, we synthesize current knowledge on coPM, identify challenges and enablers of coPM, and build a socio-technical framework and agenda for future research.

Design/methodology/approach – We conducted a literature review of 66 articles and summarized the findings according to the framework for Information Technology (IT)-enabled inter-organizational coordination (IOC) and the refined PM framework. The former states that within inter-organizational relationships, uncertainty sources determine information processing needs and coordination mechanisms determine information processing capabilities, while the fit between needs and capabilities determines the relationships' performance. The latter distinguishes three categories of PM activities: cartography, auditing and navigation.

Findings – Past literature focused on coPM techniques, for example, algorithms for ensuring privacy and PM for cartography. Future research should focus on socio-technical aspects and follow four steps: First, determine uncertainty sources within coPM. Second, design, develop and evaluate coordination mechanisms. Third, investigate how the mechanisms assist with handling uncertainty. Fourth, analyze the impact on coPM performance. In addition, we present 18 challenges (e.g. integrating distributed data) and 9 enablers (e.g. aligning different strategies) for coPM application.

Originality/value – This is the first article to systematically investigate the status quo of coPM research and lay out a socio-technical research agenda building upon the well-established framework for IT-enabled IOC.

Keywords Cross-organizational process mining, Inter-organizational coordination, Literature review, Challenges, Enablers, Research agenda

Paper type Literature review

1. Introduction

Process mining (PM) recently evolved as a key technology for continuously gaining insights into the actual business processes of an organization. Compliance violations and performance optimization potentials can be detected (Van Der Aalst, 2011c), process transparency

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increased, process standardization assisted and process deviations reduced (Buijs and Reijers, 2014; Yilmaz and Senkul, 2015). Despite its potential for cross-organizational optimization, it has mainly been implemented and investigated in the context of a single firm or system (Mendling *et al.*, 2020; Thiede *et al.*, 2018). Globalization and digital transformation, however, marked a paradigm shift in how organizations run their operations (Mendling *et al.*, 2020). Value chains are increasingly going beyond the boundaries of a single firm, for example, to efficiently produce and deliver products in supply chains (Lamghari *et al.*, 2020). Hence, an organization is only responsible for certain parts of the overall process and does not have access to all the process data, as the information exchange is hampered by specific barriers, for example, a lack of trust, incompatible Information Technology (IT) systems or a lack of interest alignment (Beynon-Davies and Wang, 2019; Engel *et al.*, 2013b; Ghosh and Fedorowicz, 2005) but also a lack of awareness about the optimization potential. Thus, operational inefficiencies are omnipresent, and business processes are not optimized across organizations (Capgemini, 2012). To improve operations in inter-organizational settings, however, an involved organization needs to obtain additional perspectives from outside; for example, by collaborating with partners for business process optimization (Claes and Poels, 2014). When data from multiple organizations is shared and analyzed with PM, this is called cross-organizational PM (coPM), one of the main challenges of PM (Van Der Aalst *et al.*, 2012; R'bigui and Cho, 2017). In the same way, Vom Brocke *et al.* (2021) called for research on the ecosystem level of PM and thereby on PM across organizational boundaries, while Martin *et al.* (2021) identified inter-organizational value creation from PM as a highly relevant opportunity for practitioners, for example, by understanding large, complex processes and the interactions taking place between actors within the process (Helm and Küng, 2016) to increase process efficiency or leverage monetary and non-monetary values (Badakhshan *et al.*, 2022).

Organizations can generally achieve technological innovation and progress with a sole engineering spirit. The adoption, however, is also influenced by organizational and environmental factors (Tornatzky and Fleischer, 1990). Literature reviews have already proven value in synthesizing, advancing and guiding knowledge in multiple areas surrounding PM and business process management (BPM), for example, the usage of PM in organizations (Thiede *et al.*, 2018), the application of artificial neural networks for PM (Maita *et al.*, 2015), agile BPM (Badakhshan *et al.*, 2020), and the relationship between Industry 4.0 and BPM (Bazan and Estevez, 2022). As we will present in this article, current literature on coPM is widely dispersed and lacks socio-technical aspects. Hence, to synthesize the status quo, understand the involved challenges, identify enablers of coPM and point out valuable future research directions, we conducted an assessing literature review (Leidner, 2018). As stated by Leidner (2018), an assessing literature review builds upon an established framework or theory, which is used during the literature coding process to identify under- and over-investigated areas. Accordingly, we applied the research framework for inter-organizational coordination (IOC) (Bensaou and Venkatraman, 1996) as an organizing device for synthesizing the current state of knowledge and building a research framework and a research agenda for coPM. Hence, we aim to answer the following three research questions:

RQ1. What is the current state of the literature regarding coPM?

RQ2. Which challenges evolve from applying PM in a cross-organizational context?

RQ3. Which enablers assist researchers and organizations in applying coPM?

In addition, we build a research framework and agenda that lays the ground for future socio-technical research on PM across organizational boundaries. We expect practitioners to leverage the challenges and enablers arising in their respective contexts and encourage researchers to reduce the number of research gaps identified.

Overall, we add to the BPM and Information Systems (IS) literature by emphasizing the importance of studying coPM as a broad socio-technical phenomenon, rather than a pure technical challenge. In addition, we derive a future research agenda, pointing to critical, promising, and so far under-investigated topics and provide a conceptual background for future research. This will assist researchers in advancing our understanding of how PM can unleash value potentials across organizational boundaries (Martin *et al.*, 2021). We further add to the literature body on inter-organizational IS and inter-organizational data analysis by presenting the current state of knowledge on coPM. This and the identified challenges and enablers will also assist practitioners in applying coPM.

The rest of the article is structured as follows. Section 2 presents the theoretical background on BPM and (cross-organizational) PM. Section 3 describes the literature review design and introduces the framework for IOC that guides our literature analysis. Section 4 presents the results of our literature review in four sub-sections. Beginning with a descriptive overview of the data and processes analyzed within the selected articles, it continues with summarizing the current state of knowledge on coPM according to the dimensions of the framework for IOC and the refined PM framework. Subsequently, challenges and enablers of coPM are presented. Section 5 discusses the research results, presents future research directions, describes the theoretical and practical implications and outlines the research's limitations. Finally, Section 6 concludes the paper.

2. Theoretical background

This section will first introduce BPM as an overarching approach in which PM is embedded. Second, we explain the founding aspects of PM in and across organizations. We limit our description to the fundamentals, as we will elaborate on coPM as a result of the literature review in detail during Section 4. Third, we will summarize the identified research gaps and thereby provide additional motivation for our study.

2.1 Business process management

Organizations execute business processes during their operation to satisfy their customers. It is in their utmost interest to ensure that their processes run smoothly and are performed efficiently and effectively. These processes, however, are usually not fully optimized, resulting in inefficiencies and unwanted financial consequences, for example, higher costs or longer cycle times (Capgemini, 2012). Therefore, BPM aims to tackle those inefficiencies and increase an organization's operational performance. Toward this end, six phases need to be implemented: *Process identification* seeks to select the process to investigate and improve, including defining a systematic way to identify the next process to tackle. Subsequently, the *process discovery* phase creates a process model representing how the process is executed. Afterward, the *process is analyzed* to identify improvement potentials, for example, redundant activities. Then, the *process is redesigned* to overcome the previously identified issues before the new *process is implemented* in reality. Finally, the *process is monitored* to gather information on its execution and increase operational transparency. Organizations iterate through these cycles to ensure continuous improvement, thereby implementing a BPM lifecycle (see Figure 1). The application of those stages is supported by various tools, methods, and techniques, for example, interviews to gather information on process behavior or a workflow system to ensure the process is executed as intended (Dumas *et al.*, 2018).

2.2 Process mining in and across organizations

The Big Data Analytics (BDA) technology PM was developed to support the BPM lifecycle, especially during process discovery, analysis, redesign and monitoring; hence, boosting operational performance by building upon data that is already stored in organizations' IS. Following the idea of Van Der Aalst (2016), we consider PM in this article as the "missing link" between BPM and BDA, combining process-centric principles from BPM with data-centric principles from BDA.

The refined PM framework of Van Der Aalst (2016) builds upon two kinds of event data (pre-mortem: current data; post-mortem: historic data) and two types of process models (de jure models: normative; de facto models: descriptive) and distinguishes three categories of PM activities:

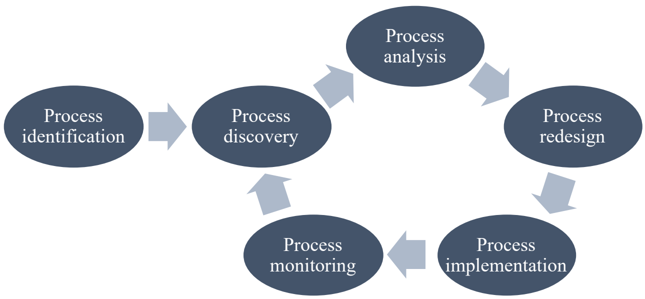
(1) *Cartography* (Discovery, Enhance, Diagnose): Process models describing the actual behavior hidden in the event log can be automatically *discovered* and further *enhanced*, for example, by adding performance-related information. Subsequently, these models can be manually *diagnosed*, for example, to discover inefficiencies or bottlenecks and identify causal dependencies between individual tasks (Van Der Aalst, 2010).

(2) *Auditing* (Detect, Check, Compare, Promote): An event log can be evaluated against an existing process model to show if it is in conformance with it. This can happen with post-mortem data (*Check*) or with pre-mortem data (*Detect*). Furthermore, multiple event logs or process models can be *compared* to identify differences and commonalities, including their root cause and performance impact as the basis for *promoting* desirable future process behavior, for example, improving a de jure process model.

(3) *Navigation* (Explore, Predict, Recommend): Navigation refers to forward-looking PM activities, either *explore* currently running cases and compare them with historic ones, *predict* future process behavior or *recommend* actions to undertake to impact process operations proactively.

Applying PM requires that within the event log, cases representing process instances can be identified (e.g. through a case ID), events happening for each case are recorded (e.g. described through activity names), and an ordering can be derived, for example, by looking at the events' timestamps (Van Der Aalst, 2011c). Additional information, such as resources, costs and location, can be integrated into the analysis to derive further insights. The event log subsequently serves as the input for PM algorithms which, for example, in the discovery use case, automatically derive a process model (Van Der Aalst, 2011c).

Organizations realizing PM projects typically pursue five steps (Van Der Aalst *et al.*, 2012). First, they plan and justify the PM project. Second, building upon an understanding of the domain, the data, and the project's goal, they extract event-log data and corresponding



Source(s): Figure by authors

Figure 1. BPM lifecycle adapted from Dumas *et al.* (2018)

information (e.g. from an organization's domain experts). Third, they discover a control-flow model linked to the event log. Fourth, they create an integrated process model by enhancing the basic model with supplemental information (e.g. resources performing activities or costs associated with activity execution). Fifth, they continuously interpret the results for process intervention, prediction and optimization; hence, applying the model for ongoing operational support. Overall, PM projects usually lead to the creation of business value in the form of improved process efficiency (e.g. reduction of cycle time), realized monetary values (e.g. working capital improvement) or non-monetary values (e.g. higher customer satisfaction) and can further enhance organizational learning and innovation (e.g. enable data-driven decisions and generate new process-related knowledge) (Badakhshan *et al.*, 2022; Mamudu *et al.*, 2023).

When multiple organizations provide data for cooperative PM analyses, it is called "cross-organizational PM," of which two variations can be distinguished (Van Der Aalst, 2011b): *Collaboration* refers to analyzing situations in which multiple organizations perform a cross-organizational business process together (e.g. in a supply chain or at airports) to pursue a worthwhile common goal (Bala and Venkatesh, 2007). In this scenario, firms can interoperate in various ways and under different forms of hierarchy (Van Der Aalst, 1999): For example, the overall process can be split into disjunct subprocesses, executed sequentially by different organizations ("Chained execution"), for example, a collaboration between an original equipment manufacturer (OEM) and several suppliers. Also, the process can be divided into various locally defined subprocesses, while only the communication protocol is known to all organizations ("Loosely coupled"), for example, at an airport, where airlines, ground handling corporations, and the airport operator cooperate (Böhm *et al.*, 2021). In this case, the goal of collaborative coPM is, for example, to identify and overcome inefficiencies at the intersection of the participating organizations or to select essential data that can be shared continuously to improve operations (Engel *et al.*, 2016). The second variant of cross-organizational process mining (coPM) is called "*exploiting commonality*" and refers to the situation where different organizations perform variants of the same intra-organizational business process and apply PM to identify reasons for performance differences, also referred to as benchmarking (Van Der Aalst, 2011b). The comparison can happen between competitors (e.g. comparing the operational performance of multiple airlines at an airport or analyzing the production process of different suppliers of an OEM) or between non-competing organizations (e.g. analyzing a patient-handling process across various hospitals or investigating citizen-related services across multiple municipalities) (Buijs and Reijers, 2014; Partington *et al.*, 2015; Van Der Aalst, 2010).

2.3 Summary of research gap and practical motivation

Van Der Aalst *et al.* (2012) stated that coPM is one of the main challenges of PM, as multiple organizations need to merge their event logs in a way that preserves privacy. R'bigui and Cho (2017) recently emphasized the remaining relevance of this challenge. As we will observe in this article, privacy preservation is only one part of multiple challenges surrounding coPM. Hence, the question arises whether the early focus on privacy-preservation guided research in this area and thereby led to defocusing other aspects of coPM, which in turn led to low coPM adoption so far.

In addition, Vom Brocke *et al.* (2021) called for research on the ecosystem level of PM and thereby on PM across organizational boundaries, while Martin *et al.* (2021) identified inter-organizational value creation from PM as a highly relevant opportunity for practitioners. Also, Grisold *et al.* (2021) reported a practitioner-based need to answer various socio-technical questions surrounding the adoption and usage of PM. Past research on coPM, however, is widely dispersed and mainly focused on technical aspects. This technical focus is demonstrated by the literature reviews by Jokonowo *et al.* (2018) and Jacobi *et al.* (2020) on

PM in supply chains with Jacobi *et al.* (2020) stating that "from a technical point of view (privacy, data conversion, and merging), we conclude that there is nothing to hinder cross-organizational process mining in supply chains." The core of the IS discipline, in contrast, is the understanding that IS are human-machine-systems, and, therefore, socio-technical systems combining machine components with humans (Krcmar, 2015; WKWI, 1994). This socio-technical perspective, linking technical systems (e.g. technologies) with social systems (e.g. people) (Bostrom and Heinen, 1977), however, was usually neglected, though it is long acknowledged that IS fail due to misalignments with organizational behavior (Bostrom and Heinen, 1977). Against this background, the premise for socio-technical research is that people and technology are mutually constituted, while this mutuality is embedded within a certain context and involves multiple parties and goals (Sawyer and Jarrahi, 2014). Also, Mendling *et al.* (2020) and Mikalef and Krogstie (2020) highlight the need to understand the context in which digital innovation, such as BDA or BPM, is executed. Furthermore, in practice, coPM is still very seldomly adopted (Thiede *et al.*, 2018) despite the widespread execution of cross-organizational business processes and high interest among organizations (Reinkemeyer, 2022; Rott and Böhm, 2022a).

Therefore, we aim to unravel the neglected areas of past coPM research and broaden the future research scope toward the inclusion of socio-technical aspects. With their focus on socio-technical phenomena, we strongly believe that BPM and IS research can provide important suggestions for research and practice, easing coPM adoption and advancing socio-technical coPM research.

3. Research approach

3.1 Design of the literature review including IT-enabled inter-organizational coordination as the theoretical foundation

According to Leidner (2018) and in line with recommendations by Rowe (2014), we conduct an assessing literature review to systematically synthesize the current state of knowledge, including challenges and enablers of coPM and with the focus on identifying trends and research gaps. The goal is to derive a research agenda for coPM, emphasizing the socio-technical relevance for the BPM and IS community, and guide practitioners conducting coPM, thereby fostering its practical implementation. An assessing literature review requires an existing framework or theory (Leidner, 2018). Hence, we searched for socio-technical cross-organizational theories via Scopus using the following search term *("collaboration" OR "inter-organizational" OR "cross-organizational") and ("theory" or "framework")*. Examining different theories resulted in the selection of the framework for IOC (Bensaou and Venkatraman, 1996). We chose it because it builds upon well-established and empirically validated theories (Organization theory, Transaction cost economics and Political economy). Furthermore, it allowed us to position coPM as part of a larger and long-lasting relationship between the organizations. This, we believe, is crucial, as the effort required for coPM would not make sense in a short- or one-time collaboration. Finally, it covers aspects of coPM that relate to the technology (e.g. algorithms for coPM) and to non-technical issues (e.g. goal compatibility of the organizations), thereby emphasizing the importance of the socio-technical cross-organizational context in which PM is applied.

Building upon established theories and the information processing view, the IOC framework by Bensaou and Venkatraman (1996) assists with understanding IT-enabled inter-organizational relationships (see Figure 2). On the one hand, it distinguishes between three types of uncertainty (environmental, partnership and task uncertainty) that determine the need for the participating organizations to process information within their relationship. On the other hand, it describes three coordination mechanisms (structural, process and IT-mediated mechanisms) that define the organizations' capability to process information.

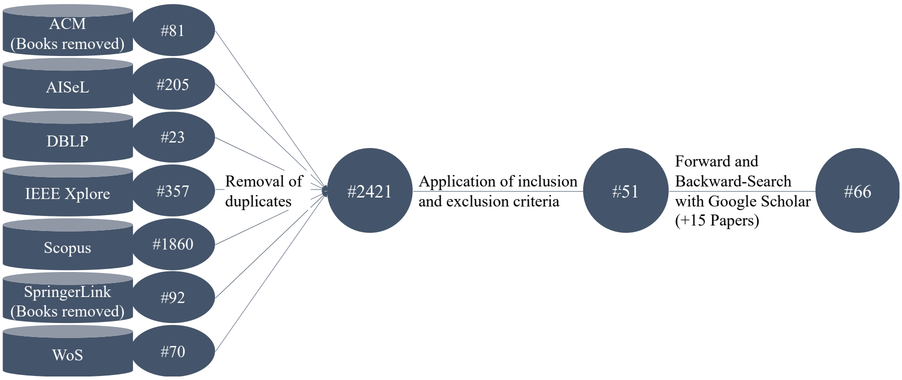


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Figure 2.
Literature-search and -screening process

Overall, the "fit" between the information processing needs and the information processing capabilities determines the inter-organizational relationship performance. Hence, the performance is hampered, when high uncertainty cannot be handled with sufficient coordination mechanisms, but also, when low uncertainty is encountered with great amounts of coordination mechanisms, resulting in a scenario where resources are wasted. To answer our research question, we focus on inter-organizational relationships enabled or supported through the application of coPM. Hence, we consider techniques for coPM (see Section 4.2.5.) as IT-enabled mechanisms (Bensaou and Venkatraman, 1996). In the following, we will briefly describe each uncertainty source and coordination mechanism, as this framework lays the theoretical foundation for summarizing the current state of the literature on coPM and building a coPM research framework and research agenda.

Environmental uncertainty: Environmental uncertainty covers the overall conditions of the market (e.g. influenced by governmental regulations) and the intra-organizational environment (e.g. educational background of employees (Duncan, 1972)) that influence an inter-organizational relationship. Specifically, it refers to aspects that cover whether the environmental conditions of the participating organizations are homogeneous or heterogeneous and whether they change over time or remain stable.

Partnership uncertainty: Partnership uncertainty refers to the expected uncertainty between the partners. It encompasses the following three aspects: First, the compatibility of each partner's goals, promoting or hampering a long-term relationship. Second, the presence of trust, influencing the need to monitor each other's actions. Third, any form of power dependence, influencing the uncertainty of opportunistic behavior by the non-dependent partner and limiting the action space for the dependent partner.

Task uncertainty: The most specific uncertainty refers to the task level and, according to organization theory, is grounded in three characteristics: Task analyzability, referring to a specification of task execution; task variety, summarizing unforeseen effects that require an adjustment in task performance; and task interdependence, stating the relationship and dependence between executed tasks, for example, sequential, parallel or reciprocal.

Structural mechanisms: Structural mechanisms assign authority and roles within the inter-organizational relationship and are characterized by five attributes (the adjective in brackets states which peculiarity leads to higher information processing capabilities): level of formalization (low), intensity (high), multiplicity (high), asymmetry (low) and boundary interpenetration (high).

Process mechanisms: Process mechanisms describe the socio-political atmosphere surrounding the structural mechanisms and "range along a cooperative-conflictual continuum" (Bensaou and Venkatraman, 1996). They influence how liberally information is shared within the relationship and are determined by the dimensions of conflict, cooperation and commitment.

IT-mediated mechanisms (coPM): They cover how IT is used to support an inter-organizational relationship. According to Bensaou and Venkatraman (1996), four dimensions can be used to characterize IT-mediated mechanisms (the adjective in brackets states which peculiarity leads to higher information processing capabilities): level of intensity of use (high), asymmetry (low), integration (high) and scope (large). For the rest of the article, IT-mediated mechanisms are focused on the technology of PM and its application in a cross-organizational context.

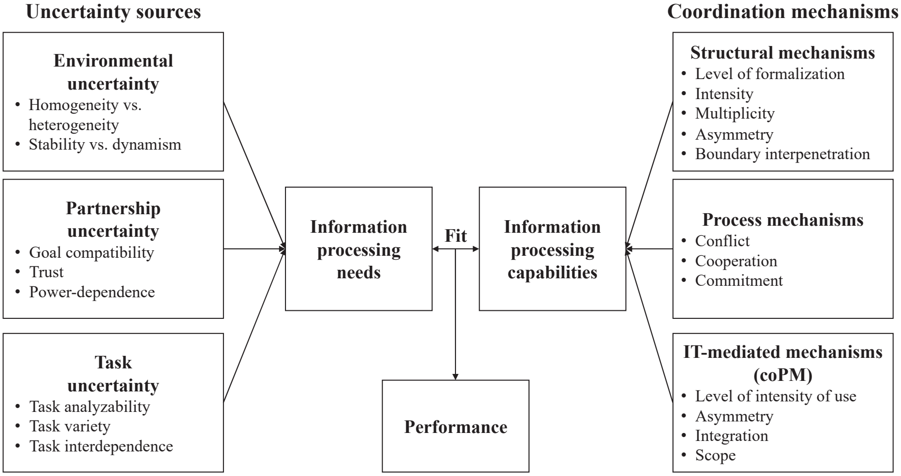
3.2 Literature search and selection

Throughout the systematic literature-search process, which is guided by Vom Brocke *et al.* (2009) and Webster and Watson (2002), we used the following search term:

> ("process mining" OR "workflow mining") AND ("cross-organization"* OR "inter-organization"* OR "cross-firm" OR "inter-firm" OR "across organization"* OR "interorganizational" OR "crossorganizational" OR "supply chain" OR "federated")

We iterated multiple times until this term was formed. Originally and in line with suggestions of Vom Brocke *et al.* (2009), we searched broadly and included the terms *"Process orchestration," "Process Management"* and *"Workflow management."* This assisted us with identifying the right terminology, leading to the inclusion of different styles of writing certain terms (e.g. *"inter-organizational," "interorganizational"* and *"inter-organization"*). However, it also resulted in the majority of articles covering aspects not related to PM. Furthermore, we decided to include the term "federated," which was recently introduced by Van Der Aalst (2021) and the term *"supply chain"* since we found several articles mentioning PM in supply chains, thereby referring to coPM without explicitly stating it. We applied our search term in a database search including the following popular databases: ACM (Association for Computing Machinery) Digital Library, AISeL (Association for IS eLibrary), DBLP (Database Systems and Logic Programming) Computer Science (CS) Bibliography, IEEE Xplore, Scopus, SpringerLink and WoS (Web of Science). Together, these databases cover various relevant outlets for our topic. On the one hand, several conferences and journals on PM and BPM are included (e.g. international conference on PM and BPM journal). On the other hand, several outlets with a strong focus on technological and engineering aspects of coPM are covered (e.g. IEEE Access and Lecture Notes in CS). Finally, the database search covers IS journals (e.g. the recommended journals of the AIS special interest group on decision support and analytics (Association for Information Systems, 2023) and the leading IS journals, indicated through the AIS Senior Scholars' List of Premier Journals (Association for Information Systems, 2023)) and IS conferences. This, we believe is important, as it is at the core of the IS discipline to investigate IT-enabled socio-technical phenomena, and in our case, cross-organizational collaboration through process mining.

Using our search term led to 2,421 unique hits (see Figure 3). We read the abstract of every article and in case of doubt, the full article, and selected 51 publications by applying our inclusion and exclusion criteria. We selected articles where PM was applied or discussed (mandatory inclusion criteria). To be included, the article further needed to cover a process mining use case with event-log data (real or artificial) from at least two distinct organizations, develop a new technique, enabling coPM analysis or data pre-processing for coPM or cover socio-technical aspects of coPM. Hence, we excluded articles where cross-organizational business processes were analyzed without PM techniques or without event-log data and



Source(s): Figure by authors

Figure 3. Framework for inter-organizational coordination adapted from Bensaou and Venkatraman (1996)

articles that developed or applied PM techniques on intra-organizational processes or solely with data from a single organization. By recursively searching back and forth (Webster and Watson, 2002) with the help of Google Scholar, 15 additional publications in line with our inclusion and exclusion criteria were added to the selection, resulting in a set of 66 articles for the literature review (see Table 1). In addition to the search and selection of scientific articles, we looked for practitioner-oriented resources (e.g. blogs on PM or white papers from vendors and consultancies) using Google, and searched with the terms "cross-organizational process mining," "inter-organizational process mining" and "process mining across organizations." This, however, did not reveal additional articles matching our inclusion and exclusion criteria. Instead, most of the search results were either links to the scientific articles already identified within our database search, or only mentioned coPM as an interesting future topic.

Overall, all articles are spread over 47 different outlets, while only two outlets provide more than three articles for our literature analysis (International Conference on BPM: seven; International Carnahan Conference on Security Technology: four). Despite that, no dominant outlet exists (the outlet of each selected article can be found in Appendix 2). In addition, the topic was more prevalent in various specialized conferences with a narrow focus on certain domains or technological aspects (e.g. *International Conference on Information Technology in Bio- and Medical Informatics*, and *Studies in Health Technology and Informatics*), than in general IS and CS journals or conferences. Hence, our literature review has the potential to link the dispersed coPM literature to the BPM and IS domain, trigger research interest among BPM and IS scholars, and provide a structured and conceptual background for future research. As we will elaborate on within the next sections, this is desperately needed. CoPM was mentioned 20 years ago for the first time (Maruster *et al.*, 2003), stated as one of the main challenges of PM in 2012 (Van Der Aalst *et al.*, 2012) and 2017 (R'bigui and Cho, 2017), and still remains unsolved in practice. This, however, is the case despite technological advances that have been achieved, for example, regarding algorithms for preserving privacy and concepts for cross-organizational data pre-processing and integration (Jacobi *et al.*, 2020). Hence, we strongly believe that the root causes for little coPM adoption need to be explained and laid out adopting a socio-technical perspective, thereby providing a unique possibility for the BPM and IS domain to trigger research on various aspects of coPM and provide assistance for researchers and practitioners.

Outlet	Number of selected articles
ACM Transactions Management Information Systems	1
Annual SRII Global Conference	1
Applied Sciences	1
Asia–Pacific Conference on Business Process Management	2
Collaborative Systems for Production Management	1
Decision Support Systems	1
Enterprise, Business Process and Information Systems Modeling	3
European Conference on Advances in Databases and Information Systems	1
European Conference on Web Services	1
Expert Systems with Applications	1
Hawaii International Conference on System Sciences	2
IEEE Access	3
IEEE Conference on Business Informatics	2
IEEE Conference on Commerce and Enterprise Computing	1
IEEE Conference on Communications and Network Security	1
IEEE International Carnahan Conference on Security Technology	4
IEEE International Congress on Big Data	1
IEEE Symposium on Computational Intelligence and Data Mining	1
IEEE Transactions on Automation Science and Engineering	1
IEEE Transactions on Services Computing	1
IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans	1
IEEE Transactions on Systems, Man, and Cybernetics: Systems	1
IFIP Working Conference on The Practice of Enterprise Modeling	1
Information Systems and e-Business Management	1
Information Systems Frontiers	2
International Conference Europe Middle East and North Africa Information Systems and Technologies to Support Learning	1
International Conference on Advanced Information Systems Engineering	2
International Conference on Business Information Systems	2
International Conference on Business Process Management	7
International Conference on Digital Government Research	1
International Conference on Electronic Commerce and Web Technologies	1
International Conference on Information Technology in Bio- and Medical Informatics	1
International Conference on Management and Service Science	1
International Conference on Process Mining	1
International Conference on Service-Oriented Computing	1
International Conference on Smart Data Services	1
International Conference on Web Services	1
International Journal of Business Process Integration and Management	1
International Journal of Production Research	1
International Symposium on Data-driven Process Discovery and Analysis	1
Journal of Information and Knowledge Management	1
Logistics Journal	1
On the Move to Meaningful Internet Systems Conference	1
Pacific Asia Conference on Information Systems	1
PeerJ Computer Science	1
Studies in Computational Intelligence	1
Studies in Health Technology and Informatics	1
Sum	66

Source(s): Table by authors

Table 1. Number of selected articles per outlet

3.3 Analysis of the identified articles

We built three concept matrices (Webster and Watson, 2002) with a different focus. In the first one (see Appendix 2), each identified article is conceptualized according to the constructs of the IOC framework (Bensaou and Venkatraman, 1996), whereby multiple categories can be assigned to one article. Appendix 2 shows the definitions we have followed to assign a category to an article. This built the foundation for summarizing the current knowledge of coPM in terms of the constructs of the IOC framework. Due to the large number of articles focusing on IT-mediated mechanisms, we further built a concept matrix according to the refined PM framework (Van Der Aalst, 2016) as the basis for summarizing the current state of the literature on coPM techniques and pointing out under-investigated areas (see Table 3). In addition, the structure of the third concept matrix (see Table 2) focuses on the type of coPM (collaboration or exploiting commonality), the data and the processes used for evaluation purposes.

For an in-depth analysis of the article information regarding challenges and enablers of coPM, we further performed an open line-by-line coding of each article to reveal first-order concepts based on direct quotes from the original article (Gioia *et al.*, 2013) using Microsoft Excel. By following an abductive approach (Gioia *et al.*, 2013) using "challenge" and "enabler" as selective codes, we identified 248 relevant first-order concepts relating to challenges and 185 first-order concepts relating to enablers. Subsequently, we grouped the first-order concepts into second-order themes, which resulted in 18 challenges and 9 enablers. For example, the first-order concepts *"comparability can be questioned," "determine comparability between organizations,"* and *"challenge of ensuring population comparability"* are summarized into the challenge *"Ensure comparability and semantic alignment."* Following the idea of Gioia *et al.* (2013), we further grouped the 18 challenges into 6 categories and the 9 enablers into 3 categories to increase the understandability for the reader. An example, representative of the general procedure, can be found in Appendix 3. The open line-by-line coding was performed by the first author. To mitigate bias, all challenges and enablers were subsequently discussed between the first two authors until an agreement was reached on how to define each. In addition, as represented through the high number of direct quotes in Section 4.3 and Section 4.4, each challenge and enabler was defined closely to the original source text fragments to ensure that the author's own background does not bias the results. Finally, we screened all first-order concepts on enablers and challenges to identify relationships between them. We draw a relation between a challenger and an enabler only in case of a direct representation in the source text, for example, the quote, "*Anonymisation of patient records was applied at the extraction level in order to preserve privacy.*" Partington *et al.* (2015), represented through the first-order concept *"Anonymization for privacy ensurance,"* relates to both the challenge *"Ensure data privacy"* and the enabler *"Pre-process data (Anonymization)."* In the same way, the first-order concept *"Replace sensitive information by ciphering or hashing,"* originating from the text fragment "*software agents can replace sensitive information in observation by ciphering it or using hash functions*" (Talamo *et al.*, 2013a), is part of the enabler *"Pre-process data"* and relates to the challenge *"Implement data security."* By doing so, we identified 48 concepts that form 17 relations between the identified challenges and enablers.

For building our research agenda, we combined gap-spotting and problematization strategies (Alvesson and Sandberg, 2013). First, building upon the current state of literature, we identified the areas of coPM that, according to the elements of the IOC framework, have not been investigated so far. Subsequently, we critically questioned the literature gaps by screening the founding papers of the IOC framework and identifying research questions that need to be addressed. Third, we problematized existing work on coPM by challenging some of the underlying assumptions (e.g. coPM always requires privacy preservation). Fourth, we reviewed theories applied in the IS discipline (see https://is.theorizeit.org/wiki/Main_Page for an overview) to identify those (see Section 5.3) that provide a theoretical foundation and perspective for our research question and, thus, can potentially be advanced by investigating

Table 2. Concept matrix including the type of coPM, the evaluation data, the investigated process, and the data acquisition description

Source	E	C	Evaluation data A	R	Origin	Type of process analyzed or used for evaluation	Description of data acquisition
Mans *et al.* (2008)	X			X	Italian hospitals	Handling of stroke patients	Yes (Electronic clinical chart + interviews)
Gerke *et al.* (2009a)		X	X		Car manufacturer	Make-to-order production process	
Ho *et al.* (2009)		X		X	Not stated if the data is cross-organizational	Manufacturing process	–
Sun *et al.* (2011)		X	X		–	Product packaging process	–
Buijs *et al.* (2012b)	X			X	Dutch municipalities	Building permits process + Handling citizen complaints on housing tax process	- (Part of CoSeLog project)
Engel *et al.* (2012)		X		X	Automotive supplier company	Purchase order process + supply chain management process	–
Rozsnyai *et al.* (2012)	X	X	X		–	Order to cash process	
Buijs *et al.* (2013)	X			X	Dutch municipalities	Building permits process (Real)	- (Part of CoSeLog project)
Engel *et al.* (2013a)		X		X	Austrian consumer goods company	Purchase order process	–
Zeng *et al.* (2013)		X	X		Multi-modal transportation Hospital	Multi-modal transportation process Health care process	–
Bernardi *et al.* (2014)	X		X		Dutch municipalities	Acknowledging an unborn child process	–
Buijs and Reijers (2014)	X			X	Dutch municipalities	Building permits process	- (Part of CoSeLog project)
Claes and Poels (2014)	Establishes pre-conditions		X	X	No cross-organizational data. A: Accounting and warehouse software for order handling R: Volvo, Ghent University	Order handling (A), call center support process (artificially divided real) Factory and customer orders (R) Payroll process (R)	Yes (provided by Volvo)
Engel and Bose (2014)		X		X	German consumer goods manufacturing company	Process of ordering, dispatching, and invoicing of goods	–
Krathu *et al.* (2014)		X		X	Beverage manufacturing company	Purchasing process	
Suriadi *et al.* (2014)	X			X	Australian hospitals	Health care process (Patients with chest pain symptoms)	Yes (central repository in each clinic)
Partington *et al.* (2015)	X			X	Australian hospitals	Health care process (Patients with chest pain symptoms)	Yes (central repository in each clinic)
Pini *et al.* (2015)	X			X	Australian hospitals		

(*continued*)

Table 2.

Source	E	C	Evaluation data A	R	Origin	Type of process analyzed or used for evaluation	Description of data acquisition
Talamo *et al.* (2015)		X		X	–	IT services (Help desk process)	–
Yilmaz and Senkul (2015)	X		X	X	Dutch municipalities	(A) Loan application process (R) Environmental Permit Application Process	- (Part of CoSeLog project)
Aksu *et al.* (2016)	X			X	ERP Software vendor (But data not described and shown)	Sales process	Yes
Engel *et al.* (2016)		X		X	German consumer goods manufacturing company	Delivery process	–
Pourmasoumi *et al.* (2017)	X		X	X	–	Purchase order process + generic process	Yes (IBM BIT library)
Bernardi *et al.* (2018)	X			X	Online shops	Online products selling process	–
Wang *et al.* (2018)		X	X	X	A: R: Manufacturer in electronic equipment (no cross-organizational data)	A: Supply chain process R: Customs supervision	–
Canjels *et al.* (2019)		X		X	Dutch hospitals	Care process of knee osteoarthritis patients	Yes (hospital information system; list)
Klinkmüller *et al.* (2019)		X		X	Crypto Kitty	Cat lifecycle process	
Liu *et al.* (2019)		X	X		–	Multi-modal transportation process	–
Mühlberger *et al.* (2019)		X		X	–	Incident management process	
Deokar and Tao (2020)		X		X	No cross-organizational data (Electronics company)	Repair process of phones	–
Elkoumy *et al.* (2020a)		X		X	(1) Car company (2) Dutch ban (3) Italian police office	(1) Incident and problem management (2) Credit card background check (3) Collection of payment fines	Yes (publicly available)
Kim *et al.* (2020)		X	X		Supply chain	Supply chain process	–
Liu (2020)		X	X	X	Dutch financial institute	Loan application process, Hotel booking process	Yes (Publicly available)
Zeng *et al.* (2020)		X	X		–	Multi-modal transportation process	

(*continued*)

Source	E	C	Evaluation data A	R	Origin	Type of process analyzed or used for evaluation	Description of data acquisition
González and Delgado (2021)		X			Exemplary real-world scenario without explicitly stating the data used (Uruguayan e-Government Interoperability Platform)	Passport application process	
Hernandez-Resendiz *et al.* (2021)		X		X	Telecommunication industry	Purchase order process	
Morales-Sandoval *et al.* (2021)		X	X		–	Supply chain process, Rehabilitation process, Incident management	
van der Aalst (2021)		X		X	Italian information system managing road traffic fines	Road traffic fine management	Yes (Publicly available)
Corradini *et al.* (2022)		X	X		Hospital	Healthcare process	–
Liu *et al.* (2023a)		X		X	Hospital (Cross-department data)	Healthcare process	Yes (Publicly available)
Liu *et al.* (2023b)		X	X	X	A: R: Dutch financial institute, NASA	R: Loan application process, Hotel booking process, NASA Crew Exploration Vehicle Unit test process	Yes (Publicly available)
Rafiei and Van Der Aalst (2023)		X		X	Hospital (Cross-department data)	Healthcare process	Yes (Publicly available)
Tajima *et al.* (2023)		X		X	Dutch financial institute	Loan application process	Yes (Publicly available)

Note(s): E (Exploiting commonality); C (Collaboration); A (Artificial data); R (Real-world data)
Source(s): Table by authors

Table 2.

coPM. Finally, we constructed the coPM research framework by logically ordering the research areas to come up with a four-step guide that assists researchers in developing and evaluating a coordination mechanism that handles specified uncertainty sources and influences the performance of coPM.

4. Results

Within this Section, we describe the results of our literature review. We split the results into four different sub-sections that are largely independent from each other. First, we summarize the data and the processes that were investigated. Second, we synthesize the content of the articles following the structure of the IOC framework in general, and the structure of the refined PM framework for the coPM techniques in specific. Third, we unravel the challenges of coPM. Fourth, we describe enablers for the application of coPM.

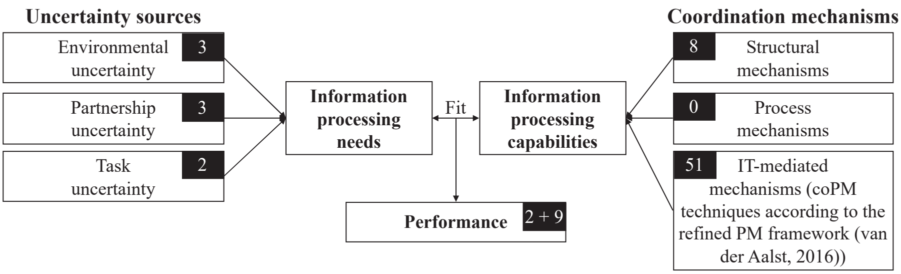
4.1 Concept matrix – data and process evaluated

Table 2 presents the processes under analysis for each article that evaluated their approach using real or artificial data, including the corresponding data. Real data originate mainly from hospitals, municipalities and manufacturing firms. Also, artificial data are regularly used. However, almost all articles lack a clear description of how the authors and companies retrieved the real data. Only one article, Aksu *et al.* (2016) described the data collection phase and problems of a cross-organizational nature. As we know from the literature body on information sharing in supply chains, this presents a challenge in practice, as firms may not be willing to share their event-log data.

Furthermore, many articles describe coPM from a conceptual point of view without using actual data. In addition, the academic PM tool ProM is the one primarily used as a data analysis tool, while, in contrast, industrial PM software is only used in three publications: Fluxicon Disco in Canjels *et al.* (2019), Fluxicon Disco in Tajima *et al.* (2023) and Celonis in Van Der Aalst (2021). Hence, we can observe a slight disconnect between the tools applied in coPM research and the ones applied in practice. Also, the analyzed processes most probably do not reflect the current state of coPM in practice as case studies with organizations are rare, indicating a possible difference between coPM as reflected through the literature and current practices of coPM applications in organizations.

4.2 Inter-organizational coordination through cross-organizational process mining

The results are described following the structure of the IOC framework (Bensaou and Venkatraman, 1996), applying PM across organizational boundaries (see Appendix 2 for a list of the articles that describe information for parts of the IOC framework). Overall (see Figure 4), most papers (51) focus on IT-mediated mechanisms (coPM techniques). Structural



Source(s): Figure by authors

Figure 4. Number of coPM articles for each construct of the IOC framework (Bensaou and Venkatraman, 1996)

mechanisms of coPM are covered in eight articles, whereas no article investigates process mechanisms. Looking at the uncertainty sources that determine information processing needs, we observe an almost even distribution of articles describing environmental (three), partnership (three) and task uncertainty sources (two). Two articles describe the impact of coPM on the performance of the inter-organizational relationship. In addition, nine articles reveal insights and thereby increase performance transparency. Hence, we can observe that mechanisms for handling information processing needs are covered more extensively than uncertainty sources determining information processing needs. This leads us to a first indicative conclusion: If we have focused our effort on structural mechanisms without knowing which uncertainty sources we have to handle, how can we ensure that our structural mechanisms assist with handling uncertainty? In the same way, as no article investigated the fit between one or multiple coordination mechanisms and their corresponding uncertainty sources, how do we ensure that we don't promote a misfit, for example, developing and recommending resource-intensive coordination mechanisms for coPM applications with low uncertainty (e.g. in a very open cross-organizational collaboration). We will elaborate more on these questions during the discussion (Section 5) and the future research section (Section 5.3).

4.2.1 Environmental uncertainty. Environmental uncertainty covers whether the organizations' conditions are homogeneous or heterogeneous and whether they remain stable or change over time (Bensaou and Venkatraman, 1996). As pointed out by Jacobi *et al.* (2020), supply chains increasingly face a dynamic and constantly evolving environment, for example, caused by more product variants and smaller order sizes. Hence, a higher uncertainty needs to be handled in coPM applications for supply chains. Wang *et al.* (2018), in addition, emphasize the relevance of international governmental regulations, when coPM is applied to early identify non-conformant behavior. Focusing on coPM to exploit commonalities, Aksu *et al.* (2016) developed a framework for accurately comparing inter-organizational business processes. Next to handling different business semantics (e.g. the activity "Evaluate a service request" may involve different steps in different organizations) and metric semantics (e.g. the throughput time of a service request process may be calculated by comparing the timestamp of the process start and the activity "Close" in one organization and the process start and the activity "Solve" in the other organization), the organizational context needs to be considered. It is determined by organization-internal factors, such as size (e.g. the number of workers) and environmental factors: locations and industry in which an organization operates and corresponding laws, regulations and geographical circumstances. These sources of environmental uncertainty are represented in the framework of Aksu *et al.* (2016) to ensure comparability when evaluating and contrasting the performance of multiple organizations.

4.2.2 Partnership uncertainty. Partnership uncertainty results from goal compatibility, trust and power dependence (Bensaou and Venkatraman, 1996). Looking at mechanisms for distributing the value between organizations of coPM, trust influences whether the organizations need to monitor the created value of each other or if they rely on the reported numbers before redistributing any form of value (Rott and Böhm, 2022b). If the organizations negotiate over value distribution shares, their power influences the outcome (Rott and Böhm, 2022b). Goal compatibility is mentioned by Ho *et al.* (2009) and Jacobi *et al.* (2020): In a global organizational network, contrasting goals may exist that hamper business process optimization (e.g. a supplier may want to increase its margin by improving process efficiency, while the manufacturer wants to use increased process efficiency to reduce the product price in order to boost product sales).

4.2.3 Task uncertainty. Three types of task uncertainty exist: task analyzability, task variety and task interdependence (Bensaou and Venkatraman, 1996). Partington *et al.* (2015) compare the patient-handling process of four Australian hospitals. *Task variety* and *task analyzability* are present, as the process is not fully automated and various paths for patient handling are possible. Which task needs to be executed is determined by patient-related factors (e.g. overall health conditions and previous treatments) and thus individually for each person. Therefore, task variety and analyzability need to be handled when multiple companies want to exploit commonalities using coPM. In contrast, *task interdependence* is especially relevant in collaborative scenarios. Engel *et al.* (2012) present a solution to pre-process EDIFACT messages (a standard for inter-organizational message exchange) to enable coPM. In this case, a product needs to be sent from the supplier to the manufacturer before it can be received (sequential task interdependence). If messages are exchanged, the supplier first issues a "product send" message, which is received by the supplier. Second, after receiving the product, the manufacturer issues a "product received" message, which is sent to and received by the supplier. Hence, the message exchange tasks are reciprocally interdependent. Process analysts need to be aware of task interdependence when evaluating the performance of a collaborative cross-organizational process; for example, when the throughput time of task B, executed by organization B, depends on the successful execution of task A, conducted by organization A.

4.2.4 Structural mechanisms. Structural mechanisms assign authority and roles within coPM (Bensaou and Venkatraman, 1996). Five kinds of them can be found in the coPM literature: methodologies for conducting coPM (Canjels *et al.*, 2019; Helm and Küng, 2016; Ho *et al.*, 2009; Maruster *et al.*, 2003), definitions of comparison metrics (Buijs *et al.*, 2012b) and collaboration metrics (Kim *et al.*, 2020), mechanisms for value distribution (Rott and Böhm, 2022b), and a language for formalizing business process compliance (González and Delgado, 2021).

Rott and Böhm (2022b) built upon a systematic literature review to identify mechanisms that can be applied to (re)distribute the value of coPM between the participating organizations and thereby handle partnership uncertainty. This may be necessary, as, for example, two organizations collectively analyze the process, while only one party is able to capture value from process improvement. Three types of metrics for comparing variants of the same business process are introduced by Buijs *et al.* (2012b): process model quality metrics; for example, soundness or complexity; performance indicators, such as the average execution time per case; and comparison metrics – for instance, precision. Collaborative performance metrics are presented for four dimensions by Kim *et al.* (2020) following the balanced scorecard methodology: finance (e.g. collaborative costs reduced), partnership (e.g. new partners acquired), collaboration process (e.g. number of schedule changes) and coevolution (e.g. collaboration satisfaction). González and Delgado (2021) present the compliance requirements modeling language that assists organizations in formulating compliance requirements that should be fulfilled in an inter-organizational process. Five dimensions can be distinguished: control-flow (e.g. one task needs to be executed before another), interaction (e.g. a message must be exchanged during the process), time (e.g. a task needs to be completed within a certain time), resources (e.g. a specific organizational unit needs to pursue a certain task) and data (e.g. a data object must be issued after performing a task).

Furthermore, four models for executing coPM projects are presented in the literature:

(1) *Extended L* lifecycle model:* Helm and Küng (2016) extend the L* lifecycle model for PM projects introduced in Van Der Aalst (2011c), which consists of five steps: [1] plan and justify, [2] extract, [3] create a control-flow model and connect the event log, [4] create an integrated process model and [5] operational support. To handle cross-organizational business processes, Helm and Küng (2016) suggest adding a compare and align step to the extract phase of every participating organization and continuously using the results from steps three and four to interpret, redesign, adjust and intervene the cross-organizational process.

(2) *Local and global PM cycle:* Ho *et al.* (2009), in contrast, present a cycle-based model for coPM of manufacturing networks consisting of a local cycle, executed for each party, and a global cycle, executed for the overall process. The local cycle comprises four steps:

measure the current situation, predict potential quality defects, identify measures for correction and implement changes. After each organization has executed the local cycle, the global cycle is implemented, consisting of (1) collecting the process logs, (2) filtering and pre-processing the data, (3) performing a trade-off analysis of different local measures to ensure a global optimization and (4) implementing the changes.

(3) *Three-step methodology for healthcare processes:* Canjels *et al.* (2019) introduce a three-step approach for healthcare scenarios. First, in the advanced data preparation phase, multiple steps are performed to ensure sufficient data quality for the subsequent steps: "(1) filter relevant diagnosis, (2) merge data, (3) exclude irrelevant activities, (4) cluster activities and (5) exclude patients with incomplete processes" (Canjels *et al.*, 2019). Second, clustering algorithms are applied to identify groups of patients with similar care activities. Third, the processes are analyzed and visualized together with subject matter experts.

(4) *Task registration-based methodology for supply chain processes:* Maruster *et al.* (2003) suggest an approach for analyzing supply chain processes that starts with each partner implementing a task registration system. During the implementation, the organizations need to agree on certain parameters that later enable matching the subprocesses. Subsequently, the logs from the task registration systems are processed with PM algorithms to discover a process model, which is finally analyzed to optimize the supply chain.

Comparing the different approaches, we observe that all include a step for data pre-processing. However, while Maruster *et al.* (2003) require the parties to track their process with an additional task registration system, the others build upon existing data that are pre-processed and integrated. Furthermore, we observe that the analysis phase is less extensively covered in the articles than the steps for data preparation, indicating a lack of research on how to properly analyze cross-organizational processes to gain value from coPM adoption. Furthermore, Ho *et al.* (2009) and Helm and Küng (2016) include a step for changing the process, which is not part of the methodologies of Maruster *et al.* (2003) and Canjels *et al.* (2019).

4.2.5 IT-mediated mechanisms (coPM techniques). Due to the large number of articles focusing on IT-mediated mechanisms, we built a concept matrix (see Table 3) following the structure of the refined PM framework (Van Der Aalst, 2016) and briefly summarized the articles according to the main PM activities [1] (see Section 2.2): Cartography (models describing organizational processes), Auditing (comparison of process behavior) and Navigation (forward-looking PM activities). This involves all articles that focused on developing a new technique for coPM or presented an overall technical architecture. Also, we summarize 14 articles that focused on data pre-processing as a prerequisite of coPM and a possible way to apply standard PM techniques and 7 articles leveraging blockchain technology for coPM. Interested readers are encouraged to read the original articles for detailed information on each technique.

Overall, most articles (33) focused on analyzing post-mortem event data (data of completed cases) and building de facto process models (descriptive models), while pre-mortem event data (data of non-completed cases) and de jure models (normative process models) are leveraged in a minority of articles. Looking at the PM activities, the majority of articles (35) focused on cartography, while 13 articles developed or applied approaches for auditing and 7 for navigation purposes.

4.2.5.1 Data pre-processing. Pre-processing an event log may be needed, for example, because the available data is stored in a form that does not allow the direct application of PM algorithms:

Table 3.
Concept matrix according to the refined PM framework (van der Aalst, 2016)

Article	Event data Pre-mortem	Post-mortem	Process model De jure	De facto	Activities Cartography Discover	Enhance	Auditing Detect	Check	Compare	Promote	Navigation Explore	Predict	Recommend
Aksu *et al.* (2016)		X		X		X			X	X			
Bernardi *et al.* (2014)	X		X	X	X						X		X
Bernardi *et al.* (2018)	X		X	X	X						X		X
Buijs and Reijers (2014)		X		X		X			X				
Buijs *et al.* (2013)		X		X	X								
Corradini *et al.* (2022)		X		X	X								
D'Iddio *et al.* (2016a)	X	X	X				X	X					
D'Iddio *et al.* (2016b)	X	X	X				X	X					
Deokar and Tao (2020)		X		X	X	X							
Engel *et al.* (2016)		X		X	X	X							
Elkoumy *et al.* (2020a)		X		X	X								
Elkoumy *et al.* (2020b)		X		X	X								
Hernandez-Resendiz *et al.* (2021)		X		X	X								
Ho *et al.* (2009)	X			X	X							X	X
Ivković and Luković (2021)		X	X	X	X			X					
Khan *et al.* (2021)		X		X	X								
Kim *et al.* (2020)		X	X	X	X	X		X				X	
Krathu *et al.* (2014)		X		X	X	X							
Lamghari *et al.* (2020)		X		X	X								
Li (2010)		X		X	X								
Liu (2020)		X		X	X								
Liu *et al.* (2019)		X		X	X								
Liu *et al.* (2023a)		X		X	X								

(*continued*)

Table 3.

Article	Event data Pre-mortem	Post-mortem	Process model De jure	De facto	Activities Cartography Discover	Enhance	Auditing Detect	Check	Compare	Promote	Navigation Explore	Predict	Recommend
Liu *et al.* (2023b)		X		X	X								
Müller *et al.* (2022)		X		X	X								
Partington *et al.* (2015)		X		X	X	X			X				
Pini *et al.* (2015)		X		X	X	X			X				
Pourmasoumi *et al.* (2017)		X		X	X								
Rafiei and Van Der Aalst (2023)		X		X	X								
Rozsnyai *et al.* (2012)	X	X		X	X				X			X	
Sun *et al.* (2011)	X		X	X	X						X		X
Suriadi *et al.* (2014)		X		X	X	X			X				
Talamo *et al.* (2013a)	X		X				X						
Talamo *et al.* (2013b)	X		X				X						
Talamo *et al.* (2015)	X		X				X				X		X
van der Aalst (2011a)		X	X	X	X			X	X	X			
Wang *et al.* (2018)	X	X	X	X	X		X	X					
Yilmaz and Senkul (2015)		X		X		X			X	X			
Zeng *et al.* (2013)		X		X	X								
Zeng *et al.* (2020)		X		X	X								
Sum	11	33	12	35	32	10	6	6	8	3	4	3	5

Source(s): Table by authors

(1) *Extract events from EDIFACT messages:* Engel *et al.* (2011, 2012, 2013a, and 2016) provide a solution to convert EDIFACT messages, a standard for electronic data interchange in an inter-organizational system, to an event log. Two variants are presented: Message Flow Mining, referring to using exchanged messages as an activity (e.g. an order message corresponds to the activity "Send order"), and Physical Activity Mining, which uses information within exchanged messages to infer an activity (e.g. a shipping date indicating an event "Good shipped").

(2) *Use RFID-based EPC events:* Gerke *et al.* (2009a, b), in contrast, transform RFID (radio-frequency identification) data to event logs. This is achieved by building upon the Electronic Product Code (EPC) standard events, which include, among others, activity names and timestamps. To complete an event log, case identifiers are derived by looking at the EPC events and extracting information from aggregation activities (e.g. one part is built into a product or multiple products are packaged into a box for shipping) and transformation activities (e.g. a material is refined). This information is stored within a dependency graph that can be used to extract an event log representing the flow of a product throughout the whole supply chain.

Next to constructing events from different sources, pre-processing an event log may be required to hide sensitive information:

(1) *Only share event-log metadata:* Elkoumy *et al.* (2020a, b) handle privacy issues by encrypting the event log. In their tool *Shareprom*, the parties share metadata of the event log with each other (e.g. the number of unique activities and the maximum number of events per case) and upload the event log to a secure platform. During pre-processing, all cases are adapted to the same number of activities before an overall event log is created. By doing so, organizations can not infer detailed information about the partners' processes.

(2) *Encrypt the event log and define data spaces:* Lamghari *et al.* (2020) encrypt the event log and distinguish between forbidden (only accessible by a few authorized people), internal (event logs can be used without decryption) and external (event logs are decrypted) data spaces. Hence, only parts of the process, including corresponding analysis results (e.g. a process model), are generally visible to each organization.

Furthermore, pre-processing may be necessary in case the event log is distributed over multiple entities:

(1) *Use merging rules:* If the event-log data is split between the business partners, it will be necessary to merge it on a structured level to create a holistic event-log. In Claes and Poels (2014), this is achieved as follows. First, rules for merging the event log (e.g. a case ID in one event log is stored as an attribute in the partners' event log) are defined either manually or building upon the presented rule suggestion algorithm. Second, the merging rules are applied to identify links between the event logs, which form the basis for the merging procedure.

(2) *Calculate correlations between event logs:* Hernandez-Resendiz *et al.* (2021) present an approach for merging event logs that involves searching for correlations between the different event logs. For this purpose, bags-of-words ("a vector of words that represents each case") are created for each process instance. Subsequently, correlations are calculated based on the cosine similarity (a measure for determining whether two vectors point in the same direction) first, on the case level, and second, on the activity level before an overall process model can be discovered.

(3) *Merge event log abstractions:* In his article on federated process mining, Van Der Aalst (2021) distinguishes two ways for coPM, both building upon an object-centric event log (one event can relate to multiple cases, so-called object types). If the organizations are willing to share their event log data, a mapping needs to be defined between the event logs of all organizations before they can be merged. Otherwise, abstractions that make aggregated statements about the process (e.g. a process model represented through a directly follows graph) can be shared without revealing any details of the underlying event log.

(4) *Identify common cases for distributed event logs:* Tajima *et al.* (2023) present a procedure to determine cases from different organizations that, in reality, belong to the same case. First, the event logs of two organizations are merged. Second, related case IDs are identified based on analyzing adjacent activities of the two organizations occurring within a defined time period. Third, additional activity connections are found by looking at the combined trace of the previously determined related case IDs. Steps two and three are repeated for the remaining data (all cases and activities that have so far not been determined as belonging together) until no more relations are identified.

(5) *Identify semantic mismatches:* Azzini and Ceravolo (2013) provide an approach to integrate cross-organizational event log data using Big Data techniques. First, the organizations need to agree on a common model before the data of each organization is semantically lifted to be represented in terms of the common model. As the semantic lifting procedure is carried out individually at each organization, semantic mismatches between the organizations' data can occur, which need to be taken into account when analyzing the data.

4.2.5.2 Cartography – discovery and enhance. *4.2.5.2.1 . Discovery.* Process model discovery is one of the fundamental techniques of PM. In a cross-organizational context, different kinds of PM model discovery can be distinguished. Focusing on *coPM for exploiting commonalities*, the following techniques assist with discovering similar (parts of the) processes as a basis for further analysis:

(1) *Mining configurable process models for exploiting commonalities:* Buijs *et al.* (2013) and Van Der Aalst (2011a) present different approaches for mining configurable process models that can represent multiple process variants, thereby assisting in determining commonalities and differences between them. Either individually discovered models are merged, a process model is discovered and configurations added, or the process model and its configurations are discovered simultaneously. A configured process model representing a specific variant can be created by restricting the behavior of a configurable process model.

(2) *Extract morphological fragments from event logs:* Pourmasoumi *et al.* (2017) developed an algorithm that takes the event logs of multiple firms as input and discovers parts of the process that resemble the same operational procedure, so-called morphological fragments. By doing so, organizations can, for example, compare their own fragment with each other in terms of execution time or steps and resources involved.

(3) *Discover business rules:* Bernardi *et al.* (2014, 2018) present an architecture for coPM including the usage of the *Online Declare Miner*. With their solution, business rules that describe process behavior through a set of rules that need to be fulfilled can be discovered. By doing so, process variants within the recorded event logs can be identified as a basis for cross-organizational comparison.

In the case of *collaborative coPM*, the construction of a cross-organizational process model can be achieved in various ways, while it needs to be differentiated between a collaborative process model, emphasizing the interactions between the engaged parties (e.g. task interdependency), and a global process model, focusing on displaying the overall cross-organizational business process:

(1) *Mine coordination patterns:* Zeng *et al.* (2013) present an approach for mining four kinds of coordination patterns between two organizations executing cross-organizational business processes together: coordination with synchronized activities (an activity simultaneously involves both organizations), coordination with messages exchanged between the organizations, coordination with shared resources (coordination required as a resource cannot be used in two processes simultaneously) and coordination with abstract procedures (bundle activities to hide details). The cross-organizational process model is discovered by mining the model for each organization and integrating it using the coordination patterns.

(2) *Analyze message exchange for collaborative process model:* Corradini *et al.* (2022) also leverage the information of messages exchanged between the organizations. They present the *Colliery technique* for discovering a collaborative process model based on individually discovered process models, which are enriched by the messages exchanged between the parties.

(3) *Create a cooperative process model:* Liu *et al.* (2019) present an approach that first distinguishes between a private process model of an organization, including all activities, and a public fragment of this process model, involving all interactive events, which is transferred to a trusted instance. Second, a trusted third party builds a cross-organizational process model building upon the public fragments of each organization. Lastly, each organization retrieves all public process fragments related to their operations and constructs a cross-organizational process model by combining the public fragments with their private process model.

(4) *Use collaboration patterns to discover a cross-department collaborative healthcare process model:* Liu *et al.* (2023b) develop a technique that starts with processing the data from each involved medical department and discovering an intra-department process model. Subsequently, collaboration patterns (message exchange, resource sharing and task synchronization) are mined and finally combined with all intra-department models into a collaborative process model.

(5) *Discover hierarchical business processes:* Liu (2020) and Liu *et al.* (2023a) define hierarchical Petri nets as the basis for presenting a novel algorithm that discovers hierarchical business processes (processes with subprocesses, e.g., in outsourcing scenarios). Toward this end, nesting relations are detected, before a hierarchical event log is constructed based on the event log and the previously identified nesting relations as the basis for discovering a hierarchical process model.

(6) *Top-down PM based on running event logs:* Zeng *et al.* (2020) build upon a workflow system that constantly stores running event logs. Their approach distinguishes between a top-down algorithm, mining a top-level model that hides certain details and a bottom-level algorithm, detailing abstract procedures from the top-down process model. Both are integrated based on Petri net refinement operations to construct the overall model.

(7) *Build a privacy-preserving DFG:* Elkoumy *et al.* (2020a, b) present a new algorithm for building a process model as a directly follows graph (DFG) that builds upon the privacy-preserving pre-processed data (see Section 4.2.5 on data pre-processing).

(8) *Apply federated learning principles to mine a privacy-preserving global process model:* Khan *et al.* (2021) develop an algorithm based on the Heuristic mining algorithm that doesn't require organizations to share their event log. Instead, a trusted server initializes the mining process and aggregates results from the participating organizations, while only the global process model is shared with all participants.

(9) *Use abstractions for privacy-aware federated process mining:* Within the approach of Rafiei and Van Der Aalst (2023), abstractions of the actual event logs (e.g. directly follows and handover relations) are shared. These are subsequently merged before a cross-organizational process model can be discovered.

In addition to the previously described "new" techniques for the discovery of cross-organizational business processes, Sun *et al.* (2011) embed the discovery of a process model in their approach to optimize an inter-organizational workflow execution. Toward this end, a framework with four steps is introduced. First, event logs of the workflow execution are recorded. Second, a centralized workflow model is discovered, allowing for temporal analysis of the workflow. Third, the centralized workflow model is analyzed to determine the minimum time and number of servers for workflow execution. Fourth, the workflow is fragmented and distributed based on the previous analysis to increase the efficiency regarding execution time and server utilization.

The previous articles focused on mining a process model in the control-flow perspective, thereby focusing on the order of activities happening within the inter-organizational business process or the time perspective covering the timing and frequency of the events. In addition, two articles focused on the organizational perspective (the resources performing the activities) (Van Der Aalst, 2016):

(1) *Mine an organizational model:* Deokar and Tao (2020) present the organizational mining framework *OrgMiner* including a new algorithm that takes event logs and resources executing the activities as input and discovers a (cross-organizational) organizational model. To achieve this, the algorithms use behavioral patterns that describe the relation between two activities, including the number of activities happening between them, as the basis for discovering an organigram.

(2) *Discover a virtual organization's structure:* To discover the structure of a virtual organization, Li (2010) presents an approach that also requires the representation of resources executing the activities within the event log. Six types of relations between resources are introduced that, together with five rules for modeling the virtual organization, automatically discover an organizational model.

Overall, various discovery algorithms are applied or developed for coPM (see Table 4). Due to the long history of coPM articles, we find early PM algorithms (e.g. Alpha Miner) that were mainly developed to indicate the potentials of PM and for didactical purposes and more mature PM algorithms (e.g. Split Miner) that were later developed to overcome some of the limitations of the first algorithms (Augusto *et al.*, 2019b). We refer the reader to the referenced articles and the original publication for in-depth information.

4.2.5.2.2 . Collaborative enhancement. To enhance coPM analysis with key performance indicators (KPIs), Engel *et al.* (2016) and Krathu *et al.* (2014) describe a framework that assists organizations with defining KPIs building upon information from event logs and process models. These KPIs can be aligned with top-down objectives using the balanced scorecard methodology (an approach for measuring an organization's performance regarding their strategic goals) and subsequently monitored to track inter-organizational relationship performance. Also, Kim *et al.* (2020) build upon the balanced scorecard methodology (see

Algorithm	Developed for coPM	Referenced in	Original article(s)
Heuristic mining	–	Engel *et al.* (2012, 2016), Krathu *et al.* (2014), Mans *et al.* (2008), Maruster *et al.* (2003), Partington *et al.* (2015), Rozsnyai *et al.* (2012), Suriadi *et al.* (2014)	Weijters and Van Der Aalst (2001), Weijters *et al.* (2006), Weijters and Van der Aalst (2003)
Fuzzy mining	–	Partington *et al.* (2015), Suriadi *et al.* (2014)	Günther and Van der Aalst (2007)
Algorithm for merging rule suggestions	X	Claes and Poels (2014)	Claes and Poels (2014)
Online Declare miner	–	Bernardi *et al.* (2014)	Maggi *et al.* (2013)
Evolutionary Tree Mining algorithm	–	Buijs and Reijers (2014), Buijs *et al.* (2013)	Buijs *et al.* (2012a)
Message Flow Mining	X	Engel and Bose (2014), Engel *et al.* (2013a, 2016), Krathu *et al.* (2014)	Engel *et al.* (2012, a)
Physical Activity Mining	X	Engel and Bose (2014), Engel *et al.* (2013a, 2016)	Engel *et al.* (2013a)
Alpha-T algorithm	–	Lamghari *et al.* (2020)	Hermawan and Sarno (2018)
Passage mining	–	Suriadi *et al.* (2014)	van der Aalst (2012)
Inductive mining	–	Morales-Sandoval *et al.* (2021), Yilmaz and Senkul (2015)	Leemans *et al.* (2013)
Organizational Mining algorithm	–	Deokar and Tao (2020)	Deokar and Tao (2020)
Alpha Mining	–	Rozsnyai *et al.* (2012)	van der Aalst *et al.* (2004)
Biased (A custom-built algorithm)	–	Rozsnyai *et al.* (2012)	Rozsnyai *et al.* (2012)
Virtual organization structure modeling algorithm	X	Li (2010)	Li (2010)
Split Miner	–	Corradini *et al.* (2022), Hernandez-Resendiz *et al.* (2021)	Augusto *et al.* (2019a)
Abstraction-based approach for privacy-aware inter-organizational process mining	X	Rafiei and Van Der Aalst (2023)	Rafiei and Van Der Aalst (2023)
Algorithm for intra-department healthcare process discovery and algorithm for Collaboration Pattern Discovery	X	Liu *et al.* (2023b)	Liu *et al.* (2023b)
Decision Tree Miner		Kim *et al.* (2020)	Kim *et al.* (2014)
Hierarchical miner (Hierarchical behavioral model discovery approach)	X	Liu (2020), Liu *et al.* (2023a)	Liu (2020), Liu *et al.* (2023a)
Cross-silo process discovery algorithm	X	Khan *et al.* (2021)	Khan *et al.* (2021)
Top-Level discovery, Bottom-Level discovery, and integration algorithms	X	Zeng *et al.* (2020)	Zeng *et al.* (2020)

Source(s): Table by authors

Table 4. Overview of discovery algorithms applied in or developed for coPM

Section 4.2.1) to enhance collaborative process analysis within their presented PRANAS (Process ANAlytics System) framework.

4.2.5.3 Auditing – detect, check, compare and promote. *4.2.5.3.1 . Detect and check.* Three approaches for detecting and checking the conformance of a cross-organizational process are presented. D'Iddio *et al.* (2016a, b) handle the issue of an incomplete event log, especially regarding incomplete activity information and missing timestamps. Abstraction techniques are applied that, under certain conditions, can verify the correct execution of a business process. Talamo *et al.* (2013a, b), and Talamo *et al.* (2015), in contrast, present the concept of a validation tree (a special form of a computation tree storing validation rules at each node of the tree) to check conformance in real-time without knowing any details of the activities happening within each organization. To achieve this, software agents are installed at each organization that mines information on the communication layer in real-time and sends previously agreed-on information ("observations") to a validation authority. The validation authority checks the correct execution of the cross-organizational business process by constructing an event trace from the observations and comparing it with the validation tree. Finally, Wang *et al.* (2018) present a compliance monitoring framework that uses conformance checking techniques to continuously detect behavior that doesn't conform with pre-defined (e.g. governmental) regulations.

4.2.5.3.2 . Compare and promote. It is crucial to develop concepts and metrics that allow for an accurate comparison of cross-organizational business processes taking into account the organizational context and organizational semantics. Hence, when comparing metrics across organizational boundaries, population comparability (Suriadi *et al.*, 2014) has to be guaranteed to ensure that the analysis results lead to targeted and reasonable suggestions for process improvement. Therefore, Aksu *et al.* (2016) incorporated these factors (see Section 4.2.1.) in their framework.

Configurable process models are designed jointly by multiple organizations performing variants of the same process. Regarding their adoption, it is necessary to consider where to comply with the standard and where to configure the model to better handle local variations (Van Der Aalst, 2011a). For this purpose, Van Der Aalst (2011a) proposes the application of Causal nets, while alignment matrices are introduced in Buijs and Reijers (2014) as a visualization method for analyzing how the process of one organization would have behaved with the process model of another organization. Also, Pini *et al.* (2015) developed and evaluated various visualization techniques accounting for the specific needs of business process comparison. The techniques assist with effectively communicating the results of coPM analysis. Similarly, event-log data from all the organizations under comparison can be used to construct a single process model that reflects all possible variations. Subsequently replaying the event log from each organization on the general model can reveal dominant and less-frequent paths as the basis for process improvement (Partington *et al.*, 2015).

Finally, Yilmaz and Senkul (2015) present an approach that builds upon process comparison to generate recommendations for improvement. Toward this end, a process model is mined for each organization including the calculation of previously defined KPIs. Subsequently, the organizations can be clustered, for example, according to their performance on a specific KPI. Finally, by comparing the process models of better and worse-performing organizations, improvement suggestions can be generated based on so-called mismatch patterns (e.g. skipped activities or activities happening at different stages of the process).

4.2.5.4 Navigation – explore, predict and recommend. Navigation in the context of PM refers to forward-looking activities. Within the set of our coPM articles, we find techniques for optimizing task execution on distributed servers, approaches for recommending actions to take within a process, and ways to predict future process behavior and performance. Bernardi *et al.* (2014, 2018) build on a real-time discovery of business rules. They optimize resource management by distributing task execution to different nodes within their cloud-based system. Similarly, Sun *et al.* (2011) present an approach to fragment the execution of a workflow based on the discovery of the overall cross-organizational workflow. To minimize execution time, the remaining tasks of running process instances are allocated to different servers. Based on the concept of validation trees (see Section 4.2.5.3), Talamo *et al.* (2015) explore running service tickets and present a solution, where a validation authority automatically resolves issues, recommends actions or notifies a service agent. Furthermore, three articles apply prediction techniques: Ho *et al.* (2009) use artificial neural networks to predict the quality of currently produced workpieces based on a real-time analysis of quality characteristics. If necessary, their approach recommends actions that were previously generated by process experts and stored in the form of fuzzy "if-then" rules in a knowledge base to improve product quality. Kim *et al.* (2020), in contrast, present examples of how predictions can be applied to data stored in process cubes, for example, use decision trees to classify expected on-time deliveries and to show the effect of attributes on the process trace as the basis for predicting performance measures. Finally, Rozsnyai *et al.* (2012) predict future tasks and their probability of execution. Their technique builds on decision trees and a Markovian process-aware prediction approach to determine the probabilities of executing certain tasks in the remaining lifecycle of a process instance. Toward this end, a process model is discovered and enriched with a decision tree at each decision node (point in the process with multiple options for the subsequently executed task). For each running instance, an "instance-specific probabilistic process model" is then created based on the pre-mortem event log to predict the next tasks to be executed.

4.2.5.5 CoPM using blockchain technology. Various articles emphasize the suitability of blockchain-based applications for executing inter-organizational business processes and thereby develop new techniques to use blockchain data for coPM purposes. Klinkmüller *et al.* (2019) and Mühlberger *et al.* (2019) both developed a framework for retrieving data from Ethereum-based decentralized applications. The frameworks specify how the data needs to be logged and include a mechanism for extracting the data and transforming it into a format suitable for coPM. Also, Morales-Sandoval *et al.* (2021) built on a cross-organizational process that is executed and monitored on a blockchain. Smart contracts are implemented for directly logging and collecting event data including mechanisms for data cleaning. Before the data can be used for coPM, it is also transformed into a standard format.

Müller *et al.* (2022) use trusted execution environments and blockchains to enable privacy-aware coPM. Organizations need to synchronize their case IDs beforehand and agree on a process mining procedure for analyzing and processing the data. Subsequently, organizations encrypt their event log and share the key with a secret management service running in a trusted execution environment before one organization starts the process mining procedure. As all organizations previously agreed on the procedure, it cannot be changed anymore. The resulting inter-organizational process model is finally distributed to all organizations providing input data.

Next to the previously described articles that included an actual implementation of their framework, Tönnissen and Teuteberg (2019) present an abstract concept that connects so far separated intra-organizational systems (e.g. enterprise resource planning systems) through a blockchain, where smart contracts collect the data from one organization and forward it to a second one. By doing so, a cross-organizational event log can be created, enabling coPM analysis. Also, Ivković and Luković (2021) describe an abstract framework for how process mining can support smart contract validation in blockchains executing inter-organizational processes, thereby focusing on coPM for conformance checking.

4.2.5.6 Conclusion of IT-mediated mechanisms. Overall, we can conclude that the discovery of process models (collaborative process models and global process models) based on historic event data is the most researched coPM technique. In contrast, less research exists on forward-looking and real-time coPM techniques. In general, two technical approaches for handling the complexity of coPM can be distinguished. First, the event-log data are pre-processed to allow conventional PM techniques to be applied, for instance, by anonymizing or merging the data or extracting data from new sources, for example, exchanged messages. Second, specific coPM techniques are developed and implemented, for example, to handle privacy issues by encrypting the event log and only sharing aggregated results of process performance analysis (Elkoumy *et al.*, 2020a, b; Jokonowo *et al.*, 2018).

4.2.6 Performance. Various articles revealed insights into process performance. In the case of collaborative coPM, its application reveals in-depth, fact-based process-related insights, such as processual weaknesses, parties causing late deliveries in a manufacturing process (Engel and Bose, 2014; Engel *et al.*, 2016), improvement potentials for faster and more efficient patient treatment (Canjels *et al.*, 2019) and technical issues with an inter-organizational message exchange (Engel *et al.*, 2016). It can further assist by pointing toward amendable parts of the process and generating recommendations to leverage the improvement potential (Yilmaz and Senkul, 2015). Furthermore, as coPM transforms previously unused raw event-log data or exchanged messages in such a way that KPIs (e.g. related to financial performance or customer satisfaction) can be calculated, it creates a basis for identifying and discussing improvement potentials (Engel *et al.*, 2016; Krathu *et al.*, 2014). In addition, organizations improve process security by applying cross-organizational compliance checking (Talamo *et al.*, 2015).

Regarding coPM for exploiting commonalities, for example, in the case of software-as-a-service solutions, where multiple organizations share the underlying infrastructure and use configurable services, multiple variants of the same process exist, which can be analyzed by coPM in two ways: First, the service provider may compare the operations executed by its customers to improve the service. Second (only applicable in a non-competitive setting), the data can be used to benchmark different organizations. Consequently, they can learn from each other; for instance, by comparing the patient-handling process in multiple hospitals (Partington *et al.*, 2015; Van Der Aalst, 2010). In the same way, numerous process variants can be compared to derive a better understanding of the differences between process variants, for example, in hospitals (Mans *et al.*, 2008) or municipalities (Buijs and Reijers, 2014), and to identify a preferable process model executable within all organizations (Buijs and Reijers, 2014; Buijs *et al.*, 2012b). Insights resulting from such a comparison may be related, for example, to performance, to differences in patient's length of stay (Partington *et al.*, 2015) or to the process itself, such as varying strategies of patient treatment (Mans *et al.*, 2008), executing medical activities in a different order (Suriadi *et al.*, 2014) or omitting certain activities while still complying with the municipal regulations (Buijs and Reijers, 2014).

Two articles described the actual impact of coPM adoption on process performance. Canjels *et al.* (2019) identified that in their case study on arthrosis patients from Dutch hospitals, multiple steps during patient handling can be performed by less qualified and therefore less expensive personnel, resulting in an efficiency gain of approximately €75,000 per year. Also, the patients' waiting times could be reduced, which led to higher patient satisfaction. Talamo *et al.* (2015), in contrast, evaluated their approach to a distributed process involving 400,000 daily executions and a service desk or support. They identified the possibility of reducing the IT service personnel by 85% as the vast majority of involved service tickets could be automatically validated, thereby reducing manual handling effort.

4.3 Challenges of cross-organizational process mining

Based on our coding procedure, as described in Section 3.3, we derived a set of 18 challenges, which can be grouped into 6 categories (see Table 5): *Comparison and analysis*, *Complexity*, *Data*, *Organization-individual goals*, *Information protection* and *Process-related change*. Some of the challenges described are not unique to a cross-organizational setting. They can also arise when PM is conducted in a single organization, examples that were already reported in

Source	Challenge	Challenge category (definition)
Engel *et al.* (2016), Ho *et al.* (2009)	Define and calculate appropriate metrics	*Comparison and analysis* (Appropriate techniques and metrics have to be developed and applied that account for organization-specific conditions and semantics and, in turn, ensure comparability.)
Aksu *et al.* (2016), Azzini and Ceravolo (2013), Edgington *et al.* (2010), Engel *et al.* (2011, 2016), Partington *et al.* (2015), Pourmasoumi *et al.* (2017), Suriadi *et al.* (2014)	Ensure comparability and semantic alignment	
Elkoumy *et al.* (2020a), Zeng *et al.* (2013)	Choose the appropriate coPM technique	
Aouachria *et al.* (2017), Canjels *et al.* (2019), González and Delgado (2021), Helm and Küng (2016), Ho *et al.* (2009), Lamghari *et al.* (2020), Maruster *et al.* (2003), Partington *et al.* (2015), Suriadi *et al.* (2014)	Handle process size and complexity	*Complexity* (The increasing complexity of coPM is down to both the complex nature of the inter-organizational process itself and the fact that multiple business partners are involved. This means that knowledge is distributed, and each partner is only in charge of a subprocess. Hence, there is no central overview of the process as a whole.)
Aksu *et al.* (2016), Aouachria *et al.* (2017), Gerke *et al.* (2009b), Jacobi *et al.* (2020), Lamghari *et al.* (2020), Maruster *et al.* (2003), Morales-Sandoval *et al.* (2021), Rafiei and Van Der Aalst (2023), Talamo *et al.* (2015), van der Aalst (2011b, 2021)	Encounter distributed knowledge and control	
Aouachria *et al.* (2017), Corradini *et al.* (2022), Hernandez-Resendiz *et al.* (2021), Partington *et al.* (2015), Rafiei and Van Der Aalst (2023), van der Aalst (2010), van der Aalst *et al.* (2012)	Merge intra-organizational process models	
Aksu *et al.* (2016), Claes and Poels (2014), D'Iddio *et al.* (2016a, b), Deokar and Tao (2020), Elkoumy *et al.* (2020a, b), Engel *et al.* (2016), Hernandez-Resendiz *et al.* (2021), Jacobi *et al.* (2020), Khan *et al.* (2021), Liu *et al.* (2019), Partington *et al.* (2015), Rozsnyai *et al.* (2012), Tönnissen and Teuteberg (2019), van der Aalst (2010), van der Aalst (2011b), van der Aalst *et al.* (2012), Zeng *et al.* (2013)	Get access to distributed data	*Data* (The data for cross-organizational PM is usually distributed and therefore has to be collected from multiple organizations. This requires access to the data and causes further challenges in the form of varying data granularity, quality and structure. In addition, it is necessary to handle large volumes of data.)
Azzini and Ceravolo (2013), Canjels *et al.* (2019), Claes and Poels (2014), D'Iddio *et al.* (2016a, b), Edgington *et al.* (2010), Engel *et al.* (2011), Engel *et al.* (2012), Gerke *et al.* (2009a), Maruster *et al.* (2003), Rozsnyai *et al.* (2012), van der Aalst (2011a), van der Aalst *et al.* (2012)	Homogenize data quality	
Buijs and Reijers (2014), D'Iddio *et al.* (2016a, b), Edgington *et al.* (2010), Elkoumy *et al.* (2020a), Engel *et al.* (2012), Krathu *et al.* (2014), Maruster *et al.* (2003), Rozsnyai *et al.* (2012), van der Aalst *et al.* (2012)	Handle incomplete data	

Table 5.
Challenges of coPM

(*continued*)

Source	Challenge	Challenge category (definition)
Buijs and Reijers (2014), Claes and Poels (2014), Engel and Bose (2014), Ho *et al.* (2009), Rozsnyai *et al.* (2012), Suriadi *et al.* (2014), Talamo *et al.* (2013a), Tajima *et al.* (2023), van der Aalst (2011b), van der Aalst *et al.* (2012)	Resolve data granularity differences	
Rozsnyai *et al.* (2012)	Data source changes bring back challenges	
Elkoumy *et al.* (2020a), Lamghari *et al.* (2020), Rozsnyai *et al.* (2012), Suriadi *et al.* (2014), van der Aalst (2011a)	Ensure scalability with large data volumes	
Buijs and Reijers (2014), Edgington *et al.* (2010), Ho *et al.* (2009)	Handle contrasting goals	*Organization-individual goals* (Multiple organizations are involved, each pursuing different goals. This gives rise to the challenge of revealing targeted insights that are valuable for all partners, correct and simultaneously handle local priorities.)
Engel *et al.* (2011), Gerke *et al.* (2009b), Khan *et al.* (2021), Liu *et al.* (2023b), Rafiei and Van Der Aalst (2023), van der Aalst (2010)	Reveal correct and valuable insights	
Aksu *et al.* (2016), D'Iddio *et al.* (2016b), Elkoumy *et al.* (2020a, b), Jacobi *et al.* (2020), Khan *et al.* (2021), Lamghari *et al.* (2020), Liu *et al.* (2019), Müller *et al.* (2022), R'Bigui and Cho (2017), Rafiei and Van Der Aalst (2023), Talamo *et al.* (2013b), Talamo *et al.* (2013a), van der Aalst (2010, 2011b, Van Der Aalst *et al.* (2012)	Implement data security	*Information protection* (Organizations may not want to or are legally prevented from sharing information on competitive, privacy or confidentiality grounds. In addition, information has to be secured to prevent misuse.)
Aksu *et al.* (2016), Elkoumy *et al.* (2020a), Lamghari *et al.* (2020), Liu *et al.* (2019), Talamo *et al.* (2013a), van der Aalst (2010, 2012)	Ensure data privacy	
Pourmasoumi *et al.* (2017), van der Aalst (2010), van der Aalst *et al.* (2012)	Constantly handle (concept) drift	*Process-related change* ((Concept) drift, referring to changes in the process or the context that occur over time and focus shift, covering a change in the focus of a supply chain process.)
Gerke *et al.* (2009a, b)	Resolve focus shift in supply chains	

Source(s): Table by authors

Table 5.

the literature being "*Ensure scalability with large data volumes,*" "*Handle process size and complexity,*" "*Constantly handle (concept) drift*" and "*Reveal valuable insights*" (Van Der Aalst *et al.*, 2012; Process Mining Conference, 2020; Rozinat, 2020). However, the cross-organizational context promotes each challenge either in terms of the probability of their occurrence or the consequences.

4.3.1 Comparison and analysis. Define and calculate appropriate metrics: Many perspectives have to be incorporated into an inter-organizational business process (collaboration), and a variety of possible metrics exist for comparing process variants of multiple organizations (exploiting commonality). The challenge, therefore, lies in defining metrics and KPIs that match different stakeholders' expectations and provide valuable insights, for example, as they are aligned with the business strategy (Engel *et al.*, 2016; Ho *et al.*, 2009). Furthermore, the organizations need to be able to "calculate [these] KPIs from different syntaxes and semantics across heterogeneous [...] data schemas" (Engel *et al.*, 2016).

Ensure comparability and semantic alignment: Organizations operate in varying contexts. For example, the geographical circumstances differ. In addition, semantical differences exist between the compared partners. For instance, identical labels for activity names do not necessarily mean the same thing, as one activity can include different steps in different organizations (Pourmasoumi *et al.*, 2017). Hence, comparability between process variants or subgroups of process instances under analysis can usually be questioned. If comparability is not properly considered, the expressiveness of the results is reduced, thereby leading to potential mistrust in the PM analysis results (Aksu *et al.*, 2016; Partington *et al.*, 2015; Suriadi *et al.*, 2014). For example, as stated by Partington *et al.* (2015) in a case study among hospitals: "When the case study results were presented to the stakeholder group, there emerged some doubt as to whether there was consistency in the [. . .] diagnosis. While it was generally agreed [. . .] that there was likely to be little difference, it did bring into question the true comparability of [. . .] patient populations across hospitals." Or, as written by Suriadi *et al.* (2014): "Given such complexity, it can be difficult to determine appropriate ways to split the data into natural groupings for comparison purposes. A key challenge here is how to group cases such that each group is mostly homogeneous, and thus, yield usable comparison results."

Choose the appropriate coPM technique: Due to the described challenges, "normal" PM techniques can usually not be applied in a cross-organizational setting: "It is difficult to apply existing approaches directly to discover a model for a cross-organizational workflow" (Zeng *et al.*, 2013). Hence, organizations and researchers need to determine which of the described techniques should be applied in their specific setting. This is challenging, as various techniques (see Section 4.2.5) with different advantages and disadvantages were developed and presented in the literature, differing in their approach (e.g. for process model discovery, merging the event log before discovering the cross-organizational process model, or discovering individual process models and subsequently merging them toward a cross-organizational one).

4.3.2 Complexity. Handle process size and complexity: Multiple partners are involved in an inter-organizational business process, and they usually perform a large number of activities through a variety of communication patterns. Activities from different organizations thus can have different relationships (e.g. executed in parallel or sequentially). Discovering such an inter-organizational business process can hence be very complex; for example, as multiple activities are intertwined: "The complexity of logs obtained from various organizations is likely to result in highly-complex spaghetti process models" (Suriadi *et al.*, 2014) or, as stated by Lamghari *et al.* (2020), "the construction of supply chain-wide processes poses a real challenge of complexity." Overall, the process size and its complexity need to be handled to ensure meaningful results from coPM analysis.

Encounter distributed knowledge and control: As multiple organizations are involved, the knowledge of the inter-organizational process is distributed among them: "Often[,] the knowledge about the overall process is distributed over the involved parties and no single party has an overview on the complete process and all its details" (Jokonowo *et al.*, 2018). Also, every party involved has individual expertise: "Each organization can have expertise on different subjects, e.g. depending on its goals and knowledge" (Aksu *et al.*, 2016). Moreover, there might be no central control or overview, with the result that each business partner is only able to see and modify those parts of the process that he is responsible for. This hampers both discovering and analyzing cross-organizational processes as well as defining and implementing measures for handling inefficiencies unraveled through coPM analysis across different parties.

Merge intra-organizational process models: Once the organizations have discovered process models that represent their view of the overall business process, usually based on the data they have access to, it is a challenge to combine these into a process model that reflects the whole cross-organizational process. This involves handling messages exchanged between the organization that indicate interoperability issues, e.g. "the supplier (Company B) sends an invoice which is not expected by the requester (Company A)" (Aouachria *et al.*, 2017) and handling different patterns of cross-organizational collaboration on the activity level; for example, activities simultaneously involving both organizations or activities executed sequentially (Zeng *et al.*, 2013).

4.3.3 Data. Get access to distributed data: The data for coPM is usually spread over different systems, databases and servers owned by various organizations because every organization records sub-logs (collaboration) or data of multiple process variants executed by varying parties is required (exploiting commonality) (Claes and Poels, 2014). This results in a situation where the overall event log is not directly available, as the initial access to event-log data is normally limited to the organization's own data (Elkoumy *et al.*, 2020a). Hence, it remains a challenge for the participating organizations to agree on a way to either grant everybody access to each other's databases or store the individually extracted event logs in a common space.

Homogenize data quality: The quality of the PM results crucially depends on the input data quality. The challenge in a cross-organizational setting is that data might not be recorded and stored in the same quality in each organization. For example, "events may be incomplete, logs may contain outliers" (Rozsnyai *et al.*, 2012), or "events are not recorded precisely and important details to characterize and identify events are missing." (D'Iddio *et al.*, 2016b) Thus, organizations and researchers need to be aware of data quality differences that need to be resolved before coPM analysis.

Handle incomplete data: The data for coPM may be incomplete due to various reasons. For example, data fields necessary for coPM analysis are missing because they are not recorded, or the organizations are not willing to share all details of their event log (Rozsnyai *et al.*, 2012; Van Der Aalst *et al.*, 2012). Missing data fields, then, may cause several hurdles during process discovery (e.g. indistinguishable timestamps, representing only the day of activity execution, which hampers the ability to correctly identify the order of activities) and conformance checking (e.g. executed but not recorded activities may lead to the wrong conclusion of a non-conforming process behavior) (D'Iddio *et al.*, 2016a, b).

Resolve data granularity differences: As multiple organizations govern their individual event log, the granularity between multiple event logs may differ. This issue relates to timestamps: "timestamps may have different levels of granularity ranging from milliseconds precision (28-9-2011:h11m28s32ms342) to coarse date information (28-9-2011)" (Van Der Aalst *et al.*, 2012) and to the level of detail of the recorded activities (Claes and Poels, 2014): "an event log can hold data about a number of events at a high level of detail and of other events at a low level of detail." Also, organizations may use different identifiers, which complicate merging distributed data: "For example, one system uses name and birthdate to identify a person whereas another system uses the person's social security number" (Van Der Aalst *et al.*, 2012). These differences in data granularity need to be resolved when merging the individual event logs into an overall event log.

Data source changes bring back challenges: Firms' IT infrastructures do not remain constant in general because of, for example, new requirements, regulations, or optimization initiatives. Hence, IT systems and, in turn, the data sources for coPM are subject to change: "Changes may occur when IT systems are replaced, when data structures are improved, errors are fixed or new components are introduced that add additional data." (Rozsnyai *et al.*, 2012) For coPM, this complicates a continuous analysis because the variety of described challenges may reoccur for each change in one or multiple of the organization's IT infrastructure.

Ensure scalability with large data volumes: Complex inter-organizational business processes (collaboration) or multiple variants of the same business process (exploiting commonality) generate large amounts of data that must be processed. This may result in scalability issues, for example, when a specific coPM or encryption technique is resource-intensive. Looking at large organizational implementations of PM, we observe that in intra-organizational settings, use cases with multiple millions of process instances are already present (Celonis, 2022). Hence, organizations developing new techniques for coPM, for example, need to ensure that their approaches are able to handle large amounts of data.

4.3.4 Organization-individual goals. Handle contrasting goals: CoPM may be applied by business partners for different reasons and to support diverse – and possibly rival – goals (Buijs and Reijers, 2014; Helm and Küng, 2016). Also, partners may have local priorities in an inter-organizational business process. For example, a manufacturer wants to increase the process transparency of its supplier, while the supplier strives to optimize the overall efficiency while hiding certain process details to maintain a competitive advantage. This gives rise to the challenge of local versus global optimization: "today's enterprises operate on a global scale and it is a challenge to achieve global optimization within the network" (Ho *et al.*, 2009).

Reveal correct and valuable insights: In an inter-organizational context, the challenge of deriving targeted and valuable insights for all participants results from business partners providing large amounts of data, offering seemingly unrestricted ways for process discovery, conformance checking and enhancement. Also, as described in the previous challenge, different goals may require different ways of analyzing the process. Thus, it is a challenge "to not get lost" in the analytical possibilities and restrict coPM analysis to valuable opportunities. Further, the insights need to be correct, which is a particularly important challenge when only abstractions of process models are shared, merged or analyzed (Liu *et al.*, 2023a; Rafiei and Van Der Aalst, 2023).

4.3.5 Information protection. Implement data security: Data security refers to the challenge of protecting the data from misuse or unauthorized access and is rooted in three aspects: confidentiality, integrity and availability of the data. Confidentiality refers to preventing secret information from one organization from being accessed by unauthorized third parties. For example, "with the increasing number of participants in supply chain business processes [. . .], it is important to secure data, where it will be only accessible to authorized persons" (Lamghari *et al.*, 2020). Data integrity ensures that the data are not modified unauthorizedly. For example, it should not be possible for one organization to manipulate the data from another organization. Data availability ensures that the data can be accessed by authorized institutions at the required point in time while maintaining confidentiality requirements. This, for example, "might require that certain data are hashed or encrypted before being transmitted" (Talamo *et al.*, 2013b).

Ensure data privacy: Privacy requirements and regulations (e.g. the general data protection regulation by the European Union [2]) have to be fulfilled to protect the rights of the individuals who interact with the cross-organizational process and, thereby, whose data are processed. This is especially relevant when the data is being shared between multiple organizations (Elkoumy *et al.*, 2020b): "Due to confidentiality concerns and privacy regulations [. . .] the involved organizations are unwilling to, or sometimes legally prevented from, sharing their event logs." Thus, it needs to be clarified whether person-related data originating from one organization can be shared with another organization without disregarding any privacy regulations.

4.3.6 Process-related change. Constantly handle (concept) drift: (Concept) drift is a challenge in two ways: First, the process might change while being analyzed, or a discovered process model can become outdated. Second, seasonal effects might result in process variants being executed under varying conditions (Van Der Aalst, 2010). For example, there may be seasonal effects affecting the features of a process. The same process may have long flow times in December and short flow times in January due to differences in workload. This should be taken into account when comparing variants. In a cross-organizational context, those drifts happen at each organization at different points in time, leading to the challenge of constantly adjusting coPM analysis to handle (concept) drifts.

Resolve focus shift in supply chains: This challenge arises because goods processed in a supply chain are hard to follow between the first and final activity. This originates from a change in the process focus – including the recorded data – due to the assembly and packaging operations (Gerke *et al.*, 2009b): "The main challenge is assigning different events [. . .] to a process instance in such a way that the shifting focus between different assembled and disassembled business objects of varying granularity is handled appropriately." For example, the early process focus within a car production process may be on the delivery of a car wheel, which is subsequently mounted on a car (new process focus: car) before the car gets transported by a truck to the customer (new process focus: truck transport).

4.4 Enablers for cross-organizational process mining

The identified articles further present enablers for handling the challenges of coPM. Based on the described procedure (see Section 3.3), we derived nine enablers from three categories (Data preparation, Data and process analysis, Governance) that assist in conducting PM across organizational boundaries (see Table 6).

Source	Enabler	Enabler category (Definition)
Azzini and Ceravolo (2013), Canjels *et al.* (2019), Claes and Poels (2014), Corradini *et al.* (2022), D'Iddio *et al.* (2016a), Elkoumy *et al.* (2020a, b), Engel and Bose (2014), Gerke *et al.* (2009b), Lamghari *et al.* (2020), Morales-Sandoval *et al.* (2021), Partington *et al.* (2015), Rafiei and Van Der Aalst (2023), Rozsnyai *et al.* (2012), Suriadi *et al.* (2014), Talamo *et al.* (2013a), van der Aalst *et al.* (2012)	Pre-process data	*Data Preparation* (Preparing the data through merging, filtering, anonymizing, pseudonymizing, event data extraction, clustering or classification eases coPM analysis.)
Canjels *et al.* (2019), Deokar and Tao (2020), Pourmasoumi *et al.* (2017), Suriadi *et al.* (2014), van der Aalst (2010), Yilmaz and Senkul (2015)	Apply clustering and classification techniques (exploiting commonality)	
Aksu *et al.* (2016), Edgington *et al.* (2010), Talamo *et al.* (2013a), van der Aalst *et al.* (2012)	Continuously analyze the process and assess the created value	*Data and Process Analysis* (A valuable application of coPM is promoted through a focused and continuous analysis with the help of visualizations and an engagement with relevant stakeholders.)
Engel and Bose (2014), Partington *et al.* (2015), van der Aalst *et al.* (2012)	Focus coPM analysis	
Bernardi *et al.* (2018), Buijs *et al.* (2012b, 2013), Müller *et al.* (2022), van der Aalst (2010), van der Aalst (2011b), van der Aalst *et al.* (2012)	Provide process view flexibility and use configurable process models	
Buijs and Reijers (2014), Corradini *et al.* (2022), Deokar and Tao (2020), Engel and Bose (2014), Engel *et al.* (2013a, 2016), Krathu *et al.* (2014), Partington *et al.* (2015), Pini *et al.* (2015)	Use visualization techniques for presenting coPM results	
Aksu *et al.* (2016), Buijs and Reijers (2014), Canjels *et al.* (2019), Edgington *et al.* (2010), Engel *et al.* (2012), Partington *et al.* (2015), Yilmaz and Senkul (2015)	Discuss results with experts/stakeholders	
Edgington *et al.* (2010), Engel *et al.* (2016), Krathu *et al.* (2014), Rott and Böhm (2022b)	Align interests, strategies and goals	*Governance* (Apply governance mechanisms and consider including a third party to align interests, strategies and goals.)
Lamghari *et al.* (2020), Morales-Sandoval *et al.* (2021)	Consider including a third party for parts of coPM	

Source(s): Table by authors

Table 6. Enablers for cross-organizational process mining

4.4.1 Data preparation. Pre-process data: To handle the complexity of cross-organizational event-log data and to recognize security, privacy and confidentiality requirements, it is helpful to pre-process the data before the actual coPM analysis. The following forms of pre-processing can be applied:

(1) *Merging*: In order to enable coPM analysis, intra-organizational data can be merged to create cross-organizational data. This can happen at different levels: "raw data level (i.e. merging databases and/or files), structured data level (i.e. merging event logs), and model level (i.e. merging process models)" (Claes and Poels, 2014).

(2) *Filtering:* Filtering the data may be required to hide certain details (e.g. business-critical information) or to focus the analysis on cases that fulfill certain criteria, e.g. completeness: "In order to tailor the available data toward our research questions [. . .], we [. . .] filter the results for cases which contain complete traces" (Engel and Bose, 2014).

(3) *Anonymization and Pseudonymization*: To protect individuals whose data is processed during coPM, the data can be anonymized (process the data in such a way that the original person cannot be determined) or pseudonymized (replace personal data with pseudonyms, thereby preserving the possibility to connect data from different databases being pseudonymized in the same way).

(4) *Adding additional (noise) information*: Additional information can be added to the event log to overcome missing data (e.g. calculate approximate timestamps) or hide certain details (e.g. add activities to protect the actual order of activities executed being exposed to other organizations).

(5) *Extracting event-log data:* The data required for coPM can, in certain situations, not be directly drawn from the source systems, usually, because the data are stored in a different format. Hence, the necessary event-log information needs to be extracted; for example, building upon messages exchanged between the organizations or RFID tags scanned throughout the supply chain (see Section 4.2.5)

Apply clustering and classification techniques (exploiting commonality): Clustering (e.g. k-means clustering) and classification (e.g. decision trees) techniques can be applied when multiple organizations are compared through coPM analysis. They assist in understanding differences and commonalities between process variants and groups of process instances. As stated by Suriadi *et al.* (2014): "A key lesson learned here is that clustering techniques can be used to discover inherent clusters of cases informed purely by the features in the dataset while decision tree analysis can be used to extract the key discriminating features of each cluster." This assists organizations in learning best practices from each other.

4.4.2 Data and process analysis. Continuously analyze the process and assess the created value: Due to the high complexity involved, it is advisable to continuously repeat the coPM analysis; for instance, by performing multiple iteration cycles: "The examples from a software vendor's perspective and an organization's perspective indicate that one can obtain more specific insights by executing more interaction cycles [. . .]. In each cycle, one can define more granular process mining questions using organizational contexts, metric semantics, or business semantics" (Aksu *et al.*, 2016). Together with periodically assessing the value of the coPM project, it ensures the ongoing involvement of all participating organizations.

Focus coPM analysis: As an extensive and heavily intertwined cross-organizational business process offers many opportunities for investigation, it is advisable to focus the analysis on specific aspects: "We found that it was important to provide some focus as to which areas that we should analyze to avoid being overwhelmed by too many 'potentially-relevant' comparison points" (Partington *et al.*, 2015). In addition, organizations should analyze the process by following dedicated questions (Van Der Aalst *et al.*, 2012): "Process mining activities need to be driven by questions. Without concrete questions, it is very difficult to extract meaningful event data." Focusing the analysis thus assists with deriving valuable insights and reduces the risk of getting lost in the great number of analytical possibilities.

Provide process view flexibility and use configurable process models: The overall process model and the views thereof should be kept flexible (e.g. be able to hide activities that are irrelevant for one organization), as multiple organizations have different perspectives that they are interested in. Hence, organizations need different views to support their analysis. Providing a configurable process model that describes a set of familiar processes can further assist in standardizing process variants while still allowing for local configurations (Buijs *et al.*, 2012b): "Configurable process models [. . .] provide a way to model variability in the processes [. . .]. Given a shared configurable model, organizations can use different configurations to adapt to local needs."

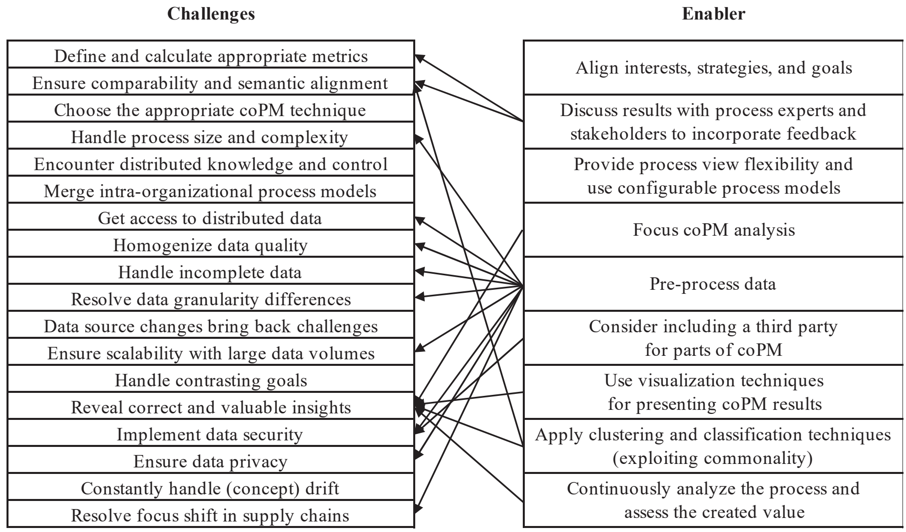
Use visualization techniques for presenting coPM results: Visualizations (e.g. process maps, alignment matrices, dotted charts, organigrams or social network visualizations) are a powerful way of deriving comprehensible analysis results, especially if the underlying cross-organizational process is large and complex (Buijs and Reijers, 2014). They trigger discussion, enhance interpretability and represent an easier way to share information between the participating organizations compared to releasing the raw event-log data (Corradini *et al.*, 2022; Pini *et al.*, 2015).

Discuss results with process experts and stakeholders to incorporate feedback: Discussing the results with process experts, data and IT specialists, and managerial stakeholders from (all) participating organizations assists in evaluating and interpreting the results: "The results from the case study were communicated back to the stakeholders, as part of an iterative engagement to ask questions, such as 'is the data actually telling us what we think it is telling us?" (Partington *et al.*, 2015). This is specifically relevant in cross-organizational settings, as the individual organizations possess unique domain knowledge that is required for correctly interpreting coPM results and deriving measures for process optimization. Furthermore, the discussions may lead to future directions in analyzing the process.

4.4.3 Governance. Align interests, strategies, and goals: Similar to information sharing in supply chains, it is beneficial for the participating organizations to align their interests, strategies and goals. This can be achieved, for example, by implementing service level agreements or aligning bottom-up coPM analysis with top-down strategic objectives (Edgington *et al.*, 2010): "metrics need to be applied within the service level agreement (SLA) in order to help align the outsourcer's actual process execution with the client's actual interests." Specifically, implementing value distribution mechanisms may ensure that the value of coPM is distributed to the organizations in such a way that everybody is incentivized to create a higher value (Rott and Böhm, 2022b).

Consider including a third party for parts of coPM: To overcome confidentiality issues, the inclusion of an additional (trustworthy) party (e.g. a PM vendor, consultancy or research institution) should be considered. It, for example, takes the event-log data of multiple organizations as input and provides the results of the coPM analysis to each party (Morales-Sandoval *et al.*, 2021). Thereby, organizations cannot access foreign information.

4.4.4 Relationships between challenges and enablers. As can be drawn from Figure 5, which is based on the described coding procedure in Section 3.3, most of the enablers are directly related to the challenges described. Overall, one dominant enabler can be observed: *Pre-process data*. It relates to nine challenges and undermines the past literature focus on technical aspects of coPM. We further observe multiple enablers and challenges being disconnected from each other, thereby indicating areas for future research (see Section 5.1 and Section 5.3).



Source(s): Figure by authors

Figure 5.
Relationships between coPM challenges and enablers

5. Discussion

5.1 Discussion of challenges and enablers

Some of the described challenges and enablers are not unique to coPM and were also described in existing PM studies. For example, Martin *et al.* (2021) built on a Delphi study with academics and practitioners to identify – among others – *"Poor data quality," "Restricting data privacy regulations"* and *"Complex data preparation"* as challenges, whereas three challenges described in the PM Manifesto are also represented in our findings (Van Der Aalst *et al.*, 2012): *"Finding, Merging and Cleaning Event Data," "Dealing with Complex Event Logs Having Diverse Characteristics" and "Dealing with Concept Drift."* Further, we observe that in comparison with the guiding principles published in the PM Manifesto, our enabler "*Continuously analyze the process and assess the created value"* is similar to "*Process Mining Should Be a Continuous Process."* In addition, "*Focus coPM analysis"* relates to *"Log Extraction Should Be Driven by Questions"* (Van Der Aalst *et al.*, 2012). However, we were able to identify numerous novel challenges and enablers describing the unique character of coPM; for example, "*Ensure comparability and semantic alignment," "Encounter distributed knowledge and control"* and *"Align interests, strategies and goals."*

The revealed challenges and enablers further cover different areas of PM (Vom Brocke *et al.*, 2021) and thereby undermine the complexity of its cross-organizational application. On a technical level, various data-related challenges need to be solved, for example, regarding the quality and granularity of event-log data. On an ecosystem level, distributed data and knowledge have to be combined, and contrasting goals need to be overcome. Hence, organizations not only need the technical abilities to extract data from existing IS and the analytical skills to perform meaningful PM analyses but also the possibility to convince the involved organizations to apply coPM, for example, through the enabler *"Align interests, strategies and goals."*

Referring to the connection of challenges and enablers presented in Figure 5, we observe that two are not connected to a challenge: *"Align interests, strategies and goals"* and *"Provide process view flexibility and use configurable process models."* Hence, future research (see Section 5.3) should investigate this matter to reveal, if and how the enabler supports handling one or multiple challenges. For example, how does the enabler *"Align interests, strategies and goals"* assist with the challenge *"Handle contrasting goals"*? In line with the observation that previous research on coPM mostly focused on technical aspects, we also identified one dominant technical enabler, *"Pre-process data,"* relating to nine different challenges. Thus, previous literature has mostly tried to solve the challenges of coPM by presenting new ways to pre-process the data in certain ways, for example, by anonymizing, filtering or merging.

Looking at the two types of coPM, exploiting commonality and collaboration, we observe that some challenges and enablers are unique to one scenario. "*Ensure comparability and semantic alignment"* is only relevant when multiple organizations are compared with each other (exploiting commonality), while "*Resolve focus shift"* is only relevant in supply chains (collaboration). Furthermore, "*Ensure Security"* might be less important if the compared organizations are not competing (exploiting commonality). However, the challenges are predominantly present in both scenarios and, therefore, also the enablers needed to overcome them.

5.2 Discussion of the current state of the literature

Current literature on coPM is widely dispersed and not prevalent in major IS conferences and journals. The distribution of articles covering aspects of the IOC framework further shows that the majority focused on coPM techniques, which were often evaluated with artificial data. Furthermore, the actual usage of coPM in practice, especially for collaborative coPM, cannot be retrieved from the articles within our literature review. We observe a lack of empirical research with companies that have already deployed large and successful PM applications. In addition, articles evaluating their coPM techniques with real-world data mostly lack details on how the data was retrieved and combined. Despite Aksu *et al.* (2016), no article systematically covered the uncertainty sources in coPM projects. They were usually presented as a by-product of the actual research or used within the articles' motivation section; for example, Ho *et al.* (2009) mentioned contrasting goals between the parties as a potential source of uncertainty. Furthermore, an early focus on privacy preservation for coPM was laid within the PM Manifesto (Van Der Aalst *et al.*, 2012). Hence, we can conclude that our knowledge of the specific sources of uncertainty within coPM is limited, while we put a strong emphasis on technological advancements. These new or advanced techniques, however, have so far not led to a broad practical adoption (Thiede *et al.*, 2018) and focused more on cartography activities than on coPM for auditing and navigation purposes. In addition, the analysis, redesign, implementation and monitoring phases of the BPM lifecycle are less extensively covered than the data preparation stage. Consequently, we also know little about the value creation mechanisms in coPM and its impact on the performance of the inter-organizational relationship. Overall, we conclude that we need to overcome the gap between coPM research and practice, for example, in terms of techniques applied, processes to be analyzed and procedures followed. This requires broadening the past technical focus of coPM research to include socio-technical research supported through empirical research methods, which is increasingly possible as the PM market is growing (Fortune Business Insights, 2023) and more organizations adopt PM. In line with the IOC framework, we, thus, argue that future research needs to dive into understanding which uncertainty sources are present and how they trigger the need for information processing. Without a deep understanding of the uncertainty sources and their implications for coPM, we cannot develop targeted coordination mechanisms that assist in successfully implementing coPM.

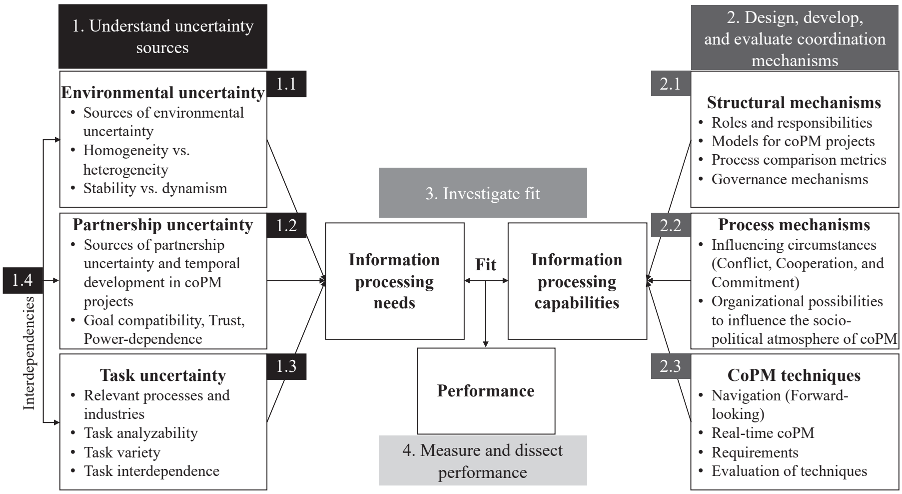
When building our research framework, we, therefore, asked ourselves: "What are steps that need to be taken to fully understand the dynamics of coPM and foster practical adoption?" Our discipline has a long-standing tradition of studying inter-organizational relations and IS, for example, in the context of outsourcing (Willcocks and Kern, 1998), IT governance

(Grant and Tan, 2013) and recently operational IT alignment (Trang *et al.*, 2021), the following research framework guides future research on coPM including its socio-technical implications and thereby fosters its relevance within the BPM and IS community. The research framework that we built along the dimensions of the IOC framework (see Figure 6) consists of four areas: First, researchers need to develop a thorough understanding of the uncertainty sources present in coPM. Second, coordination mechanisms can be designed, developed and evaluated that assist in handling uncertainty sources. Third, the fit between the information processing needs and the information processing capabilities can be investigated to better understand how the coordination mechanisms assist with handling uncertainty sources. Fourth, the performance of coPM and its impact on the performance of the cross-organizational relationship can be researched in order to determine value potentials generated through coPM. These four areas can either be investigated in isolation (e.g. determine sources of partnership uncertainty) or by interpreting the four areas as four steps that need to be followed in order to develop and evaluate a coordination mechanism that tackles one or multiple uncertainty sources: (1) Determine uncertainty source(s), (2) Design, develop and evaluate a coordination mechanism, (3) Investigate how the mechanisms' coordination capabilities assist with handling the uncertainty source and (4) Research the impact on the performance of coPM. By doing so, we ensure that we understand the overall dynamics of coPM and foster practical adoption. Within the next section, we describe in detail what future coPM research should investigate to increase our theoretical understanding of coPM, advance coPM techniques and provide assistance for practitioners and researchers in conducting coPM.

5.3 Future research areas

In the following, we provide an explanation and multiple research questions (RQs) for each research area of our research framework (see Figure 6).

5.3.1 Environmental uncertainty (1.1). Business processes are influenced by the industry and the market they are executed in Venkatesh and Bala (2012). Regulations, laws and standards have compliance requirements that have to be fulfilled (Aksu *et al.*, 2016; Knuplesch *et al.*, 2013), such as the general data protection regulation in the European Union



Source(s): Figure by authors

Figure 6.
Research framework for coPM building upon Bensaou and Venkatraman (1996)

(Elkoumy *et al.*, 2020b). Those factors of environmental uncertainty are so far only investigated for accurately comparing the performance of organizations (Aksu *et al.*, 2016). Hence, it remains unknown which factors exist and are specifically relevant in collaborative coPM settings. To identify sources of environmental uncertainty for coPM, researchers can draw on existing work on environmental uncertainty, for example, Duncan (1972), and determine the factors relevant in coPM settings. Building upon identified sources of environmental uncertainty, researchers can investigate how homogeneous and heterogenous environments as well as stable and dynamic environments impact coPM. For example, dynamic environments may require reperforming coPM analyses and reinterpreting the results, while heterogeneous environments enhance the complexity of accurately comparing multiple organizations with each other.

RQ 1.1.1. Which sources of environmental uncertainty are present in coPM projects?

RQ 1.1.2. How do heterogeneous/homogeneous environments of multiple organizations impact coPM?

RQ 1.1.3. How do stable/dynamic environments of multiple organizations impact coPM?

5.3.2 Partnership uncertainty (1.2). Diirr and Cappelli (2018) postulate that shared goals among business partners form a successful basis for inter-organizational relationships, while Pang and Bunker (2007) emphasize the importance of financial benefits, and Bala and Venkatesh (2007) conclude that in an inter-organizational relationship, power differences usually exist between the participating partners; for example, based on their market share. These differences can be leveraged, for example, to force a non-dominant partner to invest in relationship-specific technology. In coPM, one possible scenario is that a dominant firm forces a non-dominant firm to store and share event-log data in a particular format. In the same way, trust plays a vital role in hampering or promoting the success of inter-organizational cooperation (Ghosh and Fedorowicz, 2005). So far, sources of partnership uncertainty on coPM were only mentioned within the motivation of three studies, Ho *et al.* (2009), Jacobi *et al.* (2020) and Rott and Böhm (2022b). Hence, we emphasize the importance of unraveling various sources of partnership uncertainty and their effect on a coPM initiative. We believe that stakeholder theory, emphasizing the importance of individual and diverging interests of involved stakeholders (Donaldson and Preston, 1995), may assist with this research question and can be enriched by researching coPM. In addition, goal compatibility, trust, and power dependence as prominent sources of partnership uncertainty in inter-organizational relationships (Bensaou and Venkatraman, 1996) need to be investigated. As, for example, mistrust is often more prominent in the early phases of an inter-organizational relationship (Scott, 2000), we believe it is important to also analyze how these factors evolve over time, for example, with increasing maturity of the coPM analysis.

RQ 1.2.1. Which sources of partnership uncertainty are present in coPM projects?

RQ 1.2.2. How does goal compatibility/trust/power dependence between multiple organizations influence coPM?

RQ 1.2.3. How does goal compatibility/trust/power dependence evolve over time and thereby change its impact on coPM?

5.3.3 Task uncertainty (1.3). So far, two papers have mentioned sources of task uncertainty (task analyzability, task variety and task interdependence) in their work: Partington *et al.* (2015) and Engel *et al.* (2012). Hence, we know little about the situations, industries and processes that need to handle task uncertainty. Also, research on the consequences of the three task uncertainty sources and their impact on coPM is missing. Against this background, we consider it important to investigate how coPM is impacted by the presence of task uncertainty. Task analyzability may, for example, influence the comparison of tasks executed in different organizations due to different specifications of task execution, while task variety may be required to consider when comparing task performance between multiple organizations, for example, as unforeseen constraints of location, time or personnel resources restrict the task execution (Unger and Wagner, 2011). We expect both to be important for coPM to exploit commonalities and provide an opportunity to contribute to theory on IT-enabled inter-organizational learning (Scott, 2000). In contrast, task interdependence is specifically relevant for collaborative coPM, for example, when the inter-organizational business process involves the exchange of information between collaborating partners, as the outcomes of tasks executed at one organization influence the tasks of their business partners (Zhi-Jun and Tian-Mei, 2006). Hence, research on task interdependence in coPM may contribute to coordination theory, which investigates how multiple actors coordinate their actions (Malone, 1988).

RQ 1.3.1. Which processes and industries have to handle task uncertainty in which situations?

RQ 1.3.2. How does task analyzability impact coPM, especially for exploiting commonalities?

RQ 1.3.3. How does task variety impact coPM, especially for exploiting commonalities?

RQ 1.3.4. How does task interdependence impact coPM, especially for collaborative scenarios?

5.3.4 Interdependencies between environmental, partnership and task uncertainty (1.4). As stated by Bensaou and Venkatraman (1996), the uncertainty sources range from very global (environmental uncertainty) to very specific (task uncertainty). Looking at the papers from our literature review, we see that no paper simultaneously investigated two or all three uncertainty sources. Hence, we know little about the interdependence between environmental, partnership and task uncertainty. However, we believe that this is important to understand if some uncertainty sources depend on each other or promote, hamper or eliminate the need for IOC through coPM.

RQ 1.4.1. What are the interdependencies between environmental, partnership and task uncertainty?

RQ 1.4.2. How do the interdependencies between uncertainty sources influence coPM?

5.3.5 Structural mechanisms (2.1). Structural mechanisms assign authority and roles within coPM (Bensaou and Venkatraman, 1996). Existing coPM literature has focused on models for executing coPM, value distribution mechanisms, metrics for business process comparison and collaboration, and the formalization of business process compliance. Roles that are required for coPM projects, including their responsibilities (e.g. *Who performs the coPM analysis?*), are missing. Hence, we lack explicit guidelines for distributing tasks within coPM to specific participants (e.g. *Is it beneficial to include a trusted third party for data integration and coPM analysis?*). Furthermore, the different models for executing coPM were not empirically evaluated. Thus, we lack an understanding of the applicability of these models in different situations. In addition, governance mechanisms for coPM that assist researchers and practitioners have not been investigated thus far. Hence, we lack an understanding of ways to govern coPM and an understanding of how certain governance mechanisms impact coPM. For the latter, we think that the resource-based view of the firm (Wernerfelt, 1984) may serve as a theory for guiding this research. Building upon understanding governance mechanisms, we can further develop guidelines for implementing them in practice.

RQ 2.1.1. Which roles, including their responsibilities, exist in coPM projects?

RQ 2.1.2. Which tasks should be assigned to which participants in coPM projects?

RQ 2.1.3. What are the circumstances that define the applicability of a specific model for coPM project execution?

RQ 2.1.4. Which governance mechanisms assist with coPM in what situations, under which circumstances?

RQ 2.1.5. How can a specific governance mechanism be implemented in organizations?

5.3.6 Process mechanisms (2.2). Current literature on coPM has neglected process mechanisms that describe the socio-political atmosphere within the inter-organizational relationship and directly influence information processing capabilities. As stated by Bensaou and Venkatraman (1996), process mechanisms can be described using the three dimensions of conflict, cooperation and commitment, while it is expected that lower conflict, higher cooperation and higher commitment increase the ability to liberally share information. Hence, we first need to analyze the socio-political atmosphere in established coPM projects and inter-organizational collaborations to understand circumstances that promote and hamper them. Building upon this knowledge, we can subsequently investigate how organizations can positively influence the socio-political climate. Social network theory, for example, may assist with this research area by characterizing relationships between organizations as links between individuals within each organization (Haythornthwaite, 1996).

RQ 2.2.1. Which circumstances promote and hamper the socio-political atmosphere of coPM in terms of the dimensions of conflict, cooperation and commitment?

RQ 2.2.2. How can organizations influence the socio-political atmosphere of coPM to increase the ability to liberally share information?

5.3.7 IT-mediated mechanisms (coPM techniques) (2.3). As it can be drawn from Section 4.2, the majority of articles within this literature review focused on coPM techniques. Hence, organizations and researchers can draw on various techniques for the main coPM activities (Cartography, Auditing and Navigation), data pre-processing for coPM and coPM based on blockchain data. However, the discovery of process models is more extensively covered than coPM for auditing and navigation purposes. In addition, articles on navigation techniques for coPM were, surprisingly, published between 2009 and 2020, including only two publications from the last five years (see Table 3). This is in contrast to recent publications emphasizing the importance and value of forward-looking PM (Van Der Aalst and Carmona, 2022). Hence, we believe that it is valuable to increase research on coPM for navigation. Furthermore, most of the techniques are designed for post-mortem event data. Thus, we also call for research on real-time coPM, for example, for detecting non-conformant behavior. More specific research questions, for example, building upon the limitations of the already developed techniques, can be found in the articles of this literature review themselves. As we focus on the BPM and IS domain within this research agenda, we also want to point out socio-technical questions concerning coPM techniques. Multiple articles evaluated their approach using artificial data or presented abstract concepts of coPM techniques without any evaluation (see Table 2). Hence, we think that the disciplines of BPM and IS can advance research on coPM techniques by evaluating them in real-world empirical scenarios, understanding when certain techniques can be applied, and how the techniques assist with handling environmental, partnership, and task uncertainty.

RQ 2.3.1. How can coPM techniques for navigation (Explore, Predict and Recommend) be advanced?

RQ 2.3.2. How can real-time coPM techniques be advanced?

RQ 2.3.3. Which requirements for advancing coPM techniques can be unraveled by empirically investigating and comparing multiple coPM techniques?

RQ 2.3.4. Which coPM technique should be applied by organizations in which situations?

RQ 2.3.5. How do coPM techniques assist with handling environmental, partnership, and task uncertainty?

5.3.8 Investigate fit between needs and capabilities (3). The success of coPM is, according to the IOC framework, determined by the fit between the information processing needs originating from the uncertainty sources and the information processing capabilities determined through the coordination mechanisms (Bensaou and Venkatraman, 1996). Looking at the current coPM literature, we observe that no article has systematically looked into this. Hence, it remains unknown how the information processing needs and capabilities themselves, as well as the fit between both, can be determined for an inter-organizational collaboration performing coPM. This is of crucial importance for understanding how organizations can positively impact the success of coPM, as a misfit between needs and capabilities hampers the performance, either by wasting resources (low information processing needs and high information processing capabilities) or by not being able to properly handle uncertainty (high information processing needs and low information processing capabilities). In addition to directly contributing to the IOC framework, we expect this research area to also contribute to research on the impact of IS on the resilience of organizations (Heeks and Ospina, 2019), for example, by revealing how the coPM coordination mechanisms increase (inter-)organizational resilience.

RQ 3.1. How can the information processing needs originating from the presence and interplay of different uncertainty sources be determined for an inter-organizational relationship conducting coPM?

RQ 3.2. How can the information processing capabilities originating from the deployment and interplay of different coordination mechanisms be determined for an inter-organizational relationship conducting coPM?

RQ 3.3. How can the fit between information processing needs and capabilities be determined for an inter-organizational relationship conducting coPM?

5.3.9 Measure and dissect performance (4). Measure and dissect the performance of coPM requires extensive cooperation between research and practice. Following the conclusion of Thiede *et al.* (2018) that coPM publications in IS research are underrepresented, we call for empirical research that looks into the outcomes of coPM. As the focus of the present literature is mostly on hospitals, municipalities and manufacturing firms (see Table 2), future research can investigate other scenarios; for instance, multi-modal transportation or software-as-a-service. Building upon cross-case analysis, researchers can advance the model of Badakhshan *et al.* (2022) for value creation from PM to account for cross-organizational scenarios and thereby investigate whether different types of affordances are required and new types of value can be realized (e.g. increasing inter-organizational trust by making the collaborative process transparent).

RQ 4.1. Which insights and value potentials can be created through the application of coPM?

RQ 4.2. How does the application of coPM lead to the creation of business value?

5.3.10 Future research on challenges and enablers of coPM (5). Referring to the type of evaluation data from Table 2, many developed techniques and enablers were evaluated with artificial data, while some enablers and challenges are disconnected from each other (see Figure 5). Hence, investigating the impact of an enabler on one or more challenges requires empirical (quantitative) evaluation. As all challenges and enablers were drawn from the coPM literature, we further emphasize the need to reveal more of these grounded in practical experience as well as more detailed information and examples. For instance, how do firms gain access to data from business partners (collaboration), competitors or non-competitors (exploiting commonality)? This is desperately needed, as coPM is still lacking practical application despite the technological advancements in the past fifteen years (see Section 4.2.5 and Appendix 1). We expect qualitative empirical research, such as interviewing practitioners, PM vendors and consultancies that have implemented PM across organizational boundaries, to add valuable experience. Finally, after enhancing the list of challenges and enablers, it will be valuable to unravel their relative importance and priority for supporting (enabler) or hampering (challenges) coPM in industry and research, for example, through performing a Delphi study (Häder, 2014).

RQ 5.1. What challenges and enablers can be revealed through empirical research?

RQ 5.2. In what way do the enablers of coPM assist with solving the challenges of coPM?

RQ 5.3. What is the relative importance of challenges and enablers for coPM research and practice?

5.3.11 Overall research agenda. Overall, this leads to the following research agenda for coPM (see Table 7). Building upon an understanding of the uncertainty sources, research can develop targeted coordination mechanisms that assist organizations in adopting coPM and handling the information processing needs caused by the uncertainty sources. In addition, future research can contribute to various theories applied in IS and thereby advance our theoretical understanding of the dynamics in coPM. Finally, empirical research on the performance of coPM will shed light on the value-creating mechanisms in coPM while investigating challenges and enablers that will assist practitioners in the adoption of coPM.

5.4 Limitations and contributions

5.4.1 Limitations. Though we followed the guidelines of Vom Brocke *et al.* (2009) and Webster and Watson (2002) including determining a search string and identifying the relevant databases, the selection and conceptualization of publications are to some extent always prone to the authors' subjectivity. Our articles range from various conferences and journals within IS, BPM and CS research. Hence, they may differ in the quality and rigor of the research conducted. However, we decided to treat every article as equally important to fully understand the current state of knowledge on coPM. Also, our manuscript represents the current state of knowledge on coPM at the time of conducting our literature review and is, thus, limited to the published articles at that time. As coPM is an emerging topic, we expect that reperforming this literature review in the medium-term future, once more socio-technical artifacts have been developed, practical adoption has increased, and scientific articles have investigated successful real-life coPM relationships, will be valuable. Furthermore, the revealed challenges and enablers are solely drawn from the literature as we did not combine the literature review with additional empirical research methods (e.g. conducting interviews with PM vendors, adopters and consultancies, or performing field studies). Thus, they require further empirical evaluation and enhancement. As our search for practitioner-oriented resources (e.g. blogs on PM or white papers from vendors and consultancies) did not yield any valuable results, we focused our analysis on scientific coPM literature. Once more practitioner-related information is published in the future, we expect that these articles can supplement the information provided in our article. This also holds for concepts from related disciplines (e.g. information sharing in supply chains) that we have not included in this manuscript.

Area		Research question
Environmental uncertainty	1.1.1	Which sources of environmental uncertainty are present in coPM projects?
	1.1.2	How do heterogeneous/homogeneous environments of multiple organizations impact coPM?
	1.1.3	How do stable/dynamic environments of multiple organizations impact coPM?
Partnership uncertainty	1.2.1	Which sources of partnership uncertainty are present in coPM projects?
	1.2.2	How does goal compatibility/trust/power dependence between multiple organizations influence coPM?
	1.2.3	How does goal compatibility/trust/power dependence evolve over time and thereby change its impact on coPM?
Task uncertainty	1.3.1	Which processes and industries have to handle task uncertainty, in which situations?
	1.3.2	How does task analyzability impact coPM, especially for exploiting commonalities?
	1.3.3	How does task variety impact coPM, especially for exploiting commonalities?
	1.3.4	How does task interdependence impact coPM, especially for collaborative scenarios?
Interdependency between uncertainty sources	1.4.1	What are the interdependencies between environmental, partnership, and task uncertainty?
	1.4.2	How do the interdependencies between uncertainty sources influence coPM?
Structural mechanisms	2.1.1	Which roles, including their responsibilities, exist in coPM projects?
	2.1.2	Which tasks should be assigned to which participants in coPM projects?
	2.1.3	What are the circumstances that define the applicability of a specific model for coPM project execution?
	2.1.4	Which governance mechanisms assist with coPM in what situations, under which circumstances?
	2.1.5	How can a specific governance mechanism be implemented in organizations?
Process mechanisms	2.2.1	Which circumstances promote and hamper the socio-political atmosphere of coPM in terms of the dimensions of conflict, cooperation, and commitment?
	2.2.2	How can organizations influence the socio-political atmosphere of coPM to increase the ability to liberally share information?
IT-mediated mechanisms (coPM)	2.3.1	How can coPM techniques for navigation (Explore, Predict, and Recommend) be advanced?
	2.3.2	How can real-time coPM techniques be advanced?
	2.3.3	Which requirements for advancing coPM techniques can be unraveled by empirically investigating and comparing multiple coPM techniques?
	2.3.4	Which coPM technique should be applied by organizations in which situations?
	2.3.5	How do coPM techniques assist with handling environmental, partnership, and task uncertainty?

(*continued*)

Table 7.
Research agenda for coPM

Area		Research question
Fit between needs and capabilities	3.1	How can the information processing needs originating from the presence and interplay of different uncertainty sources be determined for an inter-organizational relationship conducting coPM?
	3.2	How can the information processing capabilities originating from the deployment and interplay of different coordination mechanisms be determined for an inter-organizational relationship conducting coPM?
	3.3	How can the fit between information processing needs and capabilities be determined for an inter-organizational relationship conducting coPM
Performance	4.1	Which insights and value potentials can be created through the application of coPM?
	4.2	How does the application of coPM lead to the creation of business value?
Challenges and enablers of coPM	5.1	What challenges and enablers can be revealed through empirical research?
	5.2	In what way do the enablers of coPM assist with solving the challenges of coPM?
	5.3	What is the relative importance of challenges and enablers for coPM research and practice?

Source(s): Table by authors

Table 7.

5.4.2 Theoretical contributions. We show that past literature on coPM focused mainly on technical aspects and provide a comprehensive summary of existing articles relevant for every researcher willing to engage with coPM by providing an overview of already developed approaches (technical and socio-technical) and by raising awareness for challenges and enablers that are involved in coPM application. Thus, researchers can build on the synthesized knowledge presented in this paper and further take the list of existing papers on coPM as a starting point to identify relevant coPM articles for their own research project. Further, we lay the foundation for future research on coPM building upon a new, socio-technical perspective, grounded in the IOC framework. The research agenda and the research framework emphasize the importance of a strong cooperation between research and practice. While proactively developing coordination mechanisms may help organizations with coPM adoption, researching successful coPM applications is necessary to understand how coPM can lead to the creation of business value. Overall, we therefore contribute cross-disciplinary to IS, BPM and CS literature.

5.4.3 Practical contributions. We believe that our article will also serve organizations as one great starting point for engaging with coPM. An awareness of the specific technical and non-technical challenges and enablers assists in anticipating and managing implementation hurdles, while the presented techniques and socio-technical artifacts assist with coPM adoption and implementation. Furthermore, the two main areas of our future research framework (uncertainty sources and coordination mechanisms) can guide organizations that initialize and conduct coPM by raising awareness for two important aspects that influence the success of a coPM endeavor: “What uncertainty sources are present in my coPM relationship?” and “What coordination mechanisms do we need to establish?”.

6. Conclusion

PM is an emerging technology with enormous potential for implementation in a cross-organizational setting where it is underrepresented (Thiede *et al.*, 2018) despite the high level of interest within the PM community (Martin *et al.*, 2021; Reinkemeyer, 2022; Rott and Böhm, 2022a). It is against this background that we present our assessing literature review (Leidner, 2018). We have synthesized existing information about coPM according to the dimensions of the IOC framework (Bensaou and Venkatraman, 1996) and conclude that we lack a profound theoretical understanding of coPM. Past research is highly dispersed and mainly focused on coPM techniques for data pre-processing, process model discovery, and coPM based on historic event data, while uncertainty sources impacting coPM were mostly neglected. Furthermore, our results indicate that PM technology is not the primary reason it lacks practical application across organizations. Instead, it is because of new challenges, ranging from low-level ones, such as how to integrate distributed data of varying granularities, to high-level difficulties, such as aligning different strategies to incentivize firms to share their data and collectively analyze business processes. Accordingly, we present a framework for future research that comprises four steps to fully understand the dynamics of coPM and foster practical adoption. First, researchers and practitioners need to deeply understand the uncertainty sources present in coPM. Second, coordination mechanisms (structural, process and IT-mediated) can be designed, developed and evaluated that assist in handling the uncertainty sources of coPM. Third, the fit between the information processing needs and the information processing capabilities can be investigated to understand which and how the coordination mechanisms assist with handling uncertainty. Fourth, the performance of coPM and its impact on the performance of the cross-organizational relationship can be analyzed in order to understand how PM across organizational boundaries leads to the creation of business value and to determine value potentials for practitioners.

Notes

1. The PM activity "Diagnose" doesn't directly use event logs or requires specific techniques as it focuses on the manual analysis of process models (van der Aalst, 2016). Hence, it is not included in our summary on coPM techniques.
2. https://gdpr.eu

References

Aksu, Ü., Schunselaar, D.M.M. and Reijers, H.A. (2016), "A cross-organizational process mining framework for obtaining insights from software products: accurate comparison challenges", *2016 IEEE 18th Conference on Business Informatics (CBI)*, 29 Aug.-1 Sept, pp. 153-162, doi: 10.1109/CBI.2016.25.

Alvesson, M. and Sandberg, J. (2013), *Constructing Research Questions: Doing Interesting Research*, SAGE Publications, London. doi: 10.4135/9781446270035.

Aouachria, M., Leshob, A. and Ghomari, A.R. (2017), "Process adaptation patterns for cross-organizational business process modeling", *14th International Joint Conference on e-Business and Telecommunications - Volume 2: ICE-B, (ICETE 2017)*, pp. 124-129, doi: 10.5220/0006470201240129.

Association for Information Systems (2023), "Senior scholars' basket of journals", available at: https://aisnet.org/page/SeniorScholarListofPremierJournals (accessed 1 March 2023).

Augusto, A., Conforti, R., Dumas, M., La Rosa, M. and Polyvyanyy, A. (2019a), "Split miner: automated discovery of accurate and simple business process models from event logs", *Knowledge and Information Systems*, Vol. 59 No. 2, pp. 251-284, doi: 10.1007/s10115-018-1214-x.

Augusto, A., Conforti, R., Dumas, M., Rosa, M.L., Maggi, F.M., Marrella, A., Mecella, M. and Soo, A. (2019b), "Automated discovery of process models from event logs: review and benchmark", *IEEE Transactions on Knowledge and Data Engineering*, Vol. 31 No. 4, pp. 686-705, doi: 10.1109/TKDE.2018.2841877.

Azzini, A. and Ceravolo, P. (2013), "Consistent process mining over big data triple stores", *2013 IEEE International Congress on Big Data*, 27 June-2 July, pp. 54-61, doi: 10.1109/BigData.Congress.2013.17.

Badakhshan, P., Conboy, K., Grisold, T. and Vom Brocke, J. (2020), "Agile business process management", *Business Process Management Journal*, Vol. 26 No. 6, pp. 1505-1523, doi: 10.1108/BPMJ-12-2018-0347.

Badakhshan, P., Wurm, B., Grisold, T., Geyer-Klingeberg, J., Mendling, J. and Brocke, J.V. (2022), "Creating business value with process mining", *The Journal of Strategic Information Systems*, Vol. 31 No. 4, 101745, doi: 10.1016/j.jsis.2022.101745.

Bala, H. and Venkatesh, V. (2007), "Assimilation of interorganizational business process standards", *Information Systems Research*, Vol. 18 No. 3, pp. 340-362, doi: 10.1287/isre.1070.0134.

Bazan, P. and Estevez, E. (2022), "Industry 4.0 and business process management: state of the art and new challenges", *Business Process Management Journal*, Vol. 28 No. 1, pp. 62-80, doi: 10.1108/BPMJ-04-2020-0163.

Bensaou, M. and Venkatraman, N. (1996), "Inter-organizational relationships and information technology: a conceptual synthesis and a research framework", *European Journal of Information Systems*, Vol. 5 No. 2, pp. 84-91, doi: 10.1057/ejis.1996.15.

Bernardi, M.L., Cimitile, M. and Maggi, F.M. (2014), "Discovering cross-organizational business rules from the cloud", *2014 IEEE Symposium on Computational Intelligence and Data Mining (CIDM)*, 9-12 Dec, pp. 389-396, doi: 10.1109/CIDM.2014.7008694.

Bernardi, M.L., Cimitile, M. and Mercaldo, F. (2018), "Cross-Organisational process mining in cloud environments", *Journal of Information and Knowledge Management*, Vol. 17 No. 02, 1850014, doi: 10.1142/s0219649218500144.

Beynon-Davies, P. and Wang, Y. (2019), "Deconstructing information sharing", *Journal of the Association for Information Systems*, Vol. 20 No. 4, pp. 476-498, available at: https://aisel.aisnet.org/jais/vol20/iss4/1

Böhm, M., Rott, J., Eggers, J., Grindemann, P., Nakladal, J., Hoffmann, M. and Krcmar, H. (2021), "Process mining at Lufthansa CityLine: the path to process excellence", *Journal of Information Technology Teaching Cases*, Vol. 12 No. 2, pp. 1-11, doi: 10.1177/20438869211022369.

Bostrom, R.P. and Heinen, J.S. (1977), "MIS problems and failures: a socio-technical perspective. Part I: the causes", *MIS Quarterly*, Vol. 1 No. 3, pp. 17-32, doi: 10.2307/248710.

Buijs, J. C.a. M. and Reijers, H.A. (2014), "Comparing business process variants using models and event logs", in Bider, I., Gaaloul, K., Krogstie, J., Nurcan, S., Proper, H.A., Schmidt, R. and Soffer, P. (Eds), *Enterprise, Business-Process and Information Systems Modeling. BPMDS EMMSAD 2014. Lecture Notes in Business Information Processing*, Springer, Berlin, Heidelberg, pp. 154-168, doi: 10.1007/978-3-662-43745-2_11.

Buijs, J. C.a. M., Van Dongen, B.F. and Van Der Aalst, W.M.P. (2012a), "On the role of fitness, precision, generalization and simplicity in process discovery", *On the Move to Meaningful Internet Systems: OTM 2012*, Springer, Berlin, Heidelberg, pp. 305-322, doi: 10.1007/978-3-642-33606-5_19.

Buijs, J. C.a. M., Van Dongen, B.F. and Van Der Aalst, W.M.P. (2012b), *Towards Cross-Organizational Process Mining in Collections of Process Models and Their Executions*, Springer, Berlin, Heidelberg, pp. 2-13, doi: 10.1007/978-3-642-28115-0_2.

Buijs, J. C.a. M., Van Dongen, B.F. and Van Der Aalst, W.M.P. (2013), "Mining configurable process models from collections of event logs", *11th International Conference on Business Process Management, 2013*, Berlin, Heidelberg, Springer, pp. 33-48, doi: 10.1007/978-3-642-40176-3_5.

Canjels, K.F., Imkamp, M.S.V., Boymans, T.a. E.J. and Vanwersch, R.J.B. (2019), "Unraveling and improving the interorganizational arthrosis care process at Maastricht UMC+: an illustration of an innovative, combined application of data and process mining", *International Conference on Business Process Management*, Vienna, Austria, pp. 178-189, 2019.

Capgemini (2012), “Global business process management report”, available at: https://www.capgemini.com/wp-content/uploads/2017/07/Global_Business_Process_Management_Report.pdf

Celonis (2022), “Deutschen Telekom + Celonis”, available at: https://www.celonis.com/de/customer-success-stories/deutsche-telekom-procure-to-pay-process-mining/ (accessed 13 May 2022).

Claes, J. and Poels, G. (2014), “Merging event logs for process mining: a rule based merging method and rule suggestion algorithm”, *Expert Systems with Applications*, Vol. 41 No. 16, pp. 7291-7306, doi: 10.1016/j.eswa.2014.06.012.

Corradini, F., Re, B., Rossi, L. and Tiezzi, F. (2022), “A technique for collaboration discovery”, *International Conference on Business Process Modeling, Development and Support - Enterprise, Business-Process and Information Systems Modeling*, Cham, Springer International Publishing, pp. 63-78, doi: 10.1007/978-3-031-07475-2_5.

D’Iddio, A.C., Schunck, C.H., Arcieri, F. and Talamo, M. (2016a), “Extending abstraction-refinement methods for compliance checking of inter-organizational business processes with incomplete information”, *2016 IEEE International Carnahan Conference on Security Technology (ICCST)*, 24-27 Oct, pp. 1-7, doi: 10.1109/CCST.2016.7815703.

D’Iddio, A.C., Schunck, C.H., Arcieri, F. and Talamo, M. (2016b), “Online and offline conformance checking of inter-organizational business processes with incomplete process logs”, *2016 IEEE International Carnahan Conference on Security Technology (ICCST)*, 24-27 Oct, pp. 1-8, doi: 10.1109/CCST.2016.7815702.

Deokar, A.V. and Tao, J. (2020), “OrgMiner: a framework for discovering user-related process intelligence from event logs”, *Information Systems Frontiers*, Vol. 23 No. 3, pp. 753-772, doi: 10.1007/s10796-020-09990-7.

Diirr, B. and Cappelli, C. (2018), “Establishing transparent interorganizational relationships through shared goals for anti-corruption in Brazil”, *International Conference on Business Process Management - Business Process Management Workshops*, Cham, Springer International Publishing, pp. 497-509, doi: 10.1007/978-3-319-74030-0_39.

Donaldson, T. and Preston, L.E. (1995), “The stakeholder theory of the corporation: concepts, evidence, and implications”, *The Academy of Management Review*, Vol. 20 No. 1, pp. 65-91, doi: 10.2307/258887.

Dumas, M., La Rosa, M., Mendling, J. and Reijers, H. (2018), *Fundamentals of Business Process Management*, Springer, Berlin, Heidelberg. doi: 10.1007/978-3-662-56509-4.

Duncan, R.B. (1972), “Characteristics of organizational environments and perceived environmental uncertainty”, *Administrative Science Quarterly*, Vol. 17 No. 3, pp. 313-327, doi: 10.2307/2392145.

Edgington, T.M., Raghu, T.S. and Vinze, A.S. (2010), “Using process mining to identify coordination patterns in IT service management”, *Decision Support Systems*, Vol. 49 No. 2, pp. 175-186, doi: 10.1016/j.dss.2010.02.003.

Elkoumy, G., Fahrenkrog-Petersen, S.A., Dumas, M., Laud, P., Pankova, A. and Weidlich, M. (2020a), “Secure multi-party computation for inter-organizational process mining”, in Nurcan, S., Reinhartz-Berger, I., Soffer, P. and Zdravkovic, J. (Eds), *Enterprise, Business-Process and Information Systems Modeling. BPMDS EMMSAD 2020. Lecture Notes in Business Information Processing*, Springer International Publishing, Cham, pp. 166-181, doi: 10.1007/978-3-030-49418-6_11.

Elkoumy, G., Fahrenkrog-Petersen, S.A., Dumas, M., Laud, P., Pankova, A. and Weidlich, M. (2020b), “Shareprom: a tool for privacy-preserving inter-organizational process mining”, *International Conference on Business Process Modeling, Development and Support*”, pp. 72-76.

Engel, R. and Bose, R.P.J.C. (2014), “A case study on analyzing inter-organizational business processes from EDI messages using physical activity mining”, *2014 47th Hawaii International Conference on System Sciences*, 6-9 Jan, pp. 3858-3867, doi: 10.1109/HICSS.2014.479.

Engel, R., Krathu, W., Zapletal, M., Pichler, C., Van Der Aalst, W.M.P. and Werthner, H. (2011), “Process mining for electronic data interchange”, *International Conference on Electronic Commerce and Web Technologies*, Berlin, Heidelberg, Springer, pp. 77-88, doi: 10.1007/978-3-642-23014-1_7.

Engel, R., Van Der Aalst, W.M.P., Zapletal, M., Pichler, C. and Werthner, H. (2012), "Mining inter-organizational business process models from EDI messages: a case study from the automotive sector", *International Conference on Advanced Information Systems Engineering, 2012*, Berlin, Heidelberg, Springer, pp. 222-237, doi: 10.1007/978-3-642-31095-9_15.

Engel, R., Bose, R.P.J.C., Pichler, C., Zapletal, M. and Werthner, H. (2013a), "EDIminer: a toolset for process mining from EDI messages", *Proceedings of the CAiSE'13 Forum at the 25th International Conference on Advanced Information Systems Engineering*, Valencia, Spain, pp. 146-153.

Engel, T., Birth, O., Goswami, S. and Krcmar, H. (2013b), "How supply chain governance influences information sharing behaviors: a multiple case study approach", *ECIS 2013 - Proceedings of the 21st European Conference on Information Systems*.

Engel, R., Krathu, W., Zapletal, M., Pichler, C., Bose, R.P.J.C., Van Der Aalst, W., Werthner, H. and Huemer, C. (2016), "Analyzing inter-organizational business processes", *Information Systems and E-Business Management*, Vol. 14 No. 3, pp. 577-612, doi: 10.1007/s10257-015-0295-2.

Fortune Business Insights (2023), "Process mining software market size, share and COVID-19 impact analysis", available at: https://www.fortunebusinessinsights.com/process-mining-software-market-104792 (accessed 14 October 2023).

Gerke, K., Claus, A. and Mendling, J. (2009a), "Process mining of RFID-based supply chains", *2009 IEEE Conference on Commerce and Enterprise Computing*, 20-23 July, pp. 285-292, doi: 10.1109/CEC.2009.72.

Gerke, K., Mendling, J. and Tarmyshov, K. (2009b), "Case construction for mining supply chain processes", in Abramowicz, W. (Ed.), *Business Information Systems. BIS 2009. Lecture Notes in Business Information Processing*, Springer, Berlin, Heidelberg, pp. 181-192, doi: 10.1007/978-3-642-01190-0_16.

Ghosh, A. and Fedorowicz, J. (2005), "Governanance mechanisms for coordination and information sharing in supply chains: the role of trust", AMCIS 2005, available at: http://aisel.aisnet.org/amcis2005/18

Gioia, D.A., Corley, K.G. and Hamilton, A.L. (2013), "Seeking qualitative rigor in inductive research: notes on the Gioia methodology", *Organizational Research Methods*, Vol. 16 No. 1, pp. 15-31, doi: 10.1177/1094428112452151.

González, L. and Delgado, A. (2021), "Towards compliance requirements modeling and evaluation of E-government inter-organizational collaborative business processes", *Hawaii International Conference on System Sciences*. doi: 10.24251/HICSS.2021.255.

Grant, G. and Tan, F.B. (2013), "Governing IT in inter-organizational relationships: issues and future research", *European Journal of Information Systems*, Vol. 22 No. 5, pp. 493-497, doi: 10.1057/ejis.2013.21.

Grisold, T., Mendling, J., Otto, M. and Vom Brocke, J. (2021), "Adoption, use and management of process mining in practice", *Business Process Management Journal*, Vol. 27 No. 2, pp. 369-387, doi: 10.1108/BPMJ-03-2020-0112.

Günther, C.W. and Van Der Aalst, W.M.P. (2007), "Fuzzy mining – adaptive process simplification based on multi-perspective metrics", *International Conference on Business Process Management, 2007*, Berlin, Heidelberg, Springer Berlin Heidelberg, pp. 328-343.

Häder, M. (2014), *Delphi-Befragungen - Ein Arbeitsbuch*, VS Verlag für Sozialwissenschaften, Springer Fachmedien Wiesbaden, Wiesbaden.

Haythornthwaite, C. (1996), "Social network analysis: an approach and technique for the study of information exchange", *Library and Information Science Research*, Vol. 18 No. 4, pp. 323-342, doi: 10.1016/S0740-8188(96)90003-1.

Heeks, R. and Ospina, A.V. (2019), "Conceptualising the link between information systems and resilience: a developing country field study", *Information Systems Journal*, Vol. 29 No. 1, pp. 70-96, doi: 10.1111/isj.12177.

Helm, E. and Küng, J. (2016), "Process mining: towards comparability of healthcare processes", in Renda, M.E., Bursa, M., Holzinger, A. and Khuri, S. (Eds), *Information Technology in Bio- and Medical Informatics. ITBAM 2016. Lecture Notes in Computer Science*, Springer International Publishing, Cham, pp. 249-252, doi: 10.1007/978-3-319-43949-5_20.

Hermawan and Sarno, R. (2018), "A more efficient deterministics algorithm in process model discovery", *International Journal of Innovative Computing, Information and Control*, Vol. 14 No. 3, pp. 971-995.

Hernandez-Resendiz, J.D., Tello-Leal, E., Marin-Castro, H.M., Ramirez-Alcocer, U.M. and Mata-Torres, J.A. (2021), "Merging event logs for inter-organizational process mining", in Zapata-Cortes, J.A., Alor-Hernández, G., Sánchez-Ramírez, C. and García-Alcaraz, J.L. (Eds), *New Perspectives on Enterprise Decision-Making Applying Artificial Intelligence Techniques*, Springer International Publishing, Cham, pp. 3-26, doi: 10.1007/978-3-030-71115-3_1.

Ho, G.T.S., Lau, H.C.W., Kwok, S.K., Lee, C.K.M. and Ho, W. (2009), "Development of a co-operative distributed process mining system for quality assurance", *International Journal of Production Research*, Vol. 47 No. 4, pp. 883-918, doi: 10.1080/00207540701441939.

Ivković, V. and Luković, I. (2021), "An approach to validation of business-oriented smart contracts based on process mining", in Bellatreche, L., Dumas, M., Karras, P., Matulevičius, R., Awad, A., Weidlich, M., Ivanović, M. and Hartig, O. (Eds), *New Trends in Database and Information Systems, 2021 Cham*, Springer International Publishing, pp. 303-309, doi: 10.1007/978-3-030-85082-1_27.

Jacobi, C., Meier, M., Herborn, L. and Furmans, K. (2020), "Maturity Model for Applying Process Mining in Supply Chains: Literature Overview and Practical Implications = Reifegradmodell zur Anwendung von Process Mining im Supply Chain Management: Literaturübersicht und Implikationen für die Praxis", *Logistics Journal/Proceedings*, Vol. 2020, pp. 1-16, doi: 10.2195/lj_Proc_jacobi_en_202012_01.

Jokonowo, B., Claes, J., Sarno, R. and Rochimah, S. (2018), "Process mining in supply chains: a systematic literature review", *International Journal of Electrical and Computer Engineering (IJECE)*, Vol. 8 No. 6, pp. 4626-4636, doi: 10.11591/ijece.v8i6.pp4626-4636.

Khan, A., Ghose, A. and Dam, H. (2021), *Cross-Silo Process Mining with Federated Learning*, Springer International Publishing, Cham, pp. 612-626, doi: 10.1007/978-3-030-91431-8_38.

Kim, A., Obregon, J. and Jung, J.-Y. (2014), *Constructing Decision Trees from Process Logs for Performer Recommendation*, Springer International Publishing, Cham, pp. 224-236, doi: 10.1007/978-3-319-06257-0_18.

Kim, A., Obregon, J. and Jung, J.-Y. (2020), "PRANAS: a process analytics system based on process warehouse and cube for supply chain management", *Applied Sciences*, Vol. 10 No. 10, p. 3521, doi: 10.3390/app10103521.

Klinkmüller, C., Ponomarev, A., Tran, A.B., Weber, I. and Aalst, W.V.D. (2019), "Mining blockchain processes: extracting process mining data from blockchain applications", *International Conference on Business Process Management, 2019*, Springer, pp. 71-86.

Knuplesch, D., Reichert, M., Mangler, J., Rinderle-Ma, S. and Fdhila, W. (2013), "Towards compliance of cross-organizational processes and their changes", *International Conference on Business Process Management - Business Process Management Workshops, 2013*, Berlin, Heidelberg, Springer, pp. 649-661, doi: 10.1007/978-3-642-36285-9_65.

Krathu, W., Pichler, C., Engel, R., Zapletal, M., Werthner, H. and Huemer, C. (2014), "A framework for inter-organizational performance analysis from EDI messages", *2014 IEEE 16th Conference on Business Informatics*, 14-17 July 2014, pp. 17-24, doi: 10.1109/CBI.2014.19.

Krcmar, H. (2015), "Management der Informationssysteme", in Krcmar, H. (Ed.), *Informations management*, Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 173-314, doi: 10.1007/978-3-662-45863-1_6.

Lamghari, Z., Radgui, M., Saidi, R. and Rahmani, M.D. (2020), "A framework supporting supply chain complexity and confidentiality using process mining and auto identification technology", *International Conference Europe Middle East and North Africa Information Systems and Technologies to Support Learning, 2020*, Cham, Springer International Publishing, pp. 352-361, doi: 10.1007/978-3-030-36778-7_39.

Leemans, S.J.J., Fahland, D. and Van Der Aalst, W.M.P. (2013), "Discovering block-structured process models from event logs - a constructive approach", *International Conference on Applications and Theory of Petri Nets and Concurrency, 2013*, Berlin, Heidelberg, Springer Berlin Heidelberg, pp. 311-329, doi: 10.1007/978-3-642-38697-8_17.

Leidner, D.E. (2018), "Review and theory symbiosis: an introspective retrospective", *Journal of the Association for Information Systems*, Vol. 19 No. 6, pp. 552-567, available at: https://aisel.aisnet.org/jais/vol19/iss6/1

Li, Y. (2010), "An automatic virtual organization structure modeling method in supply chain management", *2010 International Conference on Management and Service Science*, 24-26 Aug, pp. 1-4, doi: 10.1109/ICMSS.2010.5575841.

Liu, C., Li, Y., Xiang, J., Yang, X., Li, C., Zhao, Q., Zhou, L., Gong, P. and Huang, J. (2020), "Hierarchical business process discovery: identifying sub-processes using lifecycle information", *2020 IEEE International Conference on Web Services (ICWS)*, 19-23 Oct, Vol. 8, pp. 423-427, doi: 10.1109/ICWS49710.2020.00062.

Liu, C., Duan, H., Zeng, Q., Zhou, M., Lu, F. and Cheng, J. (2019), "Towards comprehensive support for privacy preservation cross-organization business process mining", *IEEE Transactions on Services Computing*, Vol. 12 No. 4, pp. 639-653, doi: 10.1109/TSC.2016.2617331.

Liu, C., Cheng, L., Zeng, Q. and Wen, L. (2023a), "Formal modeling and discovery of hierarchical business processes: a petri net-based approach", *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, Vol. 53 No. 2, pp. 1003-1014, doi: 10.1109/TSMC.2022.3195869.

Liu, C., Li, H., Zhang, S., Cheng, L. and Zeng, Q. (2023b), "Cross-department collaborative healthcare process model discovery from event logs", *IEEE Transactions on Automation Science and Engineering*, Vol. 20 No. 3, pp. 2115-2125, doi: 10.1109/TASE.2022.3194312.

Maggi, F.M., Burattin, A., Cimitile, M. and Sperduti, A. (2013), "Online process discovery to detect concept drifts in LTL-based declarative process models", *OTM Confederated International Conferences "On the Move to Meaningful Internet Systems"*, Berlin, Heidelberg, Springer Berlin Heidelberg, pp. 94-111.

Maita, A.R.C., Martins, L.C., López Paz, C.R., Peres, S.M. and Fantinato, M. (2015), "Process mining through artificial neural networks and support vector machines", *Business Process Management Journal*, Vol. 21 No. 6, pp. 1391-1415, doi: 10.1108/BPMJ-02-2015-0017.

Malone, T. (1988), *What Is Coordination Theory?*, National Science Foundation Coordination Theory Workshop, 1988 Massachusetts Institute of Technology (MIT), Cambridge, MA, available at: https://dspace.mit.edu/bitstream/handle/1721.1/2208/SWP-2051-27084940-CISR-182.pdf

Mamudu, A., Bandara, W., Leemans, S.J.J. and Wynn, M.T. (2023), "A process mining impacts framework", *Business Process Management Journal*, Vol. 29 No. 3, pp. 690-709, doi: 10.1108/BPMJ-09-2022-0453.

Mans, R., Schonenberg, H., Leonardi, G., Panzarasa, S., Cavallini, A., Quaglini, S. and Van Der Aalst, W. (2008), "Process mining techniques: an application to stroke care", *Studies in Health Technology and Informatics*, Vol. 136, pp. 573-578, doi: 10.3233/978-1-58603-864-9-573.

Martin, N., Fischer, D.A., Kerpedzhiev, G.D., Goel, K., Leemans, S.J.J., Röglinger, M., Van Der Aalst, W.M.P., Dumas, M., La Rosa, M. and Wynn, M.T. (2021), "Opportunities and challenges for process mining in organizations: results of a Delphi study", *Business and Information Systems Engineering*, Vol. 63 No. 5, pp. 511-527, doi: 10.1007/s12599-021-00720-0.

Maruster, L., Wortmann, J.H., Weijters, A.T. and Van Der Aalst, W.W. (2003), "Discovering distributed processes in supply chains", *IFIP TC5/WG5.7 Eighth International Conference on Advances in Production Management Systems*, Kluwer Acad. Publ.

Mendling, J., Pentland, B.T. and Recker, J. (2020), "Building a complementary agenda for business process management and digital innovation", *European Journal of Information Systems*, Vol. 29 No. 3, pp. 208-219, doi: 10.1080/0960085X.2020.1755207.

Mikalef, P. and Krogstie, J. (2020), "Examining the interplay between big data analytics and contextual factors in driving process innovation capabilities", *European Journal of Information Systems*, Vol. 29 No. 3, pp. 260-287, doi: 10.1080/0960085X.2020.1740618.

Morales-Sandoval, M., Molina, J.A., Marin-Castro, H.M. and Gonzalez-Compean, J.L. (2021), "Blockchain support for execution, monitoring and discovery of inter-organizational business processes", *PeerJ Computer Science*, Vol. 7, p. e731, doi: 10.7717/peerj-cs.731.

Mühlberger, R., Bachhofner, S., Di Ciccio, C., García-Bañuelos, L. and López-Pintado, O. (2019), "Extracting event logs for process mining from data stored on the blockchain", *International Conference on Business Process Management - Business Process Management Workshops, 2019*, Cham, Springer International Publishing, pp. 690-703, doi: 10.1007/978-3-030-37453-2_55.

Müller, M., Simonet-Boulogne, A., Sengupta, S. and Beige, O. (2022), "Process mining in trusted execution environments: towards hardware guarantees for trust-aware inter-organizational process analysis", *International Conference on Process Mining - Process Mining Workshops*, Cham, Springer International Publishing, pp. 369-381, doi: 10.1007/978-3-030-98581-3_27.

Pang, V. and Bunker, D. (2007), "Inter-organizational systems (IOS) for supply chain management (SCM): a multi-perspective adoption framework", *Pacific Asia Conference on Information Systems, PACIS 2007*, Auckland, New Zealand, p. 153, available at: http://aisel.aisnet.org/pacis2007/153

Partington, A., Wynn, M., Suriadi, S., Ouyang, C. and Karnon, J. (2015), "Process mining for clinical processes: a comparative analysis of four Australian hospitals", *ACM Transactions on Management Information Systems (TMIS)*, Vol. 5 No. 4, pp. 1-18, 19, doi: 10.1145/2629446.

Pini, A., Brown, R. and Wynn, M.T. (2015), "Process visualization techniques for multi-perspective process comparisons", *Asia-Pacific Conference on Business Process Management, 2015*, Cham, Springer International Publishing, pp. 183-197, doi: 10.1007/978-3-319-19509-4_14.

Pourmasoumi, A., Kahani, M. and Bagheri, E. (2017), "Mining variable fragments from process event logs", *Information Systems Frontiers*, Vol. 19 No. 6, pp. 1423-1443, doi: 10.1007/s10796-016-9662-x.

Process Mining Conference (2020), "Process mining conference 2021 call for research papers", available at: https://icpmconference.org/2021/calls/call-for-research-papers/ (accessed 12 January 2021).

R'bigui, H. and Cho, C. (2017), "The state-of-the-art of business process mining challenges", *International Journal of Business Process Integration and Management*, Vol. 8 No. 4, p. 285, doi: 10.1504/IJBPIM.2017.10009731.

Rafiei, M. and Van Der Aalst, W.M.P. (2023), "An abstraction-based approach for privacy-aware federated process mining", *IEEE Access*, Vol. 11, pp. 33697-33714, doi: 10.1109/ACCESS.2023.3263673.

Reinkemeyer, L. (2022), "Status and future of process mining: from process discovery to process execution", in Van Der Aalst, W.M.P. and Carmona, J. (Eds), *Process Mining Handbook*, Springer International Publishing, Cham, pp. 405-415, doi: 10.1007/978-3-031-08848-3_13.

Rott, J. and Böhm, M. (2022a), "Mine the right process - towards a method for selecting a suitable use case for process mining adoption", *European Conference for Information Systems (ECIS)*, Timisoara, Romania, available at: https://aisel.aisnet.org/ecis2022_rp/45

Rott, J. and Böhm, M. (2022b), "Value distribution in cross-organizational process mining: insights from related literature", *Pacific Asia Conference for Information Systems (PACIS), 2022b Virtual Conference*, pp. 1-17, available at: https://aisel.aisnet.org/pacis2022/169

Rowe, F. (2014), "What literature review is not: diversity, boundaries and recommendations", *European Journal of Information Systems*, Vol. 23 No. 3, pp. 241-255, doi: 10.1057/ejis.2014.7.

Rozinat, A. (2020), "Challenges and opportunities for process mining", available at: https://fluxicon.com/blog/2020/07/challenges-and-opportunities-for-process-mining/ (accessed 12 January 2021).

Rozsnyai, S., Lakshmanan, G.T., Muthusamy, V., Khalaf, R. and Duftler, M.J. (2012), "Business process insight: an approach and platform for the discovery and analysis of end-to-end business processes", *2012 Annual SRII Global Conference*, 24-27 July, pp. 80-89, doi: 10.1109/SRII.2012.20.

Sawyer, S. and Jarrahi, M.H. (2014), "Sociotechnical approaches to the study of information systems", in *Computing Handbook*, 3rd ed., CRC Press. doi: 10.1201/b16768\.

Scott, J.E. (2000), "Facilitating interorganizational learning with information technology", *Journal of Management Information Systems*, Vol. 17 No. 2, pp. 81-113, doi: 10.1080/07421222.2000.11045648.

Sun, S.X., Zeng, Q. and Wang, H. (2011), "Process-mining-based workflow model fragmentation for distributed execution", *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, Vol. 41 No. 2, pp. 294-310, doi: 10.1109/TSMCA.2010.2069092.

Suriadi, S., Mans, R.S., Wynn, M.T., Partington, A. and Karnon, J. (2014), "Measuring patient flow variations: a cross-organisational process mining approach", *Second Asia Pacific Conference*, Brisbane, QLD, Australia, AP-BPM 2014, Springer International Publishing, pp. 43-58, doi: 10.1007/978-3-319-08222-6_4.

Tajima, K., Du, B., Narusue, Y., Saito, S., Iimura, Y. and Morikawa, H. (2023), "Step-by-Step case ID identification based on activity connection for cross-organizational process mining", *IEEE Access*, Vol. 11, pp. 60578-60589, doi: 10.1109/ACCESS.2023.3284053.

Talamo, M., Arcieri, F., Schunck, C.H. and Iddio, A.C.D. (2013a), "Conformance checking of electronic business processes to secure distributed transactions", *2013 47th International Carnahan Conference on Security Technology (ICCST)*, 8-11 Oct, pp. 1-6, doi: 10.1109/CCST.2013.6922056.

Talamo, M., Arcieri, F., Schunck, C.H. and Iddio, A.C.D. (2013b), "Providing context-based security for inter-organizational electronic business processes", *2013 IEEE Conference on Communications and Network Security (CNS)*, 14-16 Oct, pp. 393-394, doi: 10.1109/CNS.2013.6682744.

Talamo, M., Povilionis, A., Arcieri, F. and Schunck, C.H. (2015), "Providing online operational support for distributed, security sensitive electronic business processes", *2015 International Carnahan Conference on Security Technology (ICCST)*, 21-24 Sept, pp. 49-54, doi: 10.1109/CCST.2015.7389656.

Thiede, M., Fuerstenau, D. and Bezerra Barquet Ana, P. (2018), "How is process mining technology used by organizations? A systematic literature review of empirical studies", *Business Process Management Journal*, Vol. 24 No. 4, pp. 900-922, doi: 10.1108/BPMJ-06-2017-0148.

Tönnissen, S. and Teuteberg, F. (2019), "Using blockchain technology for cross-organizational process mining – concept and case study", *International Conference on Business Information Systems, 2019*, Cham, Springer International Publishing, pp. 121-131, doi: 10.1007/978-3-030-20482-2_11.

Tornatzky, L.G. and Fleischer, M. (1990), *The Processes of Technological Innovation*, Lexington Books, Lexington, MA.

Trang, S., Mandrella, M., Marrone, M. and Kolbe, L.M. (2021), "Co-creating business value through IT-business operational alignment in inter-organisational relationships: empirical evidence from regional networks", *European Journal of Information Systems*, Vol. 31 No. 2, pp. 166-187, doi: 10.1080/0960085X.2020.1869914.

Unger, T. and Wagner, S. (2011), "Collaboration aspects of human tasks", *International Conference on Business Process Management*, Berlin, Heidelberg, Springer, pp. 579-590, doi: 10.1007/978-3-642-20511-8_53.

Van Der Aalst, W. (1999), "Process-oriented architectures for electronic commerce and interorganizational workflow", *Information Systems*, Vol. 24 No. 8, pp. 639-671, doi: 10.1016/S0306-4379(00)00003-X.

Van Der Aalst, W. (2010), "Configurable services in the cloud: supporting variability while enabling cross-organizational process mining", in Meersman, R., Dillon, T. and Herrero, P. (Eds), *On the Move to Meaningful Internet Systems: OTM 2010. Lecture Notes in Computer Science*, Springer, Berlin, Heidelberg, pp. 8-25, doi: 10.1007/978-3-642-16934-2_5.

Van Der Aalst, W. (2011a), "Business process configuration in the cloud: how to support and analyze multi-tenant processes?", *2011 IEEE Ninth European Conference on Web Services*, 14-16 Sept, pp. 3-10, doi: 10.1109/ECOWS.2011.8.

Van Der Aalst, W. (2011b), "Intra- and inter-organizational process mining: discovering processes within and between organizations", in *The Practice of Enterprise Modeling*, Springer Berlin Heidelberg, Oslo, Norway, pp. 1-11, doi: 10.1007/978-3-642-24849-8_1.

Van Der Aalst, W. (2011c), *Process Mining: Discovery, Conformance and Enhancement of Business Processes*, Springer, Berlin, Heidelberg. doi: 10.1007/978-3-642-19345-3.

Van Der Aalst, W. (2012), "Decomposing process mining problems using passages", in Haddad, S. and Pomello, L. (Eds), *Application and Theory of Petri Nets. PETRI NETS 2012. Lecture Notes in Computer Science*, Springer, Berlin, Heidelberg, pp. 72-91, doi: 10.1007/978-3-642-31131-4_5.

Van Der Aalst, W. (2016), *Process Mining - Data Science in Action*, Springer, Berlin, Heidelberg. doi: 10.1007/978-3-662-49851-4.

Van Der Aalst, W. (2021), "Federated process mining: exploiting event data across organizational boundaries", *2021 IEEE International Conference on Smart Data Services (SMDS)*, 5-10 Sept, pp. 1-7, doi: 10.1109/SMDS53860.2021.00011.

Van Der Aalst, W. and Carmona, J. (2022), "Scaling process mining to turn insights into actions", in Van Der Aalst, W.M.P. and Carmona, J. (Eds), *Process Mining Handbook*, Springer International Publishing, Cham, pp. 495-502, doi: 10.1007/978-3-031-08848-3_17.

Van Der Aalst, W., Weijters, T. and Maruster, L. (2004), "Workflow mining: discovering process models from event logs", *IEEE Transactions on Knowledge and Data Engineering*, Vol. 16 No. 9, pp. 1128-1142, doi: 10.1109/TKDE.2004.47.

Van Der Aalst, W., Adriansyah, A., De Medeiros, A.K.A., Arcieri, F., Baier, T., Blickle, T., Bose, J.C., Van Den Brand, P., Brandtjen, R., Buijs, J., Burattin, A., Carmona, J., Castellanos, M., Claes, J., Cook, J., Costantini, N., Curbera, F., *et al.* (2012), *Process Mining Manifesto" Business Process Management Workshops, 2012*, Springer, Berlin, Heidelberg, pp. 169-194, doi: 10.1007/978-3-642-28108-2_19.

Venkatesh, V. and Bala, H. (2012), "Adoption and impacts of interorganizational business process standards: role of partnering synergy", *Information Systems Research*, Vol. 23 No. 4, pp. 1131-1157, doi: 10.1287/isre.1110.0404.

Vom Brocke, J., Simons, A., Niehaves, B., Riemer, K., Plattfaut, R. and Cleven, A. (2009), "Reconstructing the giant: on the importance of rigour in documenting the literature search process", *ECIS*, available at: https://aisel.aisnet.org/ecis2009/161

Vom Brocke, J., Jans, M., Mendling, J. and Reijers, H.A. (2021), "A five-level framework for research on process mining", *Business and Information Systems Engineering*, Vol. 63 No. 5, pp. 483-490, doi: 10.1007/s12599-021-00718-8.

Wang, Y., Hulstijn, J. and Tan, Y.-H. (2018), "Regulatory supervision with computational audit in international supply chains", *Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age*, Delft, The Netherlands, Association for Computing Machinery. doi: 10.1145/3209281.3209319.

Webster, J. and Watson, R. (2002), "Analyzing the past to prepare for the future: writing a literature review", *MIS Quarterly*, Vol. 26 No. 2, pp. 8-23, available at: https://www.jstor.org/stable/4132319

Weijters, A. and Van Der Aalst, W.M. (2001), "Rediscovering workflow models from event-based data", *Proceedings of the 11th Dutch-Belgian Conference on Machine Learning (Benelearn 2001)*, pp. 93-100.

Weijters, A.J. and Van Der Aalst, W.M. (2003), "Rediscovering workflow models from event-based data using little thumb", *Integrated Computer-Aided Engineering*, Vol. 10 No. 2, pp. 151-162, doi: 10.3233/ica-2003-10205.

Weijters, A., Van Der Aalst, W.M. and De Medeiros, A.A. (2006), "Process mining with the heuristics miner-algorithm", Technische Universiteit Eindhoven, Tech. Rep. WP, 166, pp. 1-34.

Wernerfelt, B. (1984), "A resource-based view of the firm", *Strategic Management Journal*, Vol. 5 No. 2, pp. 171-180, doi: 10.1002/smj.4250050207.

Willcocks, L.P. and Kern, T. (1998), "IT outsourcing as strategic partnering: the case of the UK Inland Revenue", *European Journal of Information Systems*, Vol. 7 No. 1, pp. 29-45, doi: 10.1057/palgrave.ejis.3000284.

WKWI (1994), "Profil der Wirtschaftsinformatik, Ausführungen der Wissenschaftlichen Komission der Wirtschaftsinformatik", *Wirtschaftsinformatik*, Vol. 36 No. 1, pp. 80-81.

Yilmaz, O. and Senkul, P. (2015), "Generating performance improvement suggestions by using cross-organizational process mining", *SIMPDA, 2015*, Vienna, Austria, pp. 3-17.

Zeng, Q., Sun, S.X., Duan, H., Liu, C. and Wang, H. (2013), "Cross-organizational collaborative workflow mining from a multi-source log", *Decision Support Systems*, Vol. 54 No. 3, pp. 1280-1301, doi: 10.1016/j.dss.2012.12.001.

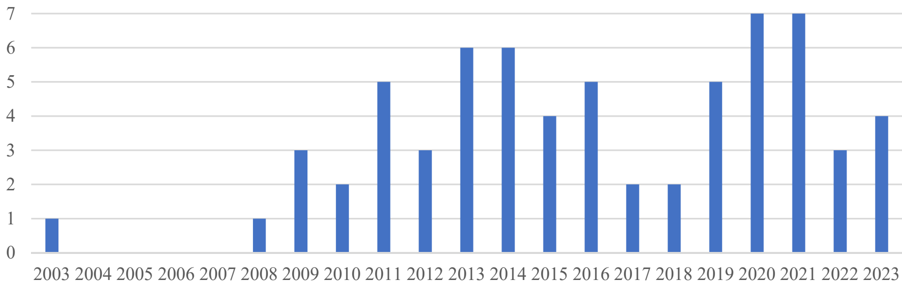
Zeng, Q., Duan, H. and Liu, C. (2020), "Top-down process mining from multi-source running logs based on refinement of petri nets", *IEEE Access*, Vol. 8, pp. 61355-61369, doi: 10.1109/ACCESS.2020.2984057.

Zhi-Jun, Y. and Tian-Mei, W. (2006), "Coupling measurement of interorganizational processes based on petri nets", *2006 International Conference on Management Science and Engineering*, 5-7 Oct. 2006, pp. 591-595, doi: 10.1109/ICMSE.2006.313969.

Appendix 1

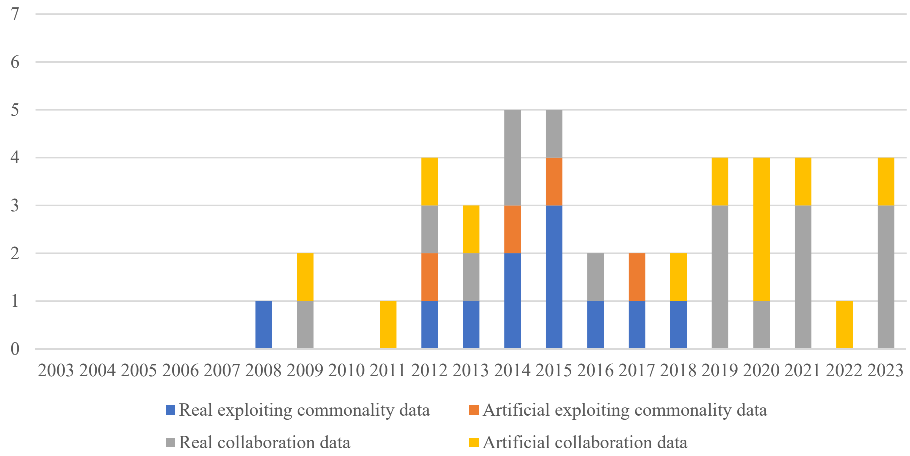
As it can be seen from Figure A1, mostly three to six articles were published per year since 2009, thus indicating a constant relevance of this topic.

By restricting our attention to the publications analyzing cross-organizational data (see Figure A2) and distinguishing between the type of coPM, as described in Section 2.2 (collaboration and exploiting commonality), we see more publications on collaboration (29) than on exploiting commonality (15).



Source(s): Figure by authors

Figure A1. Temporal distribution of publications



Source(s): Figure by authors

Figure A2.
Temporal distribution of publications according to evaluation data type and coPM type

Especially when looking at the past five years, where no article on exploiting commonalities was published. Both variants also more often use real than artificial data for evaluation purposes (Exploiting commonality: 11/4; Collaboration: 17/12). Real data refers to data drawn from information systems implemented in practice, whereas artificial data is data generated manually or through simulation. Although there was one very early publication on PM in 2003 that motivated the relevance of PM in the cross-organizational scenario of a supply chain (Maruster *et al.*, 2003), it was only in 2008 that the first paper that used real data for evaluating PM was published.

Overall, this distribution resembles the empirical and non-empirical PM publications identified and published in a systematic literature review by Thiede *et al.* (2018), who notes an increase in publications after 2009, with a peak in 2015.

Appendix 2

Table A1 shows all articles that were identified within our literature search including their outlet and the assigned categories of the IOC framework. Articles without an assigned category of the IOC framework focused on presenting challenges and scenarios of coPM.

The articles were assigned to a category if they matched the following description:

Environmental uncertainty: The article describes aspects of environmental uncertainty (market conditions influencing the inter-organizational relationship) in cross-organizational PM scenarios.

Partnership uncertainty: The article elaborates on partnership uncertainty factors (goal compatibility, trust and power-dependance) present when applying PM across organizational boundaries.

Task uncertainty: The paper contains information about uncertainties regarding tasks being part of the process to be analyzed with PM.

Structural mechanisms: The article covers how the inter-organizational relationship is structured using, for example, roles and responsibilities or stepwise approaches on how coPM should be conducted. For the latter, the requirement is that multiple techniques are combined or structured in a new way and the whole process of coPM is conducted, not only one-step of the process (e.g. data integration).

Process mechanisms: The paper contains information about the socio-political atmosphere present in the coPM relationship.

IT-mediated mechanisms (coPM): Article uncovers new technological solutions, frameworks and algorithms assisting with coPM.

Performance: Article states how the usage of coPM impacted the organizations' performance. Articles which provided transparency on the performance, despite not revealing any performance impact, where partially assigned to this category, indicated through an "(X)" in Table A1.

Table A1. Concept matrix with outlet and covered parts of the IOC framework

Source	Outlet	Uncertainty sources E	P	T	Performance	Coordination mechanisms Structural	Process	IT-mediated (coPM)
Aksu *et al.* (2016)	IEEE Conference on Business Informatics	X						X (Comparison)
Azzini and Ceravolo (2013)	IEEE International Congress on Big Data							X (Data integration)
Bernardi *et al.* (2014)	IEEE Symposium on Computational Intelligence and Data Mining							X (Architecture including Discovery)
Bernardi *et al.* (2018)	Journal of Information and Knowledge Management							X (Architecture including Discovery)
Buijs and Reijers (2014)	Enterprise, Business Process and Information Systems Modeling				(X)			X (Analytical technique and visualization for process comparison)
Buijs *et al.* (2012b)	International Conference on Business Process Management				(X)	X (Metrics identification)		
Buijs *et al.* (2013)	International Conference on Business Process Management							X (Discovery)
Canjels *et al.* (2019)	International Conference on Business Process Management				X	X (Three-step methodology)		
Claes and Poels (2014)	Expert Systems with Applications							X (Data integration)
Corradini *et al.* (2022)	Enterprise, Business Process and Information Systems Modeling							X (Discovery)
D'Iddio *et al.* (2016a)	IEEE International Carnahan Conference on Security Technology							X (Conformance Checking)
D'Iddio *et al.* (2016b)	IEEE International Carnahan Conference on Security Technology							X (Conformance Checking)
Deokar and Tao (2020)	Information Systems Frontiers							X (Discovery)
Elkoumy *et al.* (2020a)	Enterprise, Business Process and Information Systems Modeling							X (Architecture including data anonymization and Discovery)
Elkoumy *et al.* (2020b)	International Conference on Business Process Management							X (Architecture including data anonymization and Discovery)

(continued)

Table A1.

Source	Outlet	Uncertainty sources E	P	T	Per-formance	Structural	Coordination mechanisms Process	IT-mediated (coPM)
Engel and Bose (2014)	Hawaii International Conference on System Sciences				(X)			
Engel *et al.* (2011)	International Conference on Electronic Commerce and Web Technologies							X (Architecture including data pre-processing and process mining analysis)
Engel *et al.* (2012)	International Conference on Advanced Information Systems Engineering			X				X (Data pre-processing)
Engel *et al.* (2013a)	International Conference on Advanced Information Systems Engineering							X (Data pre-processing)
Engel *et al.* (2016)	Information Systems and e-Business Management				(X)			X (Architecture including data pre-processing and process mining analysis)
Gerke *et al.* (2009b)	International Conference on Business Information Systems							X (Data pre-processing)
Gerke *et al.* (2009a)	IEEE Conference on Commerce and Enterprise Computing							X (Data pre-processing)
González and Delgado (2021)	Hawaii International Conference on System Sciences					X (Compliance formalization)		
Helm and Küng (2016)	International Conference on Information Technology in Bio- and Medical Informatics					X (Extended L* lifecycle model)		
Hernandez-Resendiz *et al.* (2021)	Studies in Computational Intelligence							X (Data pre-processing and Discovery)
Ho *et al.* (2009)	International Journal of Production Research		X			X (Process Mining cycle for global optimization)		X (Architecture including process mining analysis)
Ivković and Luković (2021)	European Conference on Advances in Databases and Information Systems							X (Framework for smart contract validation)
Jacobi *et al.* (2020)	Logistics Journal	X	X					

(*continued*)

Table A1.

Source	Outlet	Uncertainty sources E	P	T	Per-formance	Structural	Coordination mechanisms Process	IT-mediated (coPM)
Khan *et al.* (2021)	International Conference on Service-Oriented Computing							X (Discovery)
Kim *et al.* (2020)	Applied Sciences					X (Colla-borative perspectives, success factors and KPIs)		X (Architecture)
Klinkmüller *et al.* (2019)	International Conference on Business Process Management							X (Framework for Blockchain data pre-processing)
Krathu *et al.* (2014)	IEEE Conference on Business Informatics				(X)			X (Framework for process mining analysis)
Lamghari *et al.* (2020)	International Conference Europe Middle East and North Africa Information Systems and Technologies to Support Learning							X (Framework including data pre-processing and Discovery)
Li (2010)	International Conference on Management and Service Science							X (Discovery)
Liu (2020)	IEEE International Conference on Web Services							X (Discovery)
Liu *et al.* (2019)	IEEE Transactions on Services Computing							X (Discovery)
Liu *et al.* (2023a)	IEEE Transactions on Automation Science and Engineering							X (Discovery)
Liu *et al.* (2023b)	IEEE Transactions on Systems, Man, and Cybernetics: Systems							X (Discovery)
Mans *et al.* (2008)	Studies in Health Technology and Informatics				(X)			
Maruster *et al.* (2003)	International Conference on Advances in Production Management Systems			X		X (Three-step methodology)		
Morales-Sandoval *et al.* (2021)	PeerJ Computer Science							X (Data pre-processing of blockchain data)

(*continued*)

Table A1.

Source	Outlet	Uncertainty sources E	P	T	Per-formance	Coordination mechanisms Structural	Process	IT-mediated (coPM)
Mühlberger *et al.* (2019)	International Conference on Business Process Management							X (Data pre-processing of blockchain data)
Müller *et al.* (2022)	Lecture Notes in Business Information Processing							X (System architecture)
Partington *et al.* (2015)	ACM Transactions on Management Information Systems			X	(X)			
Pini *et al.* (2015)	Asia–Pacific Conference on Business Process Management							X (Visualization techniques for comparison)
Pourmasoumi *et al.* (2017)	Information Systems Frontiers							X (Discovery of process fragments)
Rafiei and Van Der Aalst (2023)	IEEE Access							X (Privacy-preserving abstraction-based discovery)
R'Bigui and Cho (2017)	International Journal of Business Process Integration and Management							
Rott and Böhm (2022b)	Pacific Asia Conference on Information Systems		X			X (Value distribution concepts)		
Rozsnyai *et al.* (2012)	Annual SRII Global Conference							X (Architecture)
Sun *et al.* (2011)	IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans							X (Framework)
Suriadi *et al.* (2014)	Asia–Pacific Business Process Management				(X)			
Tajima *et al.* (2023)	IEEE Access							X (Data pre-processing)
Talamo *et al.* (2013a)	International Carnahan Conference on Security Technology							X (Conformance Checking)
Talamo *et al.* (2013b)	IEEE Conference on Communications and Network Security							X (Conformance Checking)
Talamo *et al.* (2015)	IEEE International Carnahan Conference on Security Technology				X			X (Conformance Checking)

(*continued*)

Source	Outlet	Uncertainty sources E	P	T	Per-formance	Structural	Coordination mechanisms Process	IT-mediated (coPM)
Talamo *et al.* (2015)	Lecture Notes in Business Information Processing							X (Usage of blockchain technology to create a cross-organizational event log)
van der Aalst *et al.* (2012)	International Conference on Business Process Management							
van der Aalst *et al.* (2012)	OTM Confederated International Conferences "On the Move to Meaningful Internet Systems"							
van der Aalst (2011a)	European Conference on Web Services							X (Discovery)
van der Aalst (2011b)	IFIP Working Conference on The Practice of Enterprise Modeling							
van der Aalst (2021)	IEEE International Conference on Smart Data Services							X (Data pre-processing)
Wang *et al.* (2018)	International Conference on Digital Government Research	X						(Compliance monitoring framework)
Yilmaz and Senkul (2015)	International Symposium on Data-Driven Process Discovery and Analysis				(X)			X (Enhancement and improvement recommendations)
Zeng *et al.* (2013)	Decision Support Systems							X (Discovery)
Zeng *et al.* (2020)	IEEE Access							X (Discovery)
Sum		3	3	2	2 (9)	8	0	51

Note(s): E: Environmental uncertainty; P: Partnership uncertainty; T: Task uncertainty
Source(s): Table by authors; Bensaou and Venkatraman (1996)

Table A1.

Appendix 3

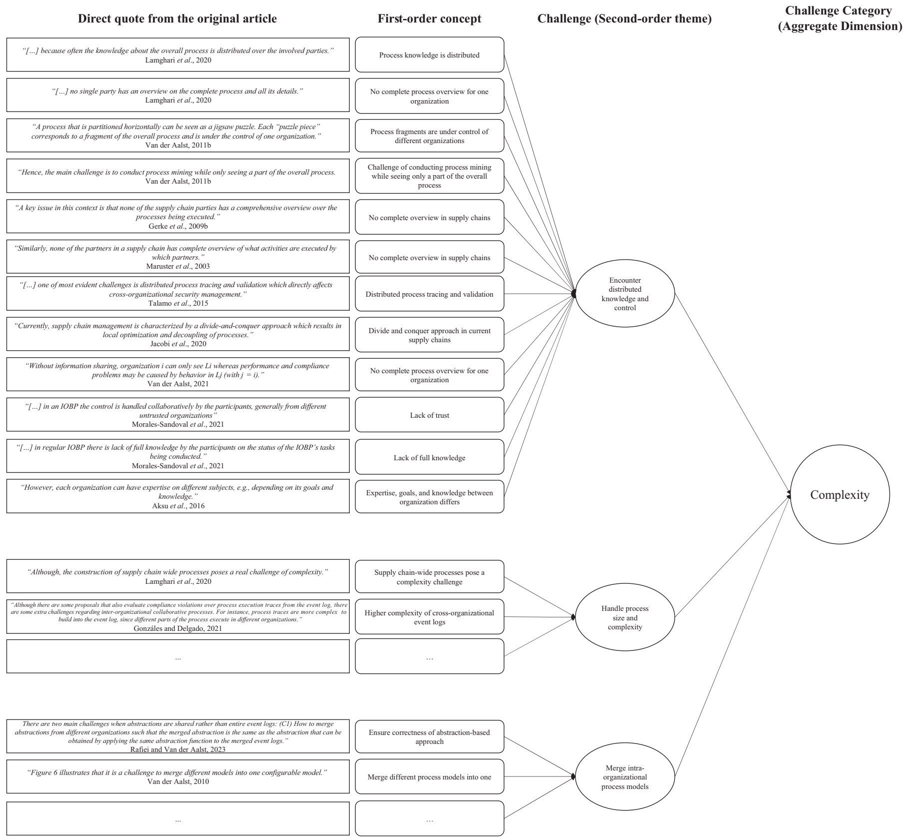


Figure A3. Identification of challenges and challenge categories according to the methodology of Gioia *et al.* (2013)

Corresponding author
Julian Rott can be contacted at: julian.rott@tum.de