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Process Science for Sustainability: Research Gaps and Research Strategy

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Abstract: This *novel direction proposal* explores how process science can transform sustainability management in industrial settings. We identify research gaps in process science related to sustainability, including the need for foundational definitions of process sustainability, methods for capturing and integrating sustainability-relevant data, approaches for analyzing process sustainability, and frameworks for managing process sustainability effectively. To address these gaps, we propose a five-phase research strategy that progressively builds from conceptual foundations to advanced implementations. This approach can be applied across various domains, as demonstrated by our ongoing work in the event management industry, where traditional sustainability reporting methods struggle with the industry's dynamic nature. Our work aims to bridge the gap between regulatory requirements and operational reality while fostering collaboration between Process Science and Sustainability research communities.

Keywords: Process Science, Sustainability, Business Process Management, Process Mining

1 Introduction

In recent years, companies have been facing mounting pressure to report on and reduce their negative environmental and social impacts as global challenges like the climate crisis intensify [El18]. The current "Omnibus" proposal by the European Commission [Eu25], which scales back sustainability reporting requirements, reflects the significant challenges and resource burdens many organizations face in implementing comprehensive sustainability frameworks. However, the urgency of climate change and other sustainability challenges remains undiminished, regardless of regulatory adjustments. Environmental degradation, resource scarcity, and social impacts continue to accelerate, creating business risks that transcend regulatory compliance [Fo24]. Existing tools and frameworks for sustainability management have been criticized for focusing too much on mere reporting rather than supporting the effective improvement and necessary change of business operations [El18].

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Process science is an emerging discipline at the intersection of technical and social fields, covering disciplines such as Business Process Management and Process Mining [AD15; vo24]. It is concerned with understanding and intervening in processes, particularly improving business processes and the performance of companies [AD15]. We therefore argue that innovative approaches to process science can indeed revolutionize sustainability management. These innovative approaches can support companies to not only overcome efficiency challenges regarding compliance with sustainability reporting regulation, but to effectively manage and improve their sustainability performance. In the following, we reflect on how this potential can be realized by identifying research gaps (Section 2), formulating a research strategy (Section 3) and discussing concrete next steps (Section 4).

2 Research Gaps

As described in [Pü24], process science can support sustainability on various levels, ranging from capturing and integration of relevant data, to the support of visualization, analysis, and management of processes. In the following, we explore research gaps and potential contributions on these different levels by formulating four research questions. We argue that sustainability is not only a worthwhile research effort in itself, but also provides interesting challenges as an application area for current research foci in the process science community such as multimodal process mining, AI support for process modeling or object-centric process mining. So, for each research question, we draw references to existing research in the field of sustainability and/or process science.

What is process sustainability? Process science needs a theory (or theories) of process sustainability. By that, we mean that concepts are needed for understanding and delineating the impacts a process can have on our planet's ability to meet human needs for current and future generations [HA15]. The novel direction we propose herein should recognize tensions between concepts of sustainability [Jo07], critically engage with the debate, and position itself clearly. For example, there are different ways to distinguish sustainability impacts, such as direct and indirect impacts, midpoint and endpoint impact categories, or attributional and consequential impact estimation [HA15; KG14]. While there is no need for process science to "reinvent the wheel", existing process science approaches have so far only scratched the surface of sustainability analysis and focused mainly on energy aspects [Fr22]. More recently, explicit connections to existing sustainability analysis methods have been drawn [Fr24; KWP25]. There is certainly room for a diversity of process sustainability theories that can build upon and extend existing sustainability literature. We also expect that the unique perspective of process science can contribute to the broader sustainability discourse. In any case, solid concepts of process sustainability are needed to inform the design of technical solutions and systems.

How to capture and integrate sustainability-relevant process data? We distinguish between two types of sustainability-relevant process data which form the technical foundation for sustainable process science [Be23]: (1) sustainability information describing and quantifying the process' inputs, outputs, and impacts (i.e., data referring to things/objects), and (2) process data describing the relationships among activities, i.e., event data. Such data has to be collected and combined using diverse and heterogeneous data sources in organizations [vo24]. One primary data source for sustainability analyses could be ERP systems of organizations [Pü24]. However, existing ERP systems often do not store sustainability-relevant information in appropriate formats or do not propagate the information upwards to e.g. process-aware information systems [Sc24]. Therefore, process science should consider the design of information systems in the long run, but also leverage other unstructured or semi-structured data sources such as invoices, material declarations, and video logs, or, in the case of low-digitized environments, people (e.g. domain and sustainability experts) [Pü24]. Existing examples of such approaches include the use of computer vision and deep learning to capture properties of products and machinery [Wa23]. Similarly, multimodal process mining approaches can be used in low digitized environments to capture event data, for example, from video logs [GBP24]. Furthermore, object-centric event logs can be used to integrate object and event data [Be23], and may be adapted for sustainability.

How can process sustainability be analyzed? There are two main areas w.r.t. sustainability analyses that have to be explored: (1) the assessment of a process' sustainability, and (2) the identification of causes for impact drivers in the system. Process science has significant potential to bring more detailed, multi-perspective analysis capabilities to sustainability. Process modeling, mining, and simulation tools can help to visualize and reason about process sustainability, and the effectiveness and usability of different designs should be explored. So far, for example, social sustainability aspects remain underexplored in existing process modeling approaches [Fr22]. In particular, we see challenges in the fact that different industries have varying requirements regarding sustainability, depending on given standards or the perceived urgency of environmental or social issues. In the future, multi-level process modeling approaches could build the foundation for the efficient provisioning of domain-specific modeling environments for different sustainability aspects and industrial domains [FC22]. Furthermore, new concepts and algorithms are needed to address particularly impactful processes (e.g. production and logistics) [GKv23]. Data-aware process modeling can be utilized and combined to integrate sustainability-relevant process data from diverse sources [Fr23]. Innovative simulation tools help with identifying improvement potential in processes [KWP25]. Compliance monitoring techniques can be used to identify how far processes adhere to sustainability regulations and to discover potential for increasing their contribution to regulatory sustainability goals [Kl25]. Overall, the combination of data-aware process modeling with simulation and mining capabilities is in itself an interesting and promising research area [LMD24], and sustainability can provide relevant application and evaluation cases for new developments.

How to manage process sustainability? Integrated process-oriented information systems can support the sustainability management of companies in new ways. Building upon the outlined data integration and analysis capabilities, real-time monitoring, conformance checking, and automated execution of processes based on sustainability criteria can be designed and explored. By this, process science can contribute to bridging the gap between the analysis of sustainability and management, i.e. the effective improvement of companies' sustainability performance. While theories on process sustainability can serve as design principles for new sustainability-oriented information systems, the operationalization of these theories and implementations of concrete systems might face hurdles that hinder their adoption in practice, in particular, economic interests that override environmental objectives, both in design and application of information systems [SRv23]. However, more empirical evidence is needed on the (adverse) pressures that these systems face in their development and use contexts, particularly in reconciling tensions that potentially arise. Addressing these challenges requires not only technological, but also strategic and managerial capabilities [Nu24]. Strategically, corporate sustainability goals must be translated into processes, for example via Sustainable Balanced Scorecards. Managerially, effective change management is essential for transitioning existing systems. Future research should explore how organizations can continuously improve the use of sustainable process-aware information systems by considering those capabilities.

With the outlined research questions, we have shown connections to current research topics in process science. We believe that the discipline can have a real impact by advancing and maturing methods and tools for sustainability analysis; further, this is a concrete angle with which research can contribute towards "process science for good" [vo24].

3 Research Strategy

While, as we have laid out, there are various potential contributions of process science to sustainability, adhering to regulatory reporting requirements is an immediate motivator for many companies. Furthermore, we observe that in many companies, data is not yet available in the form necessary for advanced process science approaches. To address these challenges, we propose a long-term research strategy that is divided into five phases.

Phase 1: Focus on basic questions concerning concepts of process sustainability, data capturing and integration, and modeling. As outlined above, existing approaches to data-aware process modeling and AI support for data capturing can support companies in simplifying and improving current reporting practices.

Phase 2: Based on existing data capturing, integration and modeling support, simulation tools can be built. These provide value by themselves (allowing in-depth analysis capabilities for sustainability), but also provide (synthetic) data for the development of process mining approaches. This way, process mining approaches can be evaluated also for domains where event log data may not yet be available in the appropriate amount or format.

Phase 3: With work in phase 1 and phase 2, researchers can learn about existing data, its structure and further sustainability requirements in companies. This, in turn, can help to design advanced systems for capturing and transforming existing data in formats that are appropriate for process mining approaches.

Phase 4: In the long term, standards can be defined to guide the design of information systems to properly log sustainability data. This will allow for the implementation of advanced approaches, e.g. for real-time monitoring or automated execution of processes based on sustainability criteria.

Phase 5: Accumulated process data and insights can be synthesized for educational purposes. Knowledge bases, reference models, or coding best practices would enable designing sustainable processes from scratch. Additionally, evidence-based training resources focused on sustainability competences, i.e., “green skills,” can be developed. This would allow process managers to foster environmentally responsible decision-making capabilities.

Note that the different phases are not to be interpreted as strictly sequential. Research can address any of the phases at any time. However, earlier phases address more foundational work, can be considered as addressing more “low hanging fruits”, or where existing approaches are already comparably mature. Work in later phases may also build upon and require advances in earlier phases.

4 Next steps

The outlined research strategy can be instantiated in various research projects to address the topics in different scopes, from different angles, and in different industries. For example, we are currently in the process of refining the research objectives and outlining a research methodology for a project in the event management industry. In dynamic industries such as event management, where each project can have unique sustainability implications, traditional reporting methods struggle to capture accurate, timely data. Manufacturing processes in this domain (e.g. production of exhibition stands) are highly individual, and sustainability relevant data (which materials are used, how they are processed, ...) may not be easily accessible. We intend to explore the use of AI-supported process modeling approaches that generate process models from textual descriptions (e.g. interviews with process participants such as carpenters) and domain-specific modeling environments to support timely, fine-grained and individual sustainability analyses. Initially, this research effort would focus on phases 1 and 2 of the outlined research strategy, but we intend to address the other phases at later stages, e.g. by developing supplementary educational material for process participants. In the broader picture, we aim to establish connections among the Process Science and Sustainability research communities, and welcome discussion and exchange about experiences with similar research endeavors.

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