sustainability

MDPI

Review

Pathways to Greener Pastures: Research Opportunities to Integrate Life Cycle Assessment and Sustainable Business Process Management Based on a Systematic Tertiary Literature Review

Andreas Fritsch [1,*], Johanna von Hammerstein [1], Clemens Schreiber [1], Stefanie Betz [2] and Andreas Oberweis [1]

[1] Institute of Applied Informatics and Formal Description Methods, Karlsruhe Institute of Technology, 76133 Karlsruhe, Germany
[2] Faculty of Computer Science, Furtwangen University, 78120 Furtwangen, Germany
* Correspondence: andreas.fritsch@kit.edu

Abstract: Sustainable Business Process Management (BPM) is a research field that aims to improve the sustainability performance of organizations' operations. With its focus on business processes, it has the potential to bring sustainability considerations from external reporting to the core of organizations. We present a systematic tertiary literature study to provide a catalog of existing literature reviews and primary work and to give a consolidated overview of the state and research needs of the field. We find that Sustainable BPM research has focused on modeling approaches and most of the work so far is largely conceptual, with a limited sustainability perspective. Based on these findings, we propose an integration of BPM and Life Cycle Assessment (LCA), an established and rigorous method for sustainability analysis. We present research opportunities to show how both disciplines can synergize and leverage methods and techniques for business process automation and innovation to effectively improve the sustainability performance of organizations.

Keywords: sustainable business process management; systematic literature review; life cycle assessment; sustainable development; research opportunities

Citation: Fritsch, A.; von Hammerstein, J.; Schreiber, C.; Betz, S.; Oberweis, A. Pathways to Greener Pastures: Research Opportunities to Integrate Life Cycle Assessment and Sustainable Business Process Management Based on a Systematic Tertiary Literature Review. *Sustainability* **2022**, *14*, 11164. https://doi.org/10.3390/su141811164

Academic Editors: Ralf Plattfaut and Amy Van Looy

Received: 2 July 2022
Accepted: 2 September 2022
Published: 6 September 2022

1. Introduction

What is a sustainable organization? From a business perspective, sustainability may simply mean to sustain the organization's capability to generate profit over multiple years or maybe decades. But when we talk about Sustainable Development, the perspective is different. Here, the focus is not on the organization. It is the planet as a whole that is to be sustained in its function to provide the means to meet human needs—not just for years or decades, but for generations to come [1]. Sustainable Development thus requires a contribution from organizations [2]. In this light, the performance of organizations should not just be measured in terms of monetary aspects (such as the reduction of costs), but also in terms of their impact on society and the environment. More specifically, the United Nations General Assembly has formulated several Sustainable Development Goals that directly address the performance of organizations, such as ensuring sustainable consumption and production patterns (Goal 12) or promoting decent work for all (Goal 8) [3]. A common concept of organizational sustainability is that of a 'triple bottom line', where Elkington [4] argues that organizations should account for social, environmental, and economic impacts. However, in a recently published piece [5], Elkington himself is rather critical of his own widely successful concept. The criticism is not so much aimed at the concept itself, but rather at the observation that it is mainly used and "diluted" to produce reports for external stakeholders rather than to provide data for "decision-takers [...] to track, understand, and manage the systemic effects of human activity". In other words, the challenge at hand is to bring sustainability from external reporting to the core of the organizations. A discipline that is traditionally concerned with improving the performance of organizations'

operations is Business Process Management (BPM). As BPM is concerned with the core of organizations, their processes, integrating sustainability into BPM could fulfill Elkington's demand. Indeed, in recent years, BPM researchers have started to address sustainability issues under the term "sustainable" or "green" BPM [6,7].

When investigating Sustainable BPM research, we have observed that a substantial body of knowledge has developed. Several systematic literature reviews (SLR) map the field by categorizing existing work. SLRs play an important role for scholars in guiding future research and also helping with developing teaching materials and textbooks [8]. However, the existing studies on Sustainable BPM vary based on the topics that were analyzed, the level of detail of the analyses, and employed categorizations. While differing perspectives and concepts are natural in a developing research field, this makes the reported results often hard to compare, and sometimes even (seemingly) contradicting. Due to these different perspectives, authors of secondary studies also identify different research needs and give different recommendations for future research.

To address this, we have conducted a tertiary study, a review of existing SLRs (secondary studies) [8,9]. The goal of our work is to provide a catalog of secondary studies (and primary papers identified in the secondary studies) for researchers, to give a comprehensive and consolidated overview of the findings, and to provide guidance for future research based on the research needs identified in the secondary studies.

Following guidelines for conducting SLRs [10], we found 11 relevant secondary studies, for which we conducted a quality analysis, extracted findings regarding the state of research, and identified research needs. We developed mappings for the employed categorizations to enable a comparison of the results and a consolidated overview of the findings and research needs. For replicated findings, our study provides a higher level of evidence by backing them with multiple studies (see [8]). For differences in findings, our study provides clarifications and interpretations.

A key finding from the secondary studies is that Sustainable BPM research has so far focused on modeling approaches, with most of the proposals in a conceptual stage. Furthermore, Sustainable BPM has a narrow focus on carbon emissions and energy use. In our tertiary study, we also diagnose an inconsistency and missing clarity regarding sustainability concepts in the secondary studies. To advance, Sustainable BPM should learn from existing sustainability research, specifically Life Cycle Assessment (LCA). To our knowledge, the potential of LCA for Sustainable BPM has been mentioned in the literature (e.g., by [11]), but was so far not explored more deeply. In order to address the identified research needs and to provide specific recommendations for future research, we contribute a discussion of research opportunities to integrate LCA and Sustainable BPM. In particular, we explore how techniques for business process automation and innovation, such as process mining and robotic process automation, can be leveraged in this regard.

In the next section, we present background on BPM, Sustainable Development, and LCA. This is followed by the presentation of our tertiary study. We briefly describe our method for conducting the study and then present our findings on the state of the art and research needs in Sustainable BPM. Based on our findings, we then present a research roadmap and discuss recommendations for Sustainable BPM.

2. Background

2.1. Business Process Management (BPM)

Business Process Management (BPM), as a field of research and practice, has been described as "the art and science of overseeing how work is performed in an organization" [12] (p. 1). Typical objectives are to reduce cost, execution times, and error rates of operations [12] (p. 1). To achieve this, BPM looks at organizations from a process perspective, i.e., the coordination of activities that are performed to achieve a business goal, such as providing a customer with an ordered product [13] (p. 5). One can distinguish between different traditions of BPM that follow different methods and concepts [14]. In recent years, however, there have been growing efforts to synthesize these traditions [14].

While the historic BPM traditions had specific foci, for example on technical aspects and information technology (IT), this emerging discipline can be seen as addressing a variety of organizational capabilities, ranging from modeling and IT-supported execution of processes to employee training and organizational culture (see [15–17]). A common conceptual framework in the field of BPM is that of a Business Process Lifecycle. Various authors have proposed slightly varying definitions (e.g., [12,13,18]). They all share the idea that business processes go through cycles, in which they are designed, analyzed, implemented, controlled, evaluated, and improved [16]. Different BPM approaches may address one or multiple of these life cycle phases; for example, modeling languages such as Business Process Model and Notation, Petri Nets, or Event-driven Process Chains, are typically employed in the "design" or "modeling" phase. Maturity models extend this view by looking at managerial and organizational aspects like the skills and attitudes of employees [16,17]. Their purpose is to measure how well organizations manage their processes and to propose improvement possibilities [16]. With their comprehensive view, they can also be used to structure the field of BPM. One example of such an application of maturity models is the "Core Elements of BPM" concept [17], where the field of BPM is structured based on previously developed maturity models. We note that [16] similarly describe six Capability Areas of BPM, synthesized from various BPM theories and evaluated by mapping the Capability Areas to maturity models from research and industry. The six Capability Areas are:

1. **Modeling:** Methods and IT for the design and analysis of business processes. This includes the modeling, i.e., the textual or graphical representation of the business processes, and also the validation, simulation, and verification of the models [16] (p. 194 and pp. 196–197).
2. **Deployment:** Methods and IT for the implementation and enactment of business processes. This includes their measurement and control during enactment [16] (p. 194).
3. **Optimization:** Methods and IT for the evaluation and improvement of business processes after enactment [16] (p. 194).
4. **Management:** Approaches that address the daily management of business processes, including the definition of required roles and responsibilities with corresponding skills and training. It also includes the linking of process goals to the organizational strategy and the management of relationships with customers, suppliers, and other stakeholders [16] (p. 194).
5. **Culture:** Approaches that consider values and their translation into attitudes and behaviors [16] (p. 194).
6. **Structure:** Approaches that are concerned with the organization chart and governance bodies that coordinate the management of all business processes within an organization [16] (p. 194).

In recent years, BPM researchers have started to consider sustainability aspects additionally to traditional objectives like time and cost improvements. To assess the state of Sustainable BPM in our literature review, we describe the concept of Sustainable Development and Life Cycle Assessment as an established method for sustainability analysis in the following section.

2.2. Sustainability and the Life Cycle Assessment Method

The Brundtland Report is often cited as the original conception of the term Sustainable Development, where it is described as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [19]. The relative vagueness of this definition has been conceived as both a weakness and a strength [20,21]. An effect of this relative vagueness is that different actors may have different understandings of Sustainable Development. The core of Sustainable Development, however, is about an integrated consideration of concerns for environmental protection, economic growth, and social justice—and different positions may deviate in the relative emphasis of these aspects [21]. For the purpose of this study, we do not explicitly posi-

tion ourselves in this spectrum. However, we employ this common [22] distinction of environmental, economic, and social concerns to provide some structure when discussing sustainability aspects. Furthermore, we want to emphasize that two properties of Sustainable Development should guide Sustainable BPM research (see [23]): First, from the perspective of Sustainable Development, the analysis of an organization's performance requires a broadened scope that exceeds the organizational boundaries. Second, one needs mechanisms to deal with the multilayered and complex nature of sustainability issues.

Life Cycle Assessment (LCA): One important way to conceptualize the broad scope and complexity of sustainability is life cycle thinking [24]. Applying life cycle thinking means to evaluate the sustainability of a product or activity via a systemic approach. The aim is to identify improvement possibilities for the whole system, and not only individual processes [25], and thereby avoid that (environmental) burdens are shifted to future generations or other regions of the world [26], as required by the Brundtland Report [19].

The importance of taking a life cycle perspective in order to analyze sustainability in organizations is also pointed out by [23,27]. Life Cycle Assessment (LCA) is the formalized method to conduct such an analysis. It is defined as a method to analyze "the environmental aspects and potential environmental impacts throughout a product's life cycle" [28]. Note that the concept of a product life cycle in LCA needs to be clearly distinguished from a Business Process Lifecycle, as we have discussed before. In LCA, a product life cycle is understood as the steps in a supply chain, where first the raw materials needed for a product are extracted, the product is then assembled, then used by a consumer, and finally disposed of or recycled. In this paper, we generally use the term life cycle when referring to the LCA concept. When referring to the BPM concept, we explicitly address it as Business Process Lifecycle.

Important LCA concepts: According to the LCA standard [28], a sustainability analysis is conducted in four phases. First is the goal and scope definition, where the system boundaries and basic requirements and assumptions are laid out. Second is the inventory analysis, where data is collected and calculations take place to quantify relevant inputs and outputs. Third is the impact assessment, where the significance of sustainability impacts is evaluated. Finally, the last step is the interpretation of the results. One important distinction in LCA is between inventory data and impact category indicators. Inventory data can be directly measured in a process (such as emissions of carbon dioxide). Inventory data then needs to be assigned to corresponding impact category indicators in order to be meaningful (in this case, carbon dioxide emissions contribute to the impact category 'global warming potential', where other greenhouse gas emissions also contribute) [26] (pp. 44–45). LCA provides a variety of covered impact categories, among which are resource depletion, climate change, stratospheric ozone depletion, smell, and noise, to name just a few examples [26] (p. 189). One has to note, and LCA researchers are well aware, that lists of environmental problem fields or impact categories are never complete and will and have to be altered with growing knowledge and public reception [26] (p. 183). Biodiversity, noise, and smell, are examples of impact categories that can be considered 'under development', as LCA researchers work on methods to integrate appropriate measures [29]. Similarly, LCA provides initial approaches and methods to measure social and economic concerns from an integrated sustainability perspective [26,30].

3. Materials and Methods

In research domains where several reviews of primary research are already available, a tertiary study is a suitable alternative to a systematic literature review (SLR) [10] (p. 5). Tertiary studies follow the same guidelines as an SLR of primary literature. Thus, following SLR guidelines [10], our study aims at consolidating the results of existing secondary studies in a tertiary study by addressing two research questions: (RQ1) What is the state of research in Sustainable BPM? and (RQ2) What research needs have been identified by researchers in Sustainable BPM? We answer our research questions by identifying existing literature studies on Sustainable BPM and extracting and consolidating their findings. A

data package with details on database results, exclusion decisions, quality assessment, and data extraction is available under [31].

3.1. Search Process

The search was performed in January 2021 on Google Scholar, ACM, IEEE Explore, Science Direct, Scopus, Springer Link, and Web of Science (see Figure 1). We applied the search string to the title of the papers. If the database allowed for a more detailed selection of searched fields, we extended the search to abstract and keywords to find more possibly relevant papers. We did not search in full text, as this resulted in too many irrelevant papers—in the case of Google Scholar alone several tens of thousands of papers. To find relevant literature in the targeted search engines and databases our search string consisted of three parts: (1) To extract literature on business process management, our search string requires the presence of the term "business process". "BPM" is added as a common acronym of Business Process Management. (2) To extract literature that addresses sustainability issues, the search string requires the presence of the terms "sustainable" or "sustainability". The term "green" is added as it is a widely used synonym for environmental sustainability. (3) As we are only interested in literature reviews of the topic, we include the term "review" in the search string. To capture systematic mapping studies as a special form of reviews [10] (p. 4) we add the term "mapping". With similar reasoning, "SLR" is included in the string as it is a common acronym for systematic literature reviews. Lastly, we included "survey" in the search string as a first search revealed that survey is often used as a synonym for review. This results in the search string (green OR sustainable OR sustainability) AND (BPM OR "business process") AND (review OR mapping OR survey OR SLR).

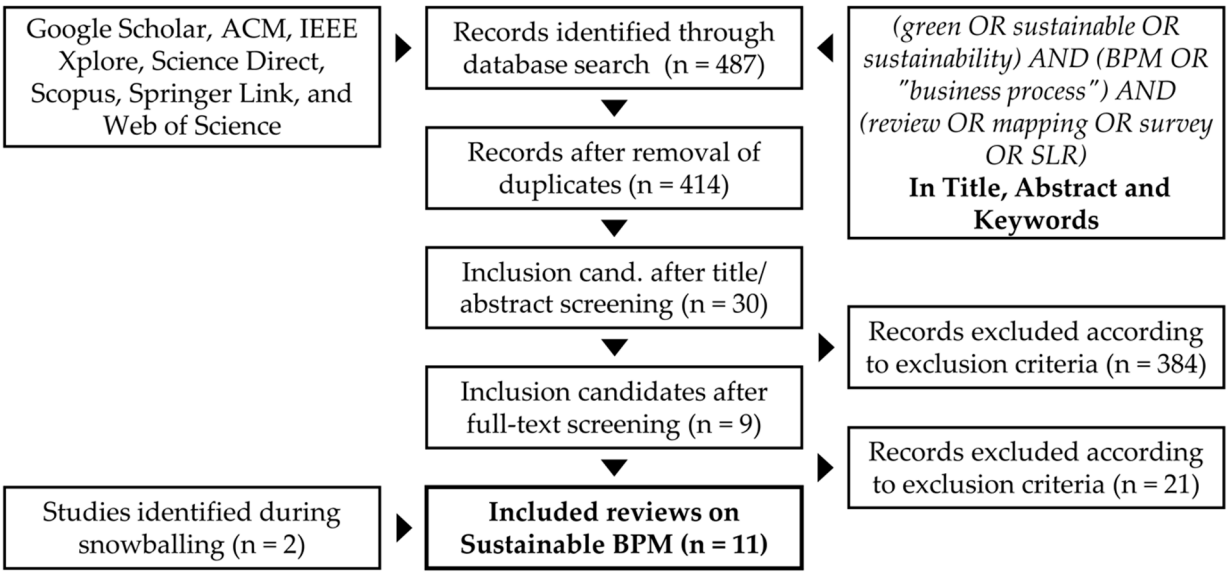

Figure 1. Study selection process.

3.2. Study Selection

Our initial search yielded 487 results (see Figure 1). Before further analysis, duplicates were removed. To select all systematic reviews of the topic, the following inclusion criteria were applied to the remaining 414 candidates. (1) Systematic literature reviews (SLRs) i.e., literature surveys with defined research questions, search process, data extraction, and data presentation on Sustainable BPM, are included. (2) Systematic mapping studies (as a special form of SLRs) on Sustainable BPM are included. The following exclusion criteria were defined based on the research questions and to ensure the quality of the findings: (1) Papers that do not explicitly address issues of sustainable development in the context of BPM are excluded. (2) Non-reviewed papers are excluded. (3) Papers not published

in English are excluded. (4) Papers not available online are excluded. (5) Papers that do not describe a systematic literature review are excluded. After applying the criteria to title and abstract, 30 candidates remained. Subsequently, the inclusion and exclusion criteria were applied to the full text of the remaining candidates, yielding nine included articles. Lastly, a snowball search of the nine final candidates resulted in eleven included reviews published between 2012 and 2020 (see Table 1, the first column shows the IDs we will use in the following to refer to the individual reviews). For the snowball search, all referenced systematic reviews in the included articles were extracted from the full text and reference lists. For each candidate, we examined whether an inclusion decision was already made; otherwise, the inclusion and exclusion criteria were applied. Each article was reviewed for inclusion by two researchers independently. To counteract researcher bias in the paper selection, disagreements were discussed among the researchers until a consensus was reached. With some exceptions, the number of reviewed primary articles in each review increases with time and reflects the growing research field. Six of the articles based their review on the guidelines of Webster and Watson [32]. Other than that, the reviews use several different guidelines [33–40].

Table 1. Sustainable BPM literature reviews overview and quality scores.

ID	Year	Guidelines	Reference	Num	Q1	Q2	Q3	Q4	Total
CST	2012	[32,33]	[6]	34	0.5	0.5	0.5	0	1.5
NOPA	2014	[32,34]	[41]	26	0.5	0.5	0	0	1
NOPB	2014	[32,34]	[42]	11	0.5	0.5	0	0.5	1.5
SGOA	2015	-	[43]	36	1	0.5	0.5	0.5	2.5
JCM	2017	[32]	[44]	42	0.5	0.5	0	1	2
TSCA	2017	[32,33]	[45]	48	1	0.5	0	1	2.5
AHG	2019	[35]	[46]	56	1	1	0.5	0	2.5
DCOA	2019	[36–38]	[11]	60	1	1	0.5	1	3.5
DCOB	2019	[39]	[7]	60	1	1	0.5	1	3.5
TSCB	2019	[32]	[47]	12	0.5	0.5	0	1	2
SGOB	2020	[40]	[48]	49	1	0.5	0.5	0.5	2.5

3.3. Quality Assessment

The quality of the identified articles was assessed by adapting the quality criteria from [10], similar to the application of quality criteria in other tertiary studies (e.g., [9]). The quality of each included article was evaluated according to four quality criteria: (Q1) The adequacy of the described inclusion and exclusion criteria: 1 if explicitly defined/0.5 if implicitly defined/0 if not defined. (Q2) The likeliness of the review to have covered all relevant studies: 1 if more than four digital libraries/0.5 if three or four or restricted set of outlets/0 if up to two or extremely restricted set. (Q3) The presence of a quality assessment: 1 if explicitly defined criteria/0.5 if quality is discussed/0 if quality is not addressed. (Q4) The adequate description of identified studies: 1 if clearly presented and traceable to primary studies/0.5 if information for each grouping is available but not traceable/0 if only very broad groupings are employed. Each article was scored by two researchers independently based on how well it satisfied the criteria. Disagreements were discussed, till a consensus was reached. The final scores for each criterion are displayed in Table 1. We would like to point out that the scoring is not intended as a judgment of the individual work, but rather to inform our analysis and discussion, and to provide a relative comparison of the different studies. For example, the lower Q4 score for the review with ID CST reflects that it is the earliest study in the field and that at that time a more

detailed grouping was apparently not possible or necessary, due to a lower number of primary works.

3.4. Data Extraction and Data Synthesis

In a preliminary investigation of the secondary studies, we identified three main topics of the conducted analyses: research context, Sustainable BPM approaches, and sustainability aspects. The data extraction for each topic was documented in a structured extraction form to capture all information required for further synthesis. To ensure the quality of the extraction, one researcher extracted the data, and the results were checked by another. Regarding the first topic, research context, five secondary studies have analyzed the questions "how?" (e.g., publication venues) and "by whom?" (e.g., author origin) research has been conducted. Nine out of the eleven secondary studies also identify BPM concepts and approaches that have been developed to address organizational sustainability. We subsume these analyses under the topic of Sustainable BPM approaches. The third topic that authors of all secondary studies have addressed is sustainability or the sustainability aspects such as carbon emissions or water consumption that have been addressed in Sustainable BPM. We present our analysis in three similar steps for each topic. First, we consolidate the classification schemes used by the secondary studies. This is necessary since the studies used different concepts for presenting their results. The second step is the consolidated presentation of the studies' findings, to answer our research question regarding the state of research (RQ1). In a third step, to answer RQ2, we present the research needs that secondary studies' authors have identified for each topic.

4. Results

4.1. Topic 1: Research Context in Sustainable BPM

To complement our analysis of Sustainable BPM, we have looked at investigations of the research context in the literature reviews. Specifically, we looked at results regarding the questions of how and by whom research has been conducted. Concerning "who?", AHG and DCOA provide an overview of the main individual contributors to the topic. DCOA additionally looks into the associated disciplines of the papers and the affiliations of the authors. CST and DCOB analyze on a more general level where the authors stem from. Concerning the question "how?", CST, SGOA, AHG, DCOA, and DCOB provide an analysis of publication types, i.e., whether the identified papers were published in conferences, journals, or books. DCOA and DCOB go a step further and also distinguish different conference topics. JCM and AHG also distinguish the research type, meaning whether a paper is rather conceptual or more applied.

State of Research Regarding Research Context (RQ1): Drawing the findings in the different studies together, we conclude that most of the research on Sustainable BPM has been conducted by few research groups in Europe, with interest from researchers in the issue since 2007, but not a consistent upward trend since then (CST, SGOA, AHG, DCOA, DCOB). The type of research has been conceptual in nature, with rare implementations and applications (JCM, AHG). Our interpretation of these findings is that Sustainable BPM is, as a research field, still young, with only first exploratory work being done by researchers.

Research Needs Regarding Research Context (RQ2): Regarding research needs, authors of secondary studies have called for more international, interdisciplinary, and practice-oriented collaboration in the field of Sustainable BPM (CST, DCOA, DCOB). These calls address specifically disciplines such as Life Cycle Assessment, where knowledge about sustainability topics is already available (DCOA). Furthermore, future efforts should focus on the implementation, application, and evaluation of approaches (CST, NOPA, SGOA, JCM, TSCA, AHG, DCOB).

4.2. Topic 2: Sustainable BPM Approaches

The second topic we address to investigate the current state and research needs of Sustainable BPM is Sustainable BPM approaches. The studies NOPB, SGOA, JCM, TSCA,

AHG, DCOA, DCOB, TSCB, and SGOB, classify existing Sustainable BPM research by using similar, yet different BPM concepts. Each column in Figure 2 represents one of the Capability Areas and each row represents one literature review. To provide a synthesis of the findings, we have mapped each category to the Capability Areas of [16], as described in our background section. Several studies used overarching BPM concepts as a reference for their categories. The study DCOB utilizes the BPM capability maturity model of [16] that distinguishes between six "Capability Areas" of BPM. This conceptualization is similar to the one used in JCM, which structures its analysis along "Core Elements of BPM" [49]. NOPB adapted another capability maturity model, "Green IT Readiness" [50], to BPM. The Governance concept utilized by JCM and NOPB has some overlap with the Management Capability Area as well as the Structure Capability Area and therefore appears for each study twice in the mapping. The authors of DCOA describe their distinction of technical and managerial capabilities as a less detailed or more generalized categorization than typically employed in capability maturity models. In AHG the analysis is structured along "Process Lifecycle Stages", in reference to a concept provided in an older Sustainable BPM review, NOPA. TSCA's, TSCB's, SGOA's, and SGOB's authors did not provide an explicit overarching BPM concept. Their categorization can be seen as emergent from their analysis of the primary literature. CST and NOPA do not appear in the table, as they did not classify their papers by BPM concepts—they followed a broader perspective, differentiating between green IT, green information systems, and "green BPM", but neglecting to analyze the "green BPM"-papers further.

The size and color of the circles in Figure 2 show how many papers were allocated by the authors of the secondary studies to the corresponding categories. From largest circle (dark red) to smallest circle (light gray), they stand for $\leq$30 and >20, $\leq$20 and >10, $\leq$10 and >5, and $\leq$5 and >0. While the visualization allows us to identify some trends, the numbers need to be handled with care. They are not immediately comparable, as the different studies employed different approaches for their categorization. We noticed two different categorization strategies. One group of studies performed a rather loose coding of the identified papers, where the primary studies were analyzed based on the appearance or discussion of certain concepts. This is the case for AHG and NOPB. In these studies, one primary paper may appear in most or even all categories. The other group of studies extracted "topics" or "concepts" from the primary papers and sorted these into one of the categories. This is the case for DCOB, JCM, SGOA, SGOB, TSCA, and TSCB. Still, one paper may describe multiple "topics" or "concepts" and thus appear in multiple categories, but the categorization was in general stricter than in the first group. DCOA employed the strictest categorization, where every paper was strictly sorted into one of the three categories. However, their distinction between "technical" and "managerial" papers together with their introduction of a category "both" also indicates that the borders between different BPM topics are not always clear-cut. We proceed with a synthesis of the findings of the secondary studies. For researchers interested in the primary papers, we have compiled a consolidated list of all primary papers and their descriptions in the literature studies, available under [51].

Modeling Approaches: The Modeling Capability Area has been the focus of Sustainable BPM research. From a topic with only a few contributions in the beginning, it has lately received the most interest from researchers, as the later studies AHG and DCOB allocate most papers to this Capability Area. It was even the subject of the dedicated reviews TSCA and TSCB as a sub-field of Sustainable BPM. Notable approaches for Sustainable BPM are the adaptation and extension of modeling languages (TSCA provide the most detailed overview on these aspects), and the definition of patterns (overview provided by TSCB).

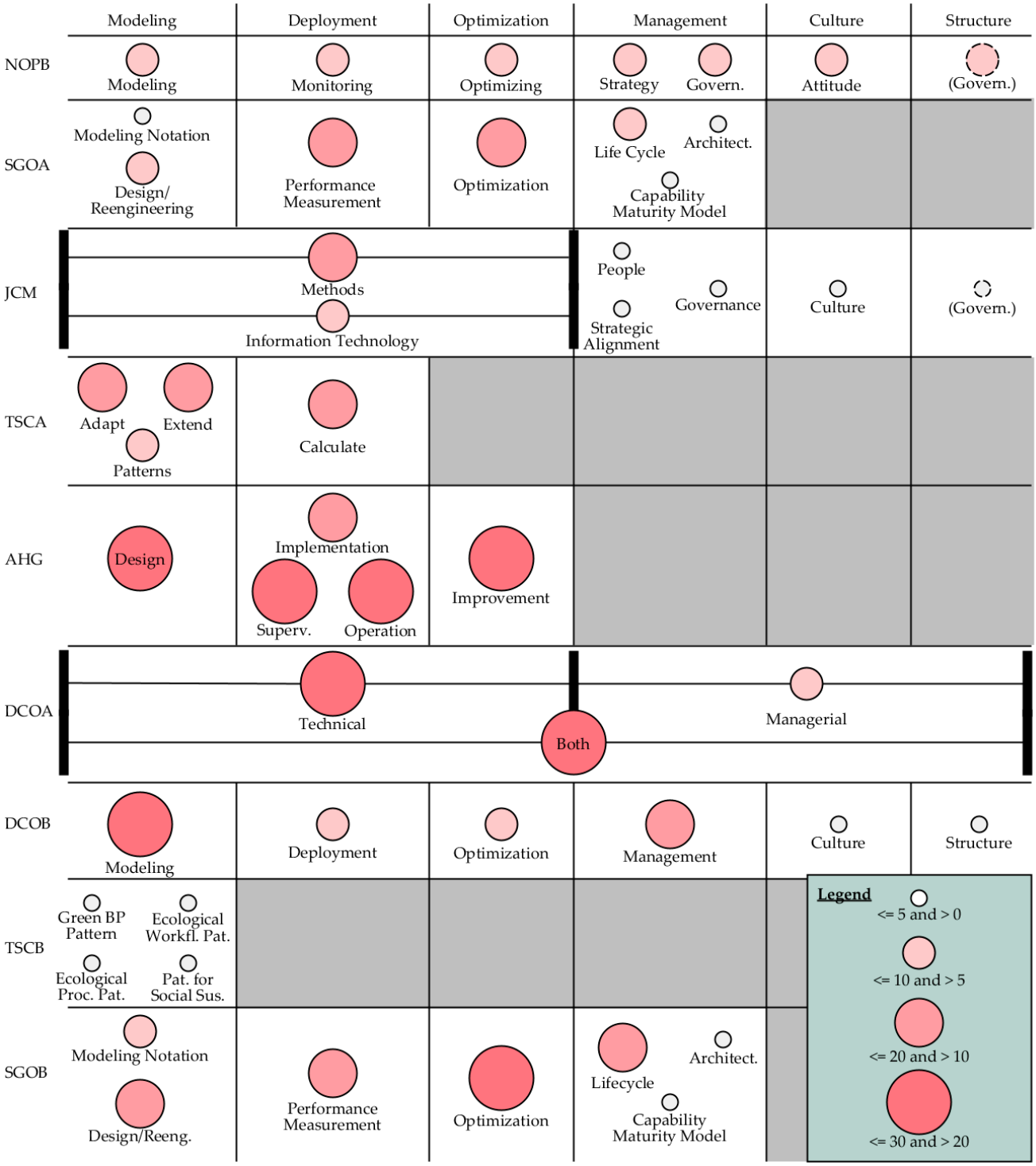

Figure 2. Mapping of Sustainable BPM approaches identified in literature reviews.

Deployment Approaches: Regarding the Deployment of sustainable business processes, researchers have proposed or mentioned different measures or indicators, but little work has been done on the actual implementation of these measures (see NOPB, SGOA, JCM, DCOB, TSCA, AHG). Comparing the earliest results from NOPB to the later results from DCOB indicate that this topic has received little attention altogether. The large number of papers allocated to Deployment by AHG seems to contradict this conclusion, but AHG followed a rather loose coding strategy, so, in our interpretation, the categorization of AHG

only provides evidence that Deployment aspects were mentioned in the primary papers, but not that specific approaches were presented.

Optimization Approaches: Only some approaches have been proposed in the Optimization Capability Area, among which are process mining, benchmarking, and semi-automatic redesign of processes, as identified by DCOB and JCM. The relatively large number of papers allocated to the corresponding categories by SGOA, SGOB, and AHG, appear to contradict this conclusion. However, all three studies provide few examples and detailed descriptions of approaches. In our interpretation, the relatively large number of papers allocated by them reflects that many papers discuss the general goal of improving the sustainability of processes without proposing many specific Optimization methods or techniques.

Management Approaches: The topic of indicators is classified by JCM as an aspect of "Strategic Alignment", as such belonging to the Management Capability Area. Correspondingly, DCOB categorizes some papers discussing "metrics" as belonging to Deployment and some discussing "indicators" as belonging to Management. In our interpretation, this seeming inconsistency within and between the studies reflects that the definition of indicators is a management task, while the application of indicators is done during the deployment of processes. Apart from this, the main contribution of Sustainable BPM researchers in this Capability Area has been different conceptual frameworks, which extend conventional BPM concepts, such as maturity models and the Business Process Lifecycle concept with sustainability aspects (SGOA, SGOB, and DCOB). Apart from this, several different topics have been discussed by some researchers, for example, collaboration with external stakeholders, or the definition of roles and responsibilities (NOPB, JCM, and DCOB).

Culture and Structure Approaches: Rare but innovative proposals can be found in the Capability Areas Culture and Structure. As can be seen in Figure 2, only three of the studies, NOPB, JCM, and DCOB, have even addressed such topics in the scope of their analysis. Notable examples in these areas are approaches that address sustainability awareness, training programs, and organizational bodies (see, e.g., DCOB). **State of Research for Sustainable BPM Approaches (RQ1):** Our consolidated analysis of the secondary studies shows that Modeling has over time developed as the Capability Area that received the most attention. In this Capability Area, approaches to adapt and extend modeling languages are most prevalent. Another prevalent topic to be found in the Capability Areas Deployment and Management is the definition and application of sustainability metrics or indicators. The Capability Area Management has received the second greatest attention with a focus on proposing conceptual frameworks that extend conventional BPM concepts with sustainability aspects. Altogether, Sustainable BPM has so far focused on technical capabilities. These findings regarding existing approaches for Sustainable BPM can be related to our conclusion for the first topic, research context. Due to the relative youth of the field, most of the work so far has been rather conceptual and is as such naturally located in the Modeling Capability Area (when it comes to modeling languages) and Management Capability Area (when it comes to overarching frameworks).

Research Needs for Sustainable BPM Approaches (RQ2): To a large extent, the research gaps pointed out by the authors of the secondary studies mirror the findings of the previous section, so the areas that have so far received little attention—Deployment (by JCM), Culture and Structure (by SGOA, SGOB, JCM, DCOA, DCOB)—are identified as gaps. We could not identify any such proposals concerning the Optimization Capability Area. In general, one has to note that an area that receives little attention is not necessarily a research gap—it may just be not relevant [52]. In this case, however, we agree with the research gap proposals of the secondary studies. We expect that, as Sustainable BPM advances towards more implementation, application, and evaluation work, the mentioned Capability Areas will receive more attention. The authors of the secondary studies have provided several ideas, which topics could be investigated in these Capability Areas, such as embedding sustainability factors into executable business process specifications (JCM), or investigations regarding the role of top management commitment and employee behavior

(DCOA). In the quantitatively strong Capability Areas Modeling and Management, the authors call for the implementation of sustainable business process modeling languages in modeling tools (CST, JCM, and SGOB) and sound conceptual frameworks (CST, SGOA, SGOB, JCM, and AHG).

4.3. Topic 3: Sustainability Aspects Considered in Sustainable BPM

Sustainability aspects are the third topic we investigate in our analysis. As Figure 3 shows, we have sorted the aspects identified in the secondary studies into the three sustainability dimensions environmental, social, and economic. Similar to the previous mapping regarding BPM approaches, the different studies are sorted chronologically, and the circles represent the categories used in the secondary studies. Only six of the studies (SGOA, SGOB, TSCA, TSCB, AHG, DCOA) explicitly analyze the primary papers regarding their coverage of sustainability aspects. SGOA, SGOB, and AHG, provide an overview of identified environmental performance indicators. TSCA extracts "Sustainability Principles" from the primary papers and sorts them into the three dimensions. DCOA and TSCB follow a broader perspective by looking not only for indicators but also for sustainability dimensions. DCOA, TSCA, and TSCB reference the triple bottom line [4] to motivate the categories "Sustainability" and "Environmental sustainability", or "Ecological", "Economical" and "Social" dimensions and add the remaining sub-categories according to their observations. The analyses of SGOA, SGOB, and AHG, are not explicitly oriented to any existing sustainability concept or indicator scheme. While the remaining studies CST, NOPA, NOPB, JCM, and DCOB, do not provide a dedicated analysis of sustainability aspects, they provide some unstructured descriptions of sustainability aspects addressed in primary papers. We have extracted these descriptions and list and discuss them here alongside the more extensive analyses. The size of the circles in Figure 3 reflects the allocation of the number of primary papers to the corresponding category by the secondary studies. From the biggest circle (dark red) to the smallest circle (light gray), they stand for $\leq$40 and >30, $\leq$30 and >20, $\leq$20 and >10, $\leq$10 and >5, and $\leq$5 and >0. For the studies that did not provide a dedicated analysis on sustainability aspects, the mentioned sustainability aspects are depicted with a small gray circle and dashed lines. As with the previous map on BPM approaches (Figure 2), the numbers need to be handled with care. SGOA, SGOB, TSCA, TSCB, and AHG, followed a more loose coding approach, so the numbers reflect whether the specific concept appears or is mentioned in any way. DCOA categorized more strictly, with a paper appearing in only one of their categories, according to its main focus. We proceed with a synthesis of the findings of the secondary studies.

Environmental Sustainability Aspects: A variety of environmental aspects have been addressed, the most prevalent being carbon emissions and energy consumption. These aspects can be found under different names: "CO_2 footprint" and "energy consumption" in SGOA, "reduce carbon footprint" and "reduce consumption" in TSCA, "emissions" and "energy efficiency" in AHG, and "carbon emissions" and "energy consumption" in DCOA. Apart from this, no clear categorization or focus has emerged from the secondary studies' results. Several aspects seem to appear in multiple studies under different terms, but a mapping was not possible, as the authors did not provide specific descriptions or clarifications for the concepts. This may also be due to unclear or inconsistent terminology in the primary papers. We also observed that several identified sustainability aspects are qualitatively different, for example, "emissions" and "biodiversity" in AHG. The measurement of direct carbon emissions in a process appears straightforward, but measuring the impact of a process on biodiversity is certainly more difficult.

Social and Economic Sustainability Aspects: Regarding the social and economic sustainability dimension, DCOA find that some primary papers discuss sustainability from a broader perspective, but they find none that focuses on social or economic aspects. TSCA identify some isolated principles that are mentioned in primary papers. In the economic dimension, these are conventional financial performance indicators such as cost, time, or profit. In the social dimension, TSCA distinguish between indicators that address an

organization's staff (e.g., "wages", "health and safety") and the society as a whole (e.g., "contribute to social equity", "track social effects"). It is worth mentioning that the one paper in the social dimension identified by TSCB is the earlier study TSCA, where some initial concepts for social business process patterns were proposed. As can be seen in the second and third columns in Figure 3, only one study, TSCA, has identified social and economic sustainability aspects. The problem of qualitative discrepancy of identified aspects mentioned for the environmental dimension also applies here. We conclude that the social and economic sustainability dimensions are underrepresented in Sustainable BPM so far.

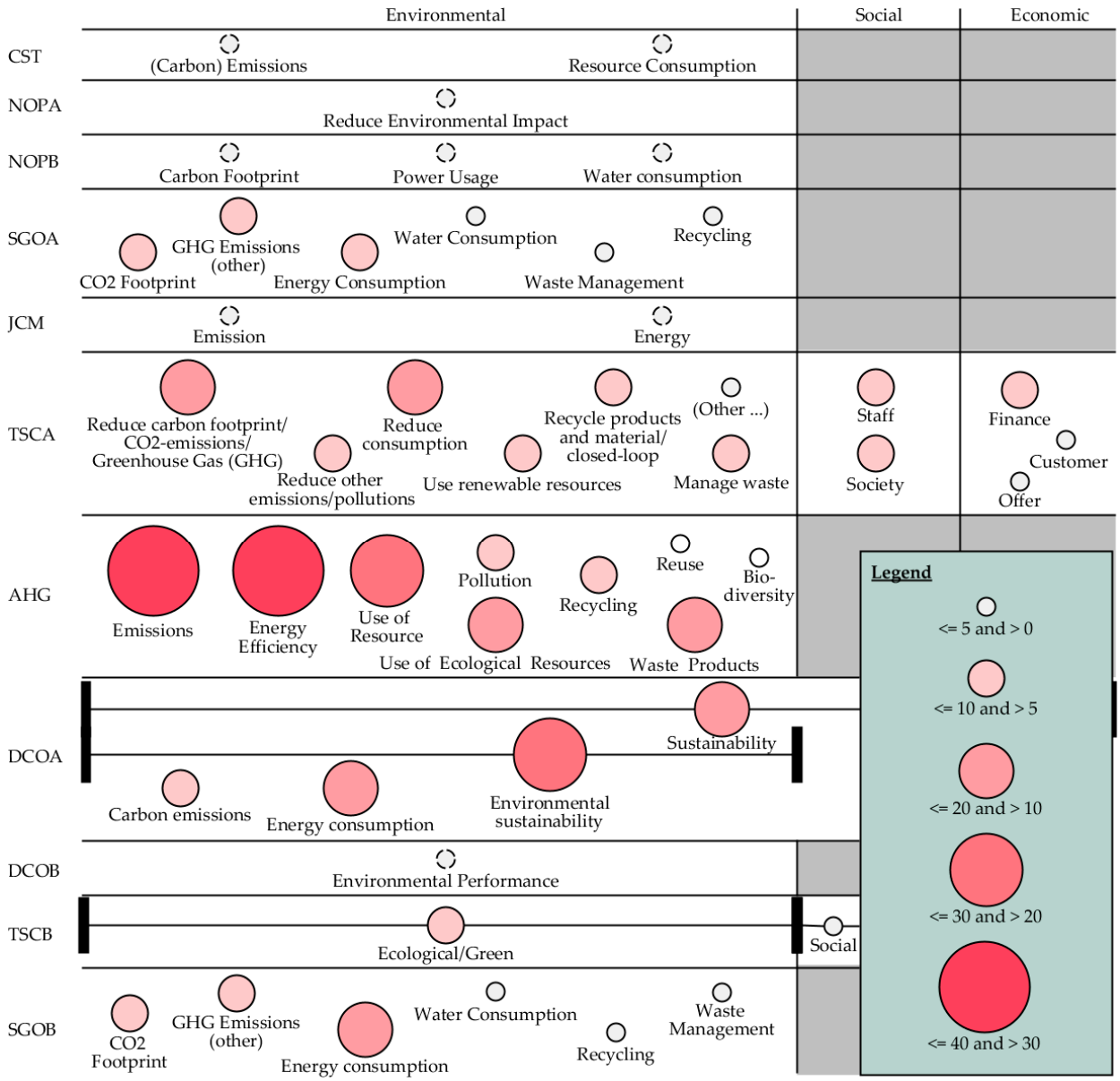

Figure 3. Mapping of Sustainability aspects identified in literature reviews.

State of Research for Sustainability Aspects (RQ1): From a sustainability perspective, the state of Sustainable BPM research can be described as focusing on carbon emissions and energy consumption, and missing a clear and shared concept of sustainability aspects. This missing clear and shared concept is most apparent in the observation that the secondary studies use categorizations that are qualitatively very dissimilar (e.g., "carbon emissions" in DCOA versus "avoid unnecessary information" in TSCA) and on various

levels of abstraction and detail. Existing concepts from environmental sciences (such as the distinction between inventory indicators and impact indicators in LCA) that could have provided structure and clarification were not employed. Note that this is not a shortcoming of the studies themselves, but may reflect the difficulty to classify the variety of sustainability aspects addressed in primary papers.

Research Needs for Sustainability Aspects (RQ2): We have extracted descriptions of proposed agendas and identified research needs regarding sustainability aspects from the secondary studies. From the papers that provided a more detailed analysis of sustainability aspects, DCOA, SGOA, and SGOB, identified the need for future research to broaden the scope of addressed environmental indicators (SGOB extend this call to social aspects). All three find that the main focus so far has been on carbon emissions and energy use, with other environmental topics largely untouched. DCOA states that knowledge about such topics is already available in environmental sciences and that Sustainable BPM researchers could learn from them. In particular, the authors mention "waste management" and "Life Cycle Assessment" as areas that Sustainable BPM researchers can learn from. This mirrors our conclusion in the previous section that a clear concept of sustainability is missing so far, but could be provided by disciplines such as LCA. The three studies that have considered a broader sustainability perspective in their analysis, DCOA, TSCA, and TSCB, all find that social aspects (and economic, in the case of TSCA) have so far been considered even less and that this should be addressed in the future. One could argue that conventional BPM, with its focus on time and cost improvements [12] (p. 1), is already concerned with the economic sustainability dimension. However, an economic sustainability analysis should also be conducted from a life cycle perspective, and should not stay within the scope of one isolated business process or organization [26] (p. 364). We will explore ways how to integrate this life cycle perspective in BPM in the next section.

5. Discussion

5.1. Pathways to Greener Pastures

Table 2 gives an overview of the research needs we identified in the secondary studies for the three topics "Research Context", "BPM Approaches" and "Sustainability Aspects". At the core of our recommendations lies the observation that several authors of literature reviews have called for more interdisciplinary work, especially with environmental sciences and LCA (the first research need in the topic "Research Context"). So far, to our knowledge, this has not been explored more deeply. The pathways we propose in the following are based on the idea to integrate BPM and LCA concepts and methods, so we implicitly address this research need. For each remaining research need, the last column of Table 2 shows the related pathways. We describe how the research needs are addressed in the following pathway descriptions.

Table 2. Linking of research needs and research opportunities (pathways).

Topic	Research Needs	Pathways
Research context	International, interdisciplinary, and practical collaboration.	all
	Implementations, applications, and evaluation of approaches.	3; 4; 5
BPM approaches	Focus on Deployment Capability Area.	2; 4
	Focus on Culture and Structure Capability Areas.	2
	Implementation of modeling tools.	2; 3
	Development of sound conceptual frameworks.	3
Sustainability aspects	Broadened scope of environmental indicators.	1
	Integration of environmental, social, and economic dimensions.	1
	Sound conceptualization of sustainability.	1

1. Application of LCA indicators: To address the identified needs regarding the topic sustainability aspects, (1) a broadened scope of environmental indicators, (2) the

integration of the environmental, social, and economic sustainability dimension, and (3) a sound conceptualization of sustainability, BPM should apply LCA indicators. The definition of key performance indicators (KPI) is an important activity in BPM [16]. As the capability to quantify sustainability impacts is a central strength of LCA [26] (p. 370), LCA-based sustainability measures could lay the ground for sustainability KPIs and alleviate weaknesses in the current state. In the following, we give an example of this weakness and how it could be addressed by following this pathway.

The one aspect that was addressed most in Sustainable BPM, energy consumption, actually does not measure an environmental impact [26] (p. 220). Only with additional information about the energy sources used to generate the energy could one quantify associated carbon emissions and their effect on global warming (or other impacts associated with the energy production). Certainly, measuring other aspects identified in the literature reviews, such as the influence of a business process on 'biodiversity' poses a challenge (just to give one example). In LCA, such questions are addressed routinely. As described in our background section, LCA distinguishes between inventory data and impact category indicators. Inventory data can be directly measured in a process, but then the inventory data needs to be assigned to impact category indicators to be meaningful. In this conception, energy use and carbon emissions are inventory indicators that need to be translated to impact indicators (e.g., a quantification of global warming potential). Similarly, the hard-to-measure environmental aspect 'biodiversity' is seen as an 'impact category'—and a variety of inventory data is needed to measure it [29] (p. 227). In general, when expanding the scope of covered sustainability aspects, LCA provides methods to translate scientific findings into process measures. As we have pointed out in the background section, there also exist LCA approaches to address social and economic sustainability concerns.

2. Integration of Life Cycle Thinking in BPM: Sustainable BPM runs the risk of neglecting burden shifting if the analysis stays within the scope of singular processes within organizations. We see a potential weakness of the BPM perspective here, as in conventional BPM, the analysis may often stay within organizational boundaries. For example, [13] (p. 5), while acknowledging that interactions with other organizations are possible, defines a business process as "enacted by a single organization". If this perspective is adapted to sustainability in an ad-hoc manner, Sustainable BPM runs a great risk of neglecting burden shifting. A simple example based on [26] (p. 5) can illustrate this. Assume we observe the business process of a kitchen that prepares potato salad. First, the potatoes are washed, then peeled, and finally cut. A business process reengineering project may propose to change the process, so the kitchen buys pre-washed potatoes. From a conventional BPM perspective, the associated time gains would be considered a great success. Additionally, the organization's potato salad preparation process suddenly uses much less water. From an ad-hoc Sustainable BPM perspective, this change may also be considered a success—while the environmental burden was actually only shifted along the supply chain to the organization that washes the potatoes. Similarly, there is the danger of neglecting trade-offs between different sustainability aspects, when for example a process change apparently decreases water use but causes an increase in energy use (maybe somewhere else in the supply chain) that goes unobserved. Such considerations lie at the center of the LCA method, so Sustainable BPM can gain valuable insights here. On a technical level, researchers should find ways to appropriately integrate life cycle data into business process models (when addressing the need for implementations of modeling tools). In this regard, Sustainable BPM will also need mechanisms to account for allocation and cut-off challenges, as they are discussed in LCA [26] (pp. 29–34): Cut-off refers to the need for transparent decisions, what data about environmental burdens not to consider (to cut off), to not overload the analysis. Allocation refers to the challenge that arises when processes have multiple inputs and outputs and the data about environmental burdens needs to be appropriately assigned.

When focusing on the Deployment Capability Area in general, the integration of life cycle data into protocols for automated processes could be a way to achieve real-time

sustainability measures. For an elaboration of such a protocol in the Internet of Things context see [53]. On a managerial level, Sustainable BPM should integrate the life cycle perspective of LCA into its frameworks and culture (when addressing the need for a focus on the Culture and Structure Capability Areas). One has to note that integrating life cycle thinking in BPM would not necessarily mean always considering all impact categories and life cycle phases in every detail. The LCA method itself allows restricting the scope—as long as this is explicitly stated. The advantage would still be that assumptions for comparisons are made transparent, so that the unknown factors, as well as the ideal to strive for, are clear. A general strength of LCA is that it is based on internationally accepted standards, as this standardization helps to counter the arbitrariness of sustainability claims and supports the comparability and general quality of sustainability analyses (see [54]).

3. Conceptual Integration of LCA and BPM: Both BPM and LCA follow a process perspective that could serve as a common ground to adapt concepts and methods. The main difference is that in BPM the focus is on activities and their coordination [13], while in LCA one models material and energy flows associated with a product [25]. A conceptual integration may require some care but appears possible, as for example Petri Nets are capable as a modeling language to represent both perspectives and have a tradition of being used in both LCA [55] and BPM [56] research and practice. Another observation is of importance in this regard. Traditionally, with its emphasis on "product" sustainability, LCA has focused on manufacturing processes, with a tendency to neglect "supporting" managerial and marketing processes [57]. However, recent developments in LCA address this, and in a newer ISO standard [58] and guideline [57], the application of the LCA method to "organizations" (not only "products") is described under the term Organizational LCA (O-LCA). With these developments, the perspectives of LCA and BPM are even more aligned, as both are concerned with organizational performance. Still, the mentioned differences in perspective require careful investigation in order to develop an integrated conceptual framework. This again would address the need for a sound conceptual framework for Sustainable BPM, as was identified in the literature reviews. As conducting an LCA study is largely a modeling and data collection task, LCA concepts and methods could be integrated into the Modeling Capability Area, and developing an LCA enhanced Sustainable BPM modeling tool would address the need for more implementations in Sustainable BPM and provide a foundation for further developments in the other Capability Areas.

4. Operationalization of LCA: In general, implementations and applications of Sustainable BPM could be a vehicle for operationalizing LCA. Typically, an LCA study is a one-time project where data is collected and analyzed. The guidelines for O-LCA (the previously mentioned variant of LCA that expands the scope of sustainability analysis from products to organizations) [57] make suggestions for the operationalization of LCA, specifically to use LCA for decision-making, target setting, and performance tracking. In this context, the guidelines note that O-LCA may help organizations to map the organization in order to understand the interlinkages between activities and processes—a goal that it certainly shares with conventional BPM. Given that LCA sustainability measures are properly integrated, sustainability-aware BPM systems could bring LCA data and insights into the organization and to decision-makers on various levels of granularity. This research pathway requires further advancement of Sustainable BPM in the Deployment Capability Area which has so far received comparatively little attention. However, given a sound conceptual framework (see pathway 3), we expect that existing approaches and tools in (conventional) BPM can be extended and adapted accordingly. As one example, recent legislative developments such as the Corporate Social Responsibility directive of the European Union [59], make sustainability considerations a question of compliance with the law. Existing business process compliance checking approaches [60] could be adapted to (semi)-automatically ensure that processes comply with emission targets (or other sustainability KPIs) that are based on comprehensive LCA analyses. Furthermore, process mining enables analyses and process management on an operational level [61]. With process mining techniques, one can analyze the as-is state of a process, using event

logs as a data source. In this way, process mining can detect deviations from the planned execution path, as soon as they occur. Hence, an adjustment can be made quicker and possible violations of sustainability constraints can be avoided.

5. BPM Methods to Support LCA Processes: This pathway is similar to pathway 4, but aims less at full operational integration of BPM and LCA, and rather looks for pragmatic applications and implementations of (conventional) BPM methods to improve the process of conducting an LCA. This appears useful, as conducting an LCA study is a complex undertaking. Data needs to be collected and updated, various stakeholders need to be involved, and results need to be reviewed and published. This leads to LCA studies being costly, time-consuming, inflexible, and difficult to update [62]. Such challenges in LCA could be supported with business process methods and techniques. Some of the activities required for efficient LCA analyses may be candidates for robotic process automation (RPA): RPA enables the automation of tedious activities for humans, which could not be automated with traditional methods (e.g., transferring data between disconnected information systems) [63]. Furthermore, in a recently published study, [64] show how process mining can be employed to efficiently and repeatedly perform LCA analyses based on event logs of machinery in a production process. As the authors of [64] point out, this is only an initial investigation, and additional work needs to be done, e.g., regarding the real-time integration of energy and material flow data. Given an integration of LCA and process mining as outlined by [64], methods for root cause analysis in process mining (e.g., [65]), may also help to uncover links between environmental consequences and their root causes in a process (see [62]).

5.2. Limitations

In our tertiary study, we have excluded papers that did not provide a systematic review, papers that do not explicitly locate themselves in the sustainability discourse, and papers not written in English. While the application of such practical exclusion criteria is common in SLRs (see [10]), future investigations with a broader scope may provide additional insights. The validity of our findings is constrained by the quality of the secondary studies. Similar to our search process, the search in the secondary studies was limited and might not have captured potentially relevant literature that is not explicitly placed in the sustainability discourse. In some cases, we observed that some results are not immediately backed by the provided evidence. Our allocation of categories for the consolidation of the secondary studies' categorizations is limited by the fact that several of the studies did not provide explicit descriptions of their categories. Even where descriptions are given, interpretations of different concepts may differ from author to author. Even though some details of our mapping can certainly be discussed, we argue that such blurring is natural in a developing research field, especially where not only strictly technical aspects are covered. As our review relies on secondary studies, the level of detail we could give regarding existing approaches and addressed sustainability aspects is limited; often, the secondary studies only provide brief and generalized descriptions for the identified primary papers. In proposing LCA as a reference for integrating sustainability considerations into BPM, we are aware that the development of the LCA method is not without challenges [66]. We argue that similar challenges necessarily arise in any serious investigation of sustainability issues. Other related methods and frameworks, such as the Greenhouse Gas Protocol [67] exist, which may also provide useful orientation for Sustainable BPM and could be investigated in future research. Still, we maintain that LCA in its comprehensiveness and similarity to BPM due to its process perspective should be strongly considered in Sustainable BPM research.

6. Conclusions

We have conducted a tertiary study in the field of Sustainable BPM. Our tertiary study complements the findings of the analyzed secondary studies by consolidating their mappings of the field and providing an overview of identified research needs (a list of all primary papers considered in the secondary studies is also available under [51]). We found

that Sustainable BPM research has so far focused on the Modeling Capability Area, with most of the proposals in a conceptual stage. We also found that, regarding sustainability aspects, Sustainable BPM has a narrow focus on carbon emissions and energy use and we diagnosed an inconsistency and missing clarity regarding the addressed sustainability topics. To address this, we have proposed several research opportunities to integrate Sustainable BPM and Life Cycle Assessment, an established and rigorous method for sustainability analysis. When discussing the research opportunities, we showed how methods and techniques for business process automation and innovation such as process mining and robotic process automation can be leveraged.

Sustainable BPM as a research field is well versed to tackle the highly pressing issue of organizational sustainability. It can achieve this by enabling managers to not only understand the sustainability impacts of their organization but to effectively enact the necessary changes in their operations. Our proposed research pathways provide the necessary guidance for researchers that work on new approaches that integrate sustainability considerations in a sound and comprehensive manner. We argued in the beginning that organizational performance should not be measured solely in financial terms, but also regarding an organization's social and environmental impacts. Considering this, one could suggest that Sustainable BPM does not differ from conventional BPM, but is just BPM that takes a broader perspective. In an analysis of conventional BPM research, [15] has called for future BPM research to be less concerned with "puzzle-solving", but rather focus on "big picture issues". One can certainly argue that Sustainable Development is a big picture issue. Our vision is that in the future there will be no distinction between Sustainable BPM and conventional BPM, but a BPM discipline that integrates economic, social, and environmental concerns and develops in a way to enable significant change towards more organizational sustainability.

Author Contributions: Conceptualization, A.F.; methodology, A.F., S.B. and J.v.H.; validation, S.B. and C.S.; formal analysis, A.F. and J.v.H.; investigation, A.F. and J.v.H.; resources, A.O.; data curation, A.F.; writing—original draft preparation, A.F., J.v.H. and C.S.; writing—review and editing, A.F., S.B. and A.O.; visualization, A.F. and J.v.H.; supervision, S.B. and A.O.; project administration, A.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: We provide a data package with database results, exclusion decisions, quality assessment, and data extraction, openly available in Figshare at [31]. A list of primary papers considered in the secondary reviews with extracted descriptions is openly available in Figshare at [51].

Acknowledgments: We acknowledge support by the KIT-Publication Fund of the Karlsruhe Institute of Technology.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Hilty, L.M.; Aebischer, B. ICT for Sustainability: An Emerging Research Field. In *ICT Innovations for Sustainability*; Hilty, L.M., Aebischer, B., Eds.; Springer International Publishing: Cham, Switzerland, 2015; pp. 3–36.
2. Garriga, E.; Melé, D. Corporate Social Responsibility Theories: Mapping the Territory. *J. Bus. Ethics* **2004**, *53*, 51–71. [CrossRef]
3. United Nations General Assembly. *Transforming Our World: The 2030 Agenda for Sustainable Development (A/RES/70/1)*; UN: New York, NY, USA, 2015.
4. Elkington, J. *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*; Capstone Publishing Limited: Oxford, UK, 1997.
5. Elkington, J. 25 Years Ago I Coined the Phrase "Triple Bottom Line." Here's Why It's Time to Rethink It. *Harv. Bus. Rev.* **2018**, *25*, 2–5.
6. Stolze, C.; Semmler, G.; Thomas, O. Sustainability in Business Process Management Research—A Literature Review. In Proceedings of the Americas Conference on Information Systems, Seattle, WA, USA, 9–11 August 2012.

7. Couckuyt, D.; Van Looy, A. A Systematic Review of Green Business Process Management. *Bus. Process Manag. J.* **2019**, *26*, 421–446. [CrossRef]
8. Kitchenham, B.; Pretorius, R.; Budgen, D.; Pearl Brereton, O.; Turner, M.; Niazi, M.; Linkman, S. Systematic Literature Reviews in Software Engineering—A Tertiary Study. *Inf. Softw. Technol.* **2010**, *52*, 792–805. [CrossRef]
9. Hoda, R.; Salleh, N.; Grundy, J.; Tee, H.M. Systematic Literature Reviews in Agile Software Development: A Tertiary Study. *Inf. Softw. Technol.* **2017**, *85*, 60–70. [CrossRef]
10. Kitchenham, B.; Charters, S. Guidelines for Performing Systematic Literature Reviews in Software Engineering. *Engineering* **2007**, *2*, 1051. [CrossRef]
11. Couckuyt, D.; Van Looy, A. Green BPM as a Business-Oriented Discipline: A Systematic Mapping Study and Research Agenda. *Sustainability* **2019**, *11*, 4200. [CrossRef]
12. Dumas, M.; La Rosa, M.; Mendling, J.; Reijers, H.A. *Fundamentals of Business Process Management*, 2nd ed.; Springer: Berlin/Heidelberg, Germany, 2018; ISBN 978-3-662-56509-4.
13. Weske, M. *Business Process Management: Concepts, Languages, Architectures*, 3rd ed.; Springer: Berlin/Heidelberg, Germany, 2019; ISBN 978-3-662-59432-2.
14. Harmon, P. The Scope and Evolution of Business Process Management. In *Handbook on Business Process Management 1*; vom Brocke, J., Rosemann, M., Eds.; Springer: Berlin/Heidelberg, Germany, 2015; pp. 37–80. ISBN 978-3-642-45100-3.
15. Recker, J. Suggestions for the Next Wave of BPM Research: Strengthening the Theoretical Core and Exploring the Protective Belt. *J. Inf. Technol. Theory Appl.* **2014**, *14*, 5–20.
16. Van Looy, A.; De Backer, M.; Poels, G. A Conceptual Framework and Classification of Capability Areas for Business Process Maturity. *Enterp. Inf. Syst.* **2014**, *8*, 188–224. [CrossRef]
17. Rosemann, M.; vom Brocke, J. The Six Core Elements of Business Process Management. In *Handbook on Business Process Management 1*; vom Brocke, J., Rosemann, M., Eds.; Springer: Berlin/Heidelberg, Germany, 2015; pp. 105–122. ISBN 978-3-642-45099-0.
18. Zur Muehlen, M.; Ho, D.T.-Y. Risk Management in the BPM Lifecycle. In Proceedings of the Business Process Management Workshops, Nancy, France, 5 September 2005.
19. United Nations General Assembly. *Report of the World Commission on Environment and Development: Our Common Future (A/42/427)*; UN: New York, NY, USA, 1987.
20. Lélé, S.M. Sustainable Development: A Critical Review. *World Dev.* **1991**, *19*, 607–621. [CrossRef]
21. Connelly, S. Mapping Sustainable Development as a Contested Concept. *Local Environ.* **2007**, *12*, 259–278. [CrossRef]
22. Purvis, B.; Mao, Y.; Robinson, D. Three Pillars of Sustainability: In Search of Conceptual Origins. *Sustain. Sci.* **2019**, *14*, 681–695. [CrossRef]
23. Melville, N.P. Information Systems Innovation for Environmental Sustainability. *MIS Q.* **2010**, *34*, 1–21. [CrossRef]
24. Heiskanen, E. The Institutional Logic of Life Cycle Thinking. *J. Clean. Prod.* **2002**, *10*, 427–437. [CrossRef]
25. Heiskanen, E. Managers' Interpretations of LCA: Enlightenment and Responsibility or Confusion and Denial? *Bus. Strategy Environ.* **2000**, *9*, 239–254. [CrossRef]
26. Klöpffer, W.; Grahl, B. *Life Cycle Assessment (LCA) a Guide to Best Practice*; Wiley-VCH: Weinheim, Germany, 2014.
27. Elkington, J. Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development. *Calif. Manag. Rev.* **1994**, *36*, 90–100. [CrossRef]
28. *ISO 14040:2006*; Environmental Management—Life Cycle Assessment—Principles and Framework. American National Standards Institute (ANSI): New York, NY, USA, 2006.
29. Finkbeiner, M.; Ackermann, R.; Bach, V.; Berger, M.; Brankatschk, G.; Chang, Y.-J.; Grinberg, M.; Lehmann, A.; Martínez-Blanco, J.; Minkov, N.; et al. Challenges in Life Cycle Assessment: An Overview of Current Gaps and Research Needs. In *Background and Future Prospects in Life Cycle Assessment*; Klöpffer, W., Ed.; Springer: Dordrecht, The Netherlands, 2014; pp. 207–258. ISBN 978-94-017-8696-6.
30. Martínez-Blanco, J.; Lehmann, A.; Chang, Y.-J.; Finkbeiner, M. Social Organizational LCA (SOLCA)—A New Approach for Implementing Social LCA. *Int. J. Life Cycle Assess.* **2015**, *20*, 1586–1599. [CrossRef]
31. Fritsch, A.; von Hammerstein, J.; Schreiber, C.; Betz, S.; Oberweis, A. Sustainable BPM Tertiary Study Data Package. Available online: https://figshare.com/s/e9235ae16d3bcd680569 (accessed on 1 September 2022).
32. Webster, J.; Watson, R.T. Analyzing the Past to Prepare for the Future: Writing a Literature Review. *MIS Q.* **2002**, *26*, 13–23.
33. Vom Brocke, J.; Simons, A.; Niehaves, B.; Riemer, K.; Plattfaut, R.; Cleven, A. Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process. In Proceedings of the European Conference on Information Systems, Verona, Italy, 8–10 June 2009.
34. Levy, Y.; Ellis, T.J. A Systems Approach to Conduct an Effective Literature Review in Support of Information Systems Research. *Inf. Sci.* **2006**, *9*, 181–212. [CrossRef]
35. Genero Bocco, M.; Cruz-Lemus, J.A.; Piattini Velthuis, M.G. *Métodos de Investigación En Ingeniería Del Software*; RA-MA: Madrid, Spain, 2014; ISBN 978-958-762-430-4.
36. Kitchenham, B.A.; Budgen, D.; Brereton, O.P. The Value of Mapping Studies—A Participant-Observer Case Study. In Proceedings of the International Conference on Evaluation and Assessment in Software Engineering, London, UK, 12–13 April 2010.
37. Petersen, K.; Feldt, R.; Mujtaba, S.; Mattsson, M. Systematic Mapping Studies in Software Engineering. In Proceedings of the International Conference on Evaluation and Assessment in Software Engineering, Bari, Italy, 26–28 June 2008.

38. Petersen, K.; Vakkalanka, S.; Kuzniarz, L. Guidelines for Conducting Systematic Mapping Studies in Software Engineering: An Update. *Inf. Softw. Technol.* **2015**, *64*, 1–18. [CrossRef]
39. Boell, S.K.; Cecez-Kecmanovic, D. A Hermeneutic Approach for Conducting Literature Reviews and Literature Searches. *Commun. Assoc. Inf. Syst.* **2014**, *34*, 257–286. [CrossRef]
40. Bandara, W.; Furtmueller, E.; Gorbacheva, E.; Miskon, S.; Beekhuyzen, J. Achieving Rigor in Literature Reviews: Insights from Qualitative Data Analysis and Tool-Support. *Commun. Assoc. Inf. Syst.* **2015**, *37*, 154–204. [CrossRef]
41. Opitz, N.; Krüp, H.; Kolbe, L.M. Green Business Process Management—A Definition and Research Framework. In Proceedings of the Hawaii International Conference on System Sciences, Waikoloa, HI, USA, 5–8 January 2014.
42. Opitz, N.; Krüp, H.; Kolbe, L.M. Environmentally Sustainable Business Process Management—Developing a Green BPM Readiness Model. In Proceedings of the Pacific Asia Conference on Information Systems, Chengdu, China, 24–28 June 2014.
43. Gohar, S.R.; Indulska, M. Business Process Management: Saving the Planet? In Proceedings of the Australasian Conference on Information Systems, Adelaide, Australia, 30 November–4 December 2015.
44. Maciel, J.C. The Core Capabilities of Green Business Process Management—A Literature Review. In Proceedings of the International Conference on Business Informatics, St. Gallen, Switzerland, 12–15 February 2017.
45. Schoormann, T.; Behrens, D.; Knackstedt, R. Sustainability in Business Process Models: A Taxonomy-Driven Approach to Synthesize Knowledge and Structure the Field. In Proceedings of the International Conference on Information Systems, Seoul, Korea, 10–13 December 2017.
46. González, A.H.; Calero, C.; Parra, D.P.; Mancebo, J. Approaching Green BPM Characterisation. *J. Softw. Evol. Process* **2019**, *31*, 1–26. [CrossRef]
47. Schoormann, T.; Kutzner, K.; Pape, S.; Knackstedt, R. Elevating Social Sustainability in Business Processes: A Pattern-Based Approach. In Proceedings of the International Conference on Information Systems, Munich, Germany, 15–18 December 2019.
48. Gohar, S.R.; Indulska, M. Environmental Sustainability through Green Business Process Management. *Australas. J. Inf. Syst.* **2020**, *24*, 1–30. [CrossRef]
49. Rosemann, M.; vom Brocke, J. The Six Core Elements of Business Process Management. In *Handbook on Business Process Management 1*; vom Brocke, J., Rosemann, M., Eds.; Springer: Berlin/Heidelberg, Germany, 2010; pp. 107–122. ISBN 978-3-540-66441-3.
50. Molla, A.; Cooper, V.; Pittayachawan, S. The Green IT Readiness (G-Readiness) of Organizations: An Exploratory Analysis of a Construct and Instrument. *Commun. Assoc. Inf. Syst.* **2011**, *29*, 67–96. [CrossRef]
51. Fritsch, A.; von Hammerstein, J.; Schreiber, C.; Betz, S.; Oberweis, A. Sustainable BPM Primary Papers. Available online: https://figshare.com/s/83840f7f29cb0f04240b (accessed on 1 September 2022).
52. Rai, A. Avoiding Type III Errors: Formulating IS Research Problems That Matter. *MIS Q.* **2017**, *41*, 3–7.
53. Van Capelleveen, G.; Pohl, J.; Fritsch, A.; Schien, D. The Footprint of Things: A Hybrid Approach towards the Collection, Storage and Distribution of Life Cycle Inventory Data. In Proceedings of the 5th International Conference on Information and Communication Technology for Sustainability, Toronto, ON, Canada, 14–18 May 2018; pp. 350–364.
54. Finkbeiner, M. The International Standards as the Constitution of Life Cycle Assessment: The ISO 14040 Series and Its Offspring. In *Background and Future Prospects in Life Cycle Assessment*; Klöpffer, W., Ed.; Springer: Dordrecht, The Netherlands, 2014; pp. 85–106.
55. Heijungs, R.; Suh, S. *The Computational Structure of Life Cycle Assessment. Eco-Efficiency in Industry and Science*; Springer: Dordrecht, The Netherlands, 2002; ISBN 978-90-481-6041-9.
56. Koschmider, A.; Oberweis, A.; Stucky, W. A Petri Net-Based View on the Business Process Life-Cycle. *Enterp. Model. Inf. Syst. Archit.* **2018**, *13*, 47–55. [CrossRef]
57. UNEP; SETAC. *Guidance on Organizational Life Cycle Assessment*; UNEP: Paris, France, 2015; ISBN 978-92-807-3453-9.
58. *ISO/TS 14072:2014*; Environmental Management—Life Cycle Assessment—Requirements and Guidelines for Organizational Life Cycle Assessment. British Standards Institution: Milton Keynes, UK, 2014.
59. European Commision. EU Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 Amending Directive 2013/34/EU as Regards Disclosure of Non-Financial and Diversity Information by Certain Large Undertakings and Groups Text with EEA Relevance. *Off. J. Eur. Union* **2014**, *L 330/1*, 1–9.
60. El Kharbili, M.; de Medeiros, A.K.A.; Stein, S.; van der Aalst, W.M.P. Business Process Compliance Checking: Current State and Future Challenges. In Proceedings of the Modellierung Betrieblicher Informationssysteme, Saarbrücken, Germany, 27–28 November 2008; pp. 107–113.
61. Van der Aalst, W.M.P. Data Science in Action. In *Process Mining*; Springer: Berlin/Heidelberg, Germany, 2016; pp. 3–23.
62. Cerdas, F.; Thiede, S.; Juraschek, M.; Turetskyy, A.; Herrmann, C. Shop-Floor Life Cycle Assessment. *Procedia CIRP* **2017**, *61*, 393–398. [CrossRef]
63. Van der Aalst, W.M.P.; Bichler, M.; Heinzl, A. Robotic Process Automation. *Bus. Inf. Syst. Eng.* **2018**, *60*, 269–272. [CrossRef]
64. Ortmeier, C.; Henningsen, N.; Langer, A.; Reiswich, A.; Karl, A.; Herrmann, C. Framework for the Integration of Process Mining into Life Cycle Assessment. *Procedia CIRP* **2021**, *98*, 163–168. [CrossRef]
65. Qafari, M.S.; van der Aalst, W.M.P. Root Cause Analysis in Process Mining Using Structural Equation Models. In Proceedings of the Business Process Management Workshops, Seville, Spain, 13–18 September 2020.
66. Hellweg, S.; Milà i Canals, L. Emerging Approaches, Challenges and Opportunities in Life Cycle Assessment. *Science* **2014**, *344*, 1109–1113. [CrossRef] [PubMed]

67. WBCSD. *WRI The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard 2004*; World Resources Institute: Washington, DC, USA; World Business Council for Sustainable Development: New York, NY, USA, 2004.