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Aligning digitalisation and sustainable development? Evidence from the analysis of worldviews in sustainability reports

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Abstract

The digitalisation of industrial production and the actual positive and negative consequences for sustainable development are not yet sufficiently understood. This study describes and evaluates the linkages between corporate digitalisation and sustainability management based on qualitative data analysis of sustainability reports of DAX 30 companies and applying the concept of sustainability worldviews. The results show a predominate worldview of weak or business-centred sustainability on digitalisation, which could potentially pose a threat to sustainable development. In particular, the focus on customer demands without stakeholder involvement and the worldview of digitalisation as a way of doing 'business as-usual' but in a more effective way reproduces unsustainable economic patterns. A holistic sustainable approach on digitalisation should also include possible negative impacts like increased resource consumption which is not the case yet in the studied companies. Different types of 'sustainability worldviews on digitalisation' can be distinguished. While 'Pioneer' companies can inform policy-making, the other types of 'Intermediates', 'Indecisive' and 'Laggards' could be addressed by information exchange, support and regulation to promote a more sustainable worldview on corporate digitalisation. The 'Unsustainable' digitalisation type would be the most difficult to address with soft policy instruments and requires a more regulated approach.

KEYWORDS
corporate social responsibility, digitalization, Industry 4.0, stakeholder involvement, strong sustainability, sustainability reports, sustainable development, worldviews

1 | INTRODUCTION

This study contributes to the understanding of the implication of industrial digitalisation for sustainable development by analysing the companies' worldviews on digitalisation in a sustainability context. Industrial digitalisation in the sense of this study encompasses all strategies, processes and technological implementation that are part of the digital transformation of industry to a holistic Industry 4.0 scenario, characterised by the merging of the physical world of production with the virtual world of Information and Communication Technologies. The spectrum covered ranges from individual measures or single fields of application to preliminary stages of Industry 4.0.

Several scholars see industrial digitalisation as a mechanism which can help achieve the Sustainable Development Goals, based on the potential to make manufacturing less wasteful, less resource-intensive, and more energy efficient, and as a result, to reduce CO_2

emissions (Bai et al., 2020; Chiarini, 2021; Ghobakhloo, 2020). Ghobakhloo et al. (2021) show that Industry 4.0 also has the potential to foster sustainable innovations. They identify 11 intertwined functions of digitalisation supporting sustainable innovation such as green product innovation capacity, new product development competency, product life-cycle management, sustainable partnership and collaboration (Ghobakhloo et al., 2021).

These expectations must be critically reflected against the potential negative impacts of digitalisation. Two pertinent examples are, first, job losses due to automation, particularly for lower qualified people, and, second, increased energy and raw material consumption caused by rebound effects of the intensified use of ICT (Beier et al., 2017; Itten et al., 2020; Jepsen & Drahokoupil, 2017; Lange et al., 2020; Sühlmann-Faul, 2018).

To ensure a sustainable outcome of the socio-technological development, the framework conditions under which industrial digitalisation is implemented play a crucial role. As the German Advisory Council on Global Change notes: 'The sustainability transformation can only succeed if the digital transformation is aligned with sustainability. Otherwise, digitalisation threatens to act as an accelerant for growth patterns that break through the planetary boundaries' (WBGU, 2019, p. 1).

While it is crucial to determine in which direction the development is heading, the implementation of Industry 4.0 is still at an early phase which makes it difficult to deliver scientific evidence or quantifications regarding the alignment or contradiction of digitalisation and sustainability. Moreover, the view of digitalisation as a process that needs to be actively shaped to become sustainable is not yet well represented in the scientific discourse (Beier et al., 2021), which also means that little is known about possible starting points for sustainability interventions.

The first contribution of this study is to consult the companies' worldview on how sustainability and digitalisation are related to assess whether the industrial implementation of digitalisation in its current manifestation is more likely to become an accelerator of unsustainable growth patterns or to support a more sustainable economy. This is done by collecting and evaluating the concrete contributions of digitalisation from companies' perspectives, as described in their sustainability reports and by analysing these findings in the context of the 'sustainability worldviews' presented in the reports. Landrum and Ohsowski (2018) described corporate sustainability worldviews as the companies' 'interpretations of what sustainability means and how it should be implemented' (Landrum & Ohsowski, 2018, p. 130). By choosing sustainability reports as the object of study, the analysis is based on the companies' selection of what is and what is not an important digitalisation topic and relevant for their own sustainability report. In this way, the reports represent the understanding of digitalisation in a sustainability context as well as the related underlying values of the reporting company (Meckenstock et al., 2016).

The second contribution of the study is to address the research gap regarding starting points for sustainable interventions. To this end, the developed theoretical framework and the empirical evidence derived from the reports are synthesized to identify 'sustainability types of digitalisation' of companies. The research questions are as follows:

1. How sustainable are the companies' digitalisation processes currently based on their sustainability reports?
   a. How is the current relationship between digitalisation and sustainable development characterised based on the presentation of digitalisation in companies' sustainability reports? and
   b. How is the current relationship between digitalisation and sustainable development characterised based on the companies' underlying sustainability worldview?
2. How are different sustainability types of digitalisation characterised?

2 | THEORETICAL BACKGROUND AND METHODOLOGICAL APPROACH

Following the definition of van Egmond and de Vries (2011), worldviews are characterised as 'a combination of a person's value orientation and his or her view on how to understand the world and the capabilities it offers, the lens through which the world is seen' (van Egmond & de Vries, 2011, p. 855). In a sustainability context, studies can be found which use the concept of worldviews to identify barriers and opportunities for sustainable development and for developing policy options: de Vries and Petersen (2009) analyse values and beliefs related to 'sustaining quality of life' and integrate the worldviews derived from them into scenarios for assessing 'risks and opportunities and the robustness of policy options' (de Vries & Petersen, 2009, p. 1006). Velasco-Herrejón et al. (2022) identify the contrasting worldviews of Indigenous populations and modernist visions of sustainability in the context of the energy transition as one source of conflicts and misunderstandings around wind energy projects in southern Mexico. Chuang et al. (2020) identify and apply three worldviews to analyse people's attitude towards sustainable mobility option as a base to address stakeholders in planning and engagement processes. The authors conclude 'that the worldviews form the bedrock of individual decisions on sustainable mobility and have a wider significance for holistic sustainability governance' (Chuang et al., 2020, p. 4034).

Landrum and Ohsowski (2018) apply the concept of worldview not on an individual level but on the corporate level when they characterize worldviews on corporate sustainability. This study is also based on this wider understanding of worldviews also described by Kassner (2010) as classifying and sorting our surrounding world and the resulting actions, partly shaped by implicit knowledge, which is not restricted to one specific individual or subject but exists above the subjective and individual level as shared knowledge (Kassner, 2010). This would also be applicable to organizations, where the shared 'worldview and culture influences and constrains the decisions and actions of an organization' (Zack, 2003, p. 67).

Depending on the companies' sustainability worldview corporate decisions and actions will differ. Or as Landrum (2018) notes, a weak sustainability worldview characterised through a business-as-usual approach with at most incremental improvements will 'not lead to sustainability and, in fact, continue to contribute to environmental degradation' (Landrum, 2018, p. 305). Moreover, Landrum (2018), referring to Senge et al. (2010), concludes that the worldview on sustainability of a company is reflected in its definitions and implementations of sustainability, and therefore 'can be determined through the rhetoric of the sustainability report' (Landrum & Ohsowski, 2018, p. 130). Based on that, she identified sustainability worldviews in corporate sustainability reports and used them to position the companies' reports within a spectrum of corporate sustainability ranging from a very weak stage to a very strong sustainability stage (see Table 2).

Thus, in the context of digital transformation, the patterns of interpretation or the worldview on how digitalisation and sustainability are related can be consulted to determine whether digital transformation contributes to unsustainable growth patterns or supports a more sustainable economy. Figure 1 illustrates the approach of this study.

For analysing the sustainability reports, a qualitative data analysis was applied, which involves the following steps (Paré, 2020, p. 11):

Searching and discovering patterns of themes in the data, describing how these patterns were identified, challenged and supported, and illustrating their relationships using narratives or visualisations in support of study findings such as conceptual propositions, causal explanations, theoretical predictions or middle-range theories.

The process of coding and analysis was based on the approach of Miles et al. (1994) (see Figure 2). The coding and analysis was performed with support of the software MAXQDA for qualitative data analysis.

The sample comprised sustainability reports from companies listed in the German DAX-Index (German Stock Index) as of 31 January 2020. The choice of sample was based on two rationales. First, DAX-Companies are large companies operating in a multinational context with a high economic and thus also sustainability significance. Second, companies are obligated by German/European law to report on sustainability impacts in a formalized manner. Companies whose business models are not based on physical products, like banks or insurance companies, were excluded. This left 20 reports in the sample, which were downloaded from the company's website.

2.1 | Reducing data

To reduce the amount of data, in a first step, text passages were identified related to digitalisation using different search terms (see Appendix A). The search terms were derived from an earlier systematic literature review conducted to identify the defining elements of industrial digitalisation in the literature (see Beier et al., 2020). The next step involved coding the data in an inductive way, using descriptive codes. The codes were then organised under broader themes or top-level codes in the code-system. These top-level codes are as follows:

- Why: Assumed Benefits/Goal of Digitalisation,
- Challenges: associated with digitalisation
- How: Approach and Participation in digital Transformation, and
- What: Digital Instruments

Two additional top-level codes were introduced for further analysis: 'observed relation' and 'digitalisation'. The top-level code 'observed relation' collected all observations concerning the relationship between sustainability and digitalisation in the reports, for example, new word creations like 'sustainable digitalisation'. The 'observed relation' top-level code was identified during the coding process based on the observation after several coding rounds. The code 'digitalisation' documented the levels of digitalisation mentioned in the documents ranging from single measures for specific processes to digital business models and pre-stages of Industry 4.0. Unlike the 'observed relation' code, the 'digitalisation' code was not derived from the coding process but used as a deductive code for further analysing potential relations between digitalisation level and sustainability. To make the assignment comprehensible, code memos were used and discussed with fellow scientists.

In addition to Miles et al. (1994), this approach is based on the textbook of Saldaña (2013), who describes coding as a method 'that

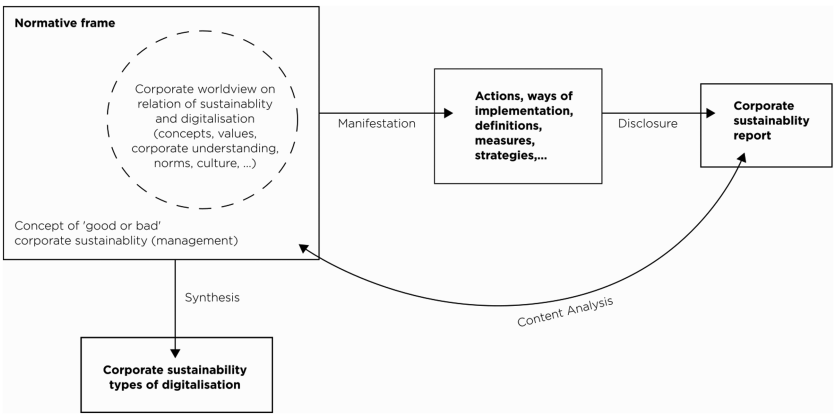

FIGURE 1 Theoretical and methodological approach of the study

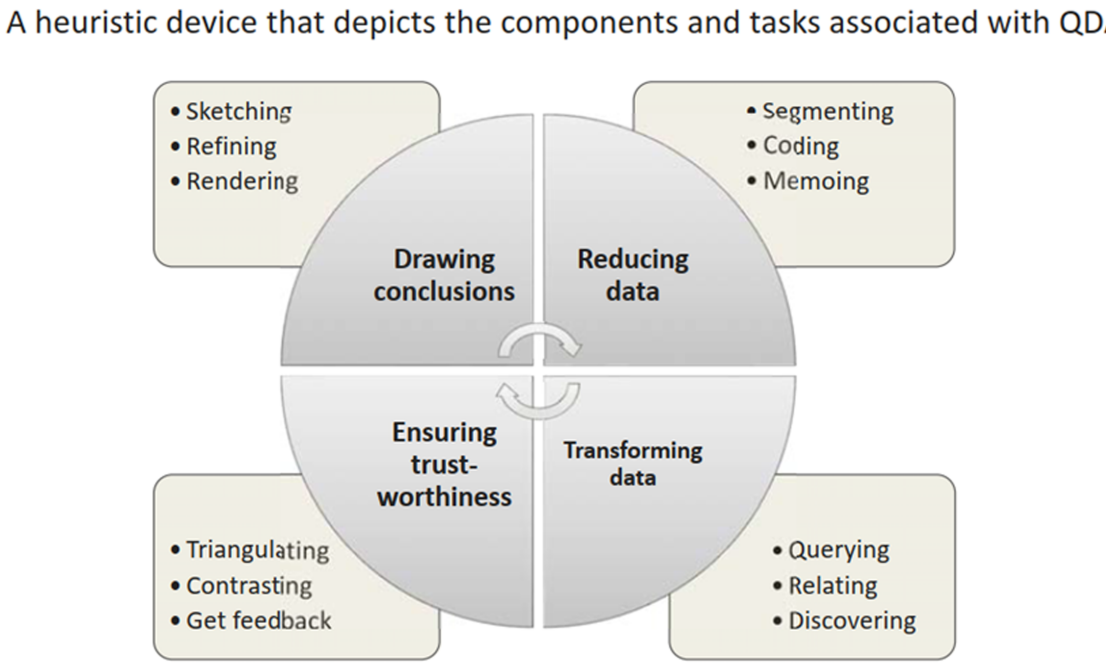

FIGURE 2 Steps of qualitative data analysis (Paré, 2020, p. 15, based on Miles et al., 1994), with permission of Marie-Hélène Paré

TABLE 1 Example of a coding operation

Text passage	Code	Top-level code
'We want to be a leader in digitalisation in our industry. This transformation process affects our jobs just as much as our products. It is therefore crucial to take our employees with us on the path to the digital future'.	'Digi as a factor of job insecurity'	Challenges

allows similarly coded data to be organized and grouped into categories or "families" because they share certain characteristics' (Saldaña, 2013, p. 9). Table 1 gives an example of the coding process.

To ensure reliability in the qualitative process, other colleagues were involved in the coding process (see also Section 2.3).

2.2 | Transforming data

The second step was the identification of underlying sustainability worldviews on digitalisation based on the code-system. Starting from the codes identified in the first round of coding in the sustainability reports, the concept of sustainability worldviews were consulted as a normative frame for the assessment. The methodology for assigning codes to a worldview was based on two steps. In a departure from Landrum and Ohsowski (2018), a qualitative approach was taken that was not based on keyword frequency. After the initial screening of reports and interviews, Landrum's approach was used as starting point to define worldviews related to sustainability and digitalisation. The resulting table (see Table 7) was then used as a reference point for mapping codes with worldviews. In this way, all codes identified in the reports were assigned to a sustainability worldview ranging from very weak to strong (see Appendix B and Figure 3). The assessment of the sustainability phase according to the criteria defined in Table 7 may deviate from the original concept of Landrum and Ohsowski (2018) in some respects, resulting in a more positive assessment. This is due to the fact that the digitalisation of industrial processes is still at an early stage, which also means that worldviews about the relationship between digitalisation and sustainability are still evolving. On the one hand, this led to the inclusion of sustainability potentials in the assessment; on the other hand, the assessment was also based on the direct comparison of companies.

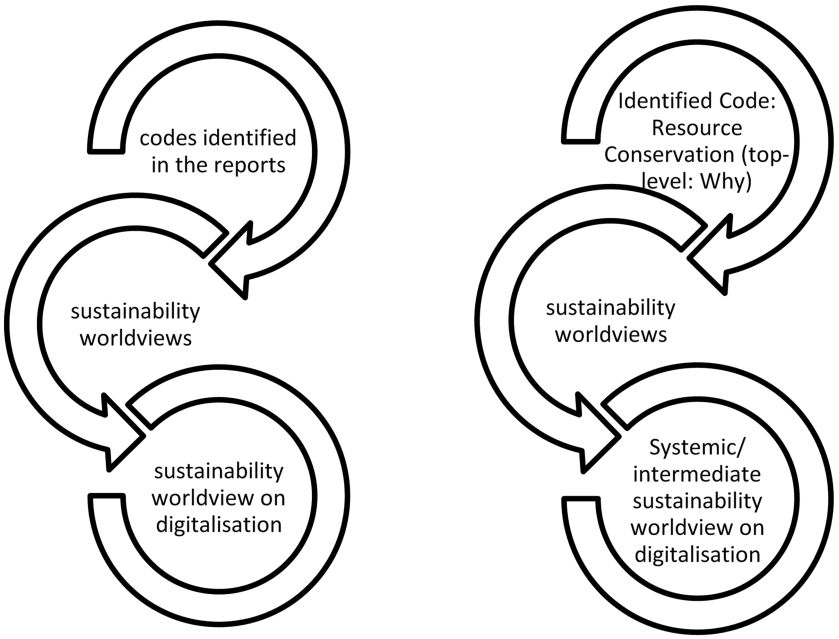

FIGURE 3 (a) Establishing worldviews on digitalisation and (b) exemplary process with identified code 'resource conservation'

TABLE 2 Corporate sustainability worldviews adapted from Landrum & Ohsowski, 2018, p. 131

	Compliance	Business-Centred	Systemic	Regenerative	Coevolutionary
Sustainability spectrum position	very weak	weak	intermediate	strong	very strong
Orientation	economic science oriented; business oriented	economic science oriented; business oriented	economic science-oriented; business-oriented	ecological science oriented; ecology oriented	ecological science oriented; ecology oriented
Understanding of sustainability	meet compliance requirements; internal firm-centric view	'do less bad'; internal firm-centric view	'do more good'; begins to look externally in defining sustainability; business is part of a larger industry and community working together toward systemic change	repair damage to systems	humans and all earth's beings are in a mutually enhancing and beneficial relationship
Relationship to natural world	to be managed and controlled; anthropocentric; resource exploitation	to be managed and controlled; anthropocentric; resource exploitation; eco-efficiency	to be managed and controlled; anthropocentric; resource exploitation; ecoefficiency	part of the natural world; operate within planetary boundaries; manage and repair	self-management as part of the natural world; participate in cooperative symbiotic relationship with the natural world
Economic growth	pursuit of production, consumption, and growth	pursuit of production, consumption, and growth	pursuit of production, consumption, and growth	Qualitative development without production, consumption, and growth; steady-state growth	no growth in production or consumption; qualitative improvements

TABLE 2 (Continued)

	Compliance	Business-Centred	Systemic	Regenerative	Coevolutionary
Sustainability concerns	externally enforced or regulated activities; defensive actions with regard to economic, environmental, or social concerns	'business case' is the motivation and measure of success; adoption and internal enforcement of activities; incremental improvements to business-as-usual; may focus on one or more realms of sustainability (economic, environmental, social)	integrates three realms of sustainability (economic, environmental, social); work with other human systems	integrates three realms of sustainability (economic, environmental, social); work with human and nonhuman systems	work in balance with other systems; contribute to flourishing of other systems
Key word (selection)	Compliance, legal, risk, regulation	Business model, competitive advantage, cost-benefit, customer, demand, efficiency, growth, market, sales, strategy	Collaboration, eco-efficiency, integration, systemic, transformation	Degrowth, holistic, planetary boundary, repair, restore	Circular, co-evolution, resilience, regenerate, ecological, ecosystem

2.3 | Ensuring reliability and trustworthiness (validity)

Different measures were taken to ensure trustworthiness. In several coding rounds, codes were refined, summarized under subtopics and delimited from each other. Criteria for distinction, especially for assigning the codes to different sustainability worldviews, were noted in memos to ensure comprehensibility. Additionally, triangulation was used to ensure the validity of results. Patton (1999) differentiates between four types of triangulation: methods, data sources, analyst and theory/perspective triangulation. For method and data source triangulation, another data source was introduced. This source consisted of 12 interviews conducted in the context of a master thesis. The purpose of this thesis was to get insights on the topic of digitalisation and sustainability by interviewing sustainability managers of German Companies (see Appendix C for an excerpt from the interview guide used). The sample was not identical to the sample of this report but only interviews from representatives of companies with more than 5000 employees were included. Only two additional subcodes were introduced based on interviews. For analyst triangulation, the code-system and underlying theoretical assumptions were discussed with fellow researchers and parts of reports as well as four complete reports were coded by three additional people. This resulted in different changes in the code-system: A strong or regenerative worldview in several categories was added and several additional coding rounds were performed. For reasons of theory/perspective triangulation, different approaches to sustainability worldviews were included (see Section 2). The reliability of the qualitative data analysis approach was ensured by involving research colleagues in all steps of the process. This was done, as described above, through partial coding of the reports by three colleagues, including the assignment of top-level codes. In particular, the analysis steps of applying the concept of worldviews to digitalisation (see Table 2) and assigning codes to worldviews were discussed with additional research colleagues. Memos as well as the 'logbook' in MAXQDA were used to document important moments in the decision-making process and to serve as a basis for later discussions.

2.4 | Drawing conclusion

For the purpose of identifying sustainability types of digitalisation, colours were assigned to the different worldviews in all categories. Based on the colour assignment, the Visual 'document portrait' was created in MAXQDA. The 'document portrait' is a visualization based on the assigned code colours of the coded segments in the document, where frequency of codes as well as the size of the coded segment act as the weighing factor. The code-matrix-browser was used to search for and compare the frequency of specific codes and combinations of them. The identified types are characterised by their dominating worldviews (>50%) in the top-level codes 'Assumed benefits (Why)', 'Challenges', 'Approach and Participation in digital Transformation (How)' and 'Digital instruments (What)', as well as by qualitative observations.

3 | RESULTS

Research Question 1 aims to assess the current sustainability of digitalisation processes, based on (a) the presentation of digitalisation

in companies' sustainability reports and (b) the underlying sustainability worldview. To answer the first part of the question, the general importance of digitalisation in sustainability reports is examined based on the frequency of mention and supplemented by qualitative observations on the depicted relationship between sustainability and digitalisation. The second part consists of identifying the associated sustainability worldviews on digitalisation.

3.1 | RQ 1a: How much digitalisation is included in sustainability reports?

The frequency with which digitalisation is mentioned in the reports gives an initial indication of the importance of digitalisation in the context of sustainability. Seven groups can be distinguished by a difference of more than 3% fewer mentions of digitalisation compared with the following group (see Table 3). In the last group, only one company stands out with 139 mentions of digitalisation in the report, which might indicate a high importance of the topic. At the beginning of the table, in the reports of four companies, the topic of digitalisation appears almost not at all (five to nine mentions), which could indicate a very low relevance from the companies' point of view.

TABLE 3 Classification of reports based on number of digitalisation mentions

Number of digitalisation codes	% Digi Codes	Group
5	3.6	Group 1 (Construction Materials I.; Conveying Technology; 2x Pharmaceuticals/Medical Technology)
7	5.0	
9	6.5	
9	6.5	
13	9.4	Group 2 (Mechanical Engineering/ Conveyor Technology; Pharmaceuticals/Medical Technology; Semiconductor/ Electrical Engineering; Consumer Goods I.)
14	10.1	
15	10.8	
17	12.2	
26	18.7	Group 3 (2x Automotive/Automotive Supplier; Industrial Complement; Consumer Goods I.)
27	19.4	
29	20.9	
32	23.0	
40	28.8	Group 4 (Automotive/Automotive Supplier; Chemical I.; Aviation I.; Apparel I.)
42	30.2	
44	31.7	
46	33.1	
51	36.7	Group 5 (Pharmaceuticals/Medical Technology)
67	48.2	Group 6 (Telecommunications, Automotive/Automotive Supplier)
67	48.2	
139	100.0	Group 7 (Automotive/Automotive Supplier

3.2 | RQ 1a: Code 'observed relation': Digitalisation for/with and near sustainability

In all reports, statements can be found suggesting a relationship between or a proximity of sustainability and digitalisation, for example: 'we also understand the importance of digitalisation, financing, and public-private partnerships for sustainable development[1]' (Industrial Complement[2]). In 13 out of 20 reports, companies clearly state a positive relationship between digitalisation and sustainability, but often the reasons for this assumption stay vague or the impression is given that digitalisation can increase sustainability by default: 'With our technologies, we connect the real world with the digital world. In this way, we help to use the possibilities of digitalisation for sustainable development'. (Semiconductor/Electrical Engineering) and 'The production sites and processes for our Laundry & Home Care business unit are digitally interconnected worldwide and all information is collected centrally in real time. Digitalisation thus serves as a driver for sustainability' (Consumer Goods Industry).

Another strategy, found in seven reports, to establish a coherence between sustainability and digitalisation is by creating word compositions like 'sustainable digitalisation', 'digital ecosystem', 'responsible digitalisation' or 'ethical digital health company'.

Where no direct link is established related to the content, often a proximity between mentions of digitalisation and sustainability can be found in the text, for example, 'our well-stocked innovation pipeline, which we have geared even more closely to sustainable solutions, includes seeds and traits, chemical and biological crop protection, and digital and regionally tailored products and solutions' (Chemical Industry). The corresponding code 'stands next to/with sustainability' is the second most used code and appears in 17 out of 20 reports.

The next paragraph contains the results relating to the second part of RQ1, which looks at the statements found in the reports and their underlying sustainability worldview. The paragraph is structured along the top-level codes 'Assumed benefits (Why)', 'Challenges', 'Approach and Participation in digital Transformation (How)' and 'Digital instruments (What)'.

3.3 | RQ1b: Assumed benefits of digitalisation: Meeting customer demands faster, cheaper and more efficiently?

Coded text passages suggest the main assumed benefit of digitalisation in the analysed sustainability reports and interviews, is

[1]All quotes from the sustainability reports are translated from German.

[2]Since the purpose of this study is not to evaluate individual companies, the name of the company is replaced by the company's sector in direct quotes.

business-centred (weak sustainability worldview). Two major assumed benefits can be identified: to remain competitive and the optimization of processes.

Digitalisation is seen as a means to meet customer demands. With 138 text segments, 'Satisfying customer demands' is the most frequently assigned code throughout 17 reports ($n = 20$) and five interviews ($n = 12$). As a company in the chemical industry reported, 'to achieve our goals and be the leading company in the chemical industry for our customers, we are strengthening our innovation and our performance as a leading chemical producer and operator of plants. We use digital technologies and data to create additional value for us and our customers'.

The second main assumed benefit can be summarized under the topic 'optimisation'. Digitalisation is framed as a tool to optimise existing processes and to improve efficiency and speed, while also reducing costs. One typical text example is 'By improving our digital capabilities across the value chain, we can not only connect with our consumers, but also become faster, better, and more efficient in all areas of our organization. We continue to make good progress with various digital accelerators' (Apparel industry). As the example illustrates, the codes 'efficiency' and 'be faster' are related in some of the documents (16 overlaps in seven reports and three interviews).

In all 20 reports and seven interviews, assumed benefits pointing to a systemic worldview or intermediate sustainability worldview can be identified. One central topic appearing in 16 reports and three interviews is resource saving and resource efficiency. Examples range from specific applications such as the changeover from paper invoices to digital invoices, to business models like digital networks combining different forms of mobility with the aim to use space and energy in a more efficient way, to the production processes themselves. Only in the minority of examples is the resource saving quantified: 'In 2018, [company name] already succeeded in producing gas turbine blades exclusively based on AM [Advanced Manufacturing] technology. As a result, around two-thirds fewer resources are required in the production process, one-third of greenhouse gas emissions can be saved, and throughput time can be halved compared with normal production' (Industrial Complement Company). It should be noted that a strict interpretation and application of Landrum and Ohsowski's (2018) concept would likely define resource savings as driven primarily by corporate financial interests, indicating a weak sustainability worldview. Because of the potential to benefit society by addressing one of the most serious problems of industrial production, and in contrast to the nonspecific version of efficiency described above as a tool for optimizing internal processes, I depart from the original concept here by assigning it a systemic worldview.

Another important assumed benefit of digitalisation under a systemic worldview (intermediate sustainability) is the code 'benefits for society', found in 12 reports. A benefit in the systemic sense is not only available for customers but society at large (to some extent). In most cases, companies expect benefits for society based on the usage of their products, for example, by providing digital assistance to minimise risks and improve comfort, or by deploying digital products to cut down emissions. A typical example combining those claims is provided by an automotive company: 'in addition to individual convenience for our customers, our aim is to increase efficiency in road traffic, firstly to reduce parking pressure and congestion, secondly to support compliance with upper limits for immissions (air quality, noise) and emissions (CO_2), and thirdly to reclaim urban space for residents' (Automotive/Automotive Supplier).

A statement frequently made is that digitalisation 'solves a problem' or is a solution. This appears in 14 reports and one interview within the business-centred (weak sustainability worldview) as well as the systemic (intermediate sustainability) worldview. Although the target group of digital solutions differ between the business-centred worldview (customers) and systemic worldview (society), the usage is in both cases often similar: rhetorical without giving a closer characterisation of the specific solution. For example, a company from the chemical industry wrote, 'we aim to strengthen our position as an integrated supplier of crop protection, seeds and digital solutions'.

Creating transparency and improving communication and knowledge exchange is another motivation behind digitalisation. With a business-centred worldview, this transparency encompasses the digital support of collecting and analysing information about production processes to optimise them to, for example, avoid downtimes, support risk assessment and improve quality. The topic of business transparency can be found in 11 reports and eight interviews with a total of 30 coded text passages.

With a systemic motivation, digitally-supported transparency is mainly used for sustainability purposes. One frequently mentioned topic in this regard is the transparency of supply chains: 'In 2020, we will continue to expand the use of the Group-wide online platform for supplier management. In this way, we will continue to systematically exploit the opportunities offered by digitalisation to ensure transparency and sustainability in the supply chain' (Construction Materials Industry).

3.4 | RQ 1b: Challenges of digital transformation: Ethical questions and future work

Companies do report on challenges for sustainability due to digitalisation. The most prominent challenge, with 64 coded text passages throughout 18 reports and two interviews, is 'data protection and cybersecurity'. This code represents a typical compliance (very weak sustainability worldview) risk.

One major topic identified in the challenges category is the future of work. In the context of a business-centred (weak sustainability) worldview, the challenge is characterised by a feared lack of (digitally) skilled specialists. In the context of a systemic (intermediate sustainability) view on the future of work, the companies focus on employees and present their efforts to (re)train them and preserve their jobs in the era of digital transformation (see Table 4). Apart from the challenges of job losses and qualifications, other topics related to the future of work include the acceptance of new technology in the workplace and health risks like higher stress levels due to digitalisation.

TABLE 4 Examples for challenge of 'Future of work' with business-centred (weak sustainability) and systemic (intermediate sustainability) worldview

Sustainability worldviews on challenges	Future of work
Business centred	'In order to be able to fill positions with professionally experienced and creative IT and digitalisation experts in the fields of the future, we are stepping up our efforts with the formation of a new recruiting unit' (Automotive/Automotive Supplier). (Overall: 27 coded text passages, 11 reports and 2 interviews)
Systemic	Long-term prospects for its employees are of central importance to the *Company*. Particularly in volatile times of digitalisation and technological change, we want to offer our employees reliable working conditions and enable continuous learning. Increasing competition with leading technology companies, a global shortage of technically qualified specialists, and demographic change present the company with major challenges (Automotive/Automotive Supplier). (Overall: 27 coded text passages, 11 reports and 4 interviews)

Despite the existence of an established scientific and societal discourse on ethical questions related to digital technologies, particularly Artificial Intelligence, this issue is only discussed in six out of 20 reports. The way in which such questions are approached also differs across reports, ranging from a more internal and reactive discussion to avoid compliance risk to a more participative and proactive approach including external stakeholders (see Table 5 and next section).

Most challenges addressed by the companies belong to the social dimension. Environmental concerns are only presented in two reports and only on a very general and abstract level. For example, a company from the semiconductor/electrical engineering industry reported, 'globalization, the growth of the world's population and the increasing use of digital technologies are putting a strain on available resources and call for sustainable, more ecological management and socially responsible action'.

In one report a partly regenerative (strong) sustainability view can be identified. This worldview is characterised by the identification of challenges beyond the company's own business model, in this case the challenges for democracy in the digital age and the individual digital competence to deal with these kinds of challenges.

3.5 | RQ 1b: How digital transformation is approached and who participates in the process

With a compliance or very weak sustainability worldview, the approach is to externalise change by buying or collaborating with other companies, such as start-ups or to primarily involve top management leaving no room for employees to participate in the transformation. A company from the pharmaceuticals/medical technology industry for instance reported, 'numerous initiatives and approaches emerged from the 2019 Leadership Conference to promote innovation, anchor digitalisation in people's minds as well, and further improve collaboration'. This compliance approach to digital transformation can be found in 12 reports with overall 52 coded text passages.

The focus is then widened with a business-centred (weak sustainability) worldview and a more cooperative approach, where preparing and training employees is an important topic (it appears in 66 coded text passages in 15 reports and two interviews). The measures presented for the qualification of employees range from the application of individual programmes to long-term qualification strategies: 'the e-learning library currently comprises more than 7,000 courses and, in addition to specific content for individual occupational groups and specialist areas, also offers overarching topics for a broad target group in the company. These include business know-how or the "Digital Transformation Collection," which helps our employees prepare for the workplace 2.0' (Pharmaceuticals/Medical Technology Industry).

Also, in the business-centred worldview, early approaches to include society in the digital transformation can be identified. With this worldview, the involvement is mostly unidirectional, for instance giving lectures or handing out teaching materials without the possibility of mutual exchange.

In 16 reports and two interviews, with a total of 58 coded text passages, the involvement of employees and civil society moves into focus, pointing to a systemic worldview (intermediate sustainability). This involvement is characterised through mutual exchange. In one case a company from the chemical industry reported, 'with the introduction of a digital talent network, [company name] supports its employees in actively shaping the digital transformation. The aim of this online network is to promote exchange on digital projects and ideas across the company and to improve collaboration across teams and units'. In five reports and one interview (22 codes), the participatory approach also opens up to other societal groups. For example, one company from the automotive/automotive supplier industry reported exploring ethical questions about the application of artificial intelligence in a newly established consortium with partners from business, politics and science.

Moreover, two initiatives can be found where companies not only involve societal actors but also cooperate and consult with them to a certain degree. One example is concerned with ethical questions regarding AI: 'in 2018, under the leadership of Group Compliance Management, we adopted guidelines for an ethical approach to artificial intelligence (AI). They clarify how we at [company name] want to deal responsibly with AI and develop our AI-based products and services in the future. We do not claim to have already found universally valid rules for dealing responsibly with AI. Rather, we want to continuously develop the guidelines in exchange with our employees and external stakeholders and firmly anchor them in the company'. (Telecommunication Company). Table 5 summarizes the different sustainability worldviews regarding the category 'Approach and Participation in the digital Transformation' based on the analysed reports.

TABLE 5 Examples of worldviews on 'Approach and Participation in the digital Transformation'

Sustainability worldviews on 'Approach and Participation in the digital Transformation'	Example
Compliance/very weak sustainability worldview	'One focus of the work of this international panel of experts in 2019 was digital ethics: If we are to develop new business models based on artificial intelligence and Big Data, then we need clear guidelines - for example, on how to handle patient data' (no involvement of stakeholders, compliance issue) (52 codes, 12 reports)
Business-Centred/weak sustainability worldview	'From November 2018 to March 2019, we held internal workshops on artificial intelligence (AI) ethics. The aim was to establish an ethical basis for all projects in the field of machine learning (AML) and AI projects in our company; furthermore, to identify potential (bio)ethical issues arising from these projects' (involvement of selected employees) (84 codes, 17 reports, 2 interviews)
Systemic/intermediate sustainability worldview	'[…] ethical applications of artificial intelligence in Europe in collaboration with partners from business, politics and science' (involvement of societal stakeholders) (58 codes, 16 reports, 2 interviews)
Regenerative/strong sustainability worldview	'We do not claim to have already found universally valid rules for dealing responsibly with AI. Rather, we want to continuously develop the guidelines in exchange with our employees and external stakeholders and firmly anchor them in the company' (ongoing process, consultation of external stakeholders) (13 codes, 5 reports)

3.6 | RQ 1b: Digital instruments mentioned in the sustainability reports—Data collection and interaction with employees

Only few digital instruments are used explicitly for compliance reasons (weak sustainability; 19 coded passages in nine reports and two interviews) and mainly for the purpose of risk management.

While instruments with a business-centred/economic aim account for 113 coded text passages throughout 18 reports and 10 interviews, systemic instruments supporting the social or environmental dimension of sustainability (management) account for 142 coded text passages in 18 reports and nine interviews. In eight reports and three interviews, planned or implemented instruments appear which could be described as 'at the brink' of a regenerative (strong sustainability) worldview.

'Data collection' and 'interaction with employees' both can be identified as two overarching topics appearing as subcodes in the business-centred, the systemic, and the regenerative worldview of the top-level code 'Digital Instruments (What)'.

With a business-centred worldview, digitally supported data collection and processing serves foremost to support an information base on which business decisions can be taken and/or business processes like logistics can be optimised. Some companies also use digital support to collect environmental and social information or plan to do so. Within a systemic worldview, the collecting and especially the analysis of environmental data is in focus. In this context, digitally-supported data collection and analysis is not only used for business decisions but also to improve sustainability management, mainly by realising efficiency gains. Within a regenerative (strong sustainability) worldview, the digital instruments are implemented to advance sustainability management by addressing problems that could not be solved before (see Table 6).

By assigning different levels of sustainability to internal company processes, this delineation approach differs from a strict application of Landrum's original concept, which draws the line between internal (business-oriented) and external (systemic) measures. I argue that although the application is internal in all cases, the different reasons for applying digital tools (focused only on business reasons, focus also on social and/or environmental reasons, and use of digital enterprises to improve sustainability management in ways not previously possible) justify the assignment to different worldviews.

3.6.1 | Other instruments with a systemic (intermediate sustainability) worldview: Collaboration and resource efficiency

In 10 reports and one interview, digital instruments (18 codes) are deployed to support internal communication and collaboration, for example, via social intranet or feedback tools. In two reports and seven interviews (10 codes), the digital support of external cooperation is discussed. However, in all but one case, where a company established a global whistle-blower system, this relates to future plans and have not been realised yet.

Within the environmental dimension, digital instruments are mainly used for data collection and processing (see above). Instruments for resource efficiency and circular economy play a minor role (nine codes, six reports). These instruments differ in complexity, including motivational games for employees to reduce plastic waste,

TABLE 6 Examples of instruments for 'Data Collection and Analysis' for business, sustainability management and sustainability performance

Sustainability worldviews on 'Digital Instruments'	Instruments for data collection and analysis
Business centred	'The use of AI also makes sense for information processing: Algorithms can search and sort highly complex data volumes quickly, efficiently and continuously. This enables, for example, precise market forecasts that include a large number of variables' (Automotive/Automotive Supplier). (Overall: 41 coded text passages, 10 reports and 10 interviews)
Systemic	'A key component of energy management in Regensburg is the energy data management system. From compressed air to chillers to gas plants: the system provides all the relevant key energy figures. Around 850 metering points are used for this purpose. Automated monitoring ensures that energy requirements are monitored transparently at all times, thus creating the basis for continuous optimization of processes and systems. Building management systems and network analysis also play an important role. The interaction of the three systems means that and monitors almost every single piece of equipment. Success in Regensburg is thus inextricably linked to the high level of degree of digitalisation' (Automotive/Automotive Supplier). (Overall: 25 coded text passages, 11 reports and 4 interviews).
Regenerative-Systemic	Use of decentralized energy systems 'We are expanding the use of decentralized energy systems at our own sites by combining combined heat and power plants, solar panels, wind turbines, small gas turbines, intelligent energy management systems and energy storage solutions. In the long term, we aim to generate 10% of our electricity requirements via decentralized energy systems at our sites' (Industrial Complement). (Overall: 16 coded text passages, 6 reports and 2 interview)

platforms for 'visualizing, reviewing and analysing resource consumption', and the automation of whole building systems to reduce energy consumption. Digitalisation is also used for waste management. One company from the industrial complement industry reports, 'digital platform models, for example [company name] own machine and material platform, also help to communicate unused resources between the individual business units and thus reduce the consumption of new raw materials. We generally attach great value to high transparency and good communication, as these are crucial steps for a functioning circular economy'.

3.7 | RQ 1b: Characterisation of the identified sustainability worldviews on digitalisation

Table 7 provides an overview on the identified sustainability worldviews on digitalisation and their characteristic features.

At the lower end, a very weak sustainability or compliance worldview on digitalisation is characterised by a lack of awareness or recognition of the relevance of digitalisation for corporate sustainability management. The benefits of digitalisation are seen primarily in the stabilisation of the business-as-usual from a sustainability perspective and the minimisation of risks, for example, when digital processes are used to document and analyse compliance-incidents. Stakeholders such as employees are not involved in the digital transformation, instead, ideas are negotiated at top management level and decisions are made top-down and presented to employees. Lack of digital competencies is often compensated by external support, for example by buying start-ups. The identified challenges of digitalisation in the sustainability context mostly relate to compliance risks for the company, for example, data security issues. Digital instruments are mainly used to avoid compliance risks in a defensive way, for example, by introducing online-tools as part of a risk management process. Based on the assigned codes, the last worldview on the upper end of the spectrum is that of a strong sustainability (regenerative) worldview on digitalisation. This regenerative worldview is characterised by an emphasis on sustainability, meaning that digital strategies and instruments are only implemented when risks to sustainable development are addressed and resolved. This also means that the economic dimension of sustainable development is not the primary focus. The digital transformation of companies is understood as a process that also affects stakeholders, who must be involved in the transformation and whose concerns must be considered. Following this participatory approach, the challenges of digitalisation which are considered by companies are not only business-related, but also include societal and environmental concerns such as resource intensity of digital technologies. Digital instruments are used to support a company's sustainability management, for example, by collecting, integrating and analysing data on the sustainability impacts of the company's production. Between these poles at both ends of the spectrum, the weak or business-centred worldview considers the sustainability gains of digitalisation only if they are also profitable, while the middle sustainability or systemic worldview also considers the environmental and societal benefits and challenges.

TABLE 7 Sustainability worldviews on digitalisation in industry (see also Landrum, 2018, and Landrum & Ohsowski, 2018)

	Compliance	Business-centred	Systemic	Regenerative	Coevolutionary
Digital transformation and sustainability	very weak	weak	intermediate	strong	very strong
Orientation/general view on digitalisation and sustainability	*Digital or Sustainable* Digital and Sustainable Mgmt. as two different independent 'tasks'	*Digital and Sustainable* Awareness for Win/win overlaps of Digital and Sustainable Mgmt.	*Digital for Sustainability* Awareness of chances but also of risks for society/ environment	*Sustainable Digitalisation* Only where risks for sustainable development are addressed and resolved Involve stakeholder for risk assessment and handling	*Digitalised Sustainability* Only for the purpose of sustainable development
Why: Assumed benefits of digitalisation in susta. context	Stabilisation of business- as-usual, minimising mistakes/risks	D. for optimising business processes, making business more competitive, satisfying customer demands	D. benefits society and environment and not only economic dimension of sustainability	D. only applied when benefit for the natural environment and society, no preference of economic dimension	D. only for sustainable development of economy
How: Approach and Participation	Addressing topics with high business relevance and cooperation just on a technical level, business to business, no employee involvement, top-down	Topics with societal relevance (e.g. qualification for employees) but cooperation only on an information/ learning basis without feedback	Topics with societal relevance and cooperation with a wider stakeholder-group, bringing in different perspectives	Participation of stakeholders in transformation processes and in establishing framework conditions	Transdisciplinary development of digitalisation
Challenges of Digitalisation in susta. context	Compliance challenges, e.g. Cybersecurity	Challenges concerning business and competitiveness	Thinking about challenges concerning stakeholders like employees closely related to the business model	Thinking about challenges in society and nature beyond the business model and how to tackle them proactively	Avoidance of unintentional side-effects by transdisciplinary approach; precautionary principle
Digital Instruments in susta. context	For risk management and compliance	For better business decisions, improved processes, economic	Including social and environmental dimension of sustainability For environmental management, transparency and support of employees, Win/Win-Situations, optimisation	For including sustainability in core business operations, no focus on economic dimension, (sustainable) transform and not only optimisation	Holistic view on benefits of technology application, e.g. only green IT for sustainability, no 'self-purpose' of digital instruments

3.8 | Synthesis RQ1: How sustainable are the companies' digitalisation processes currently based on their sustainability reports?

The overall picture (see Figure 4) shows that the worldviews from both ends of the spectrum—a very weak sustainability worldview (red, 11% $n = 1580$) and a strong sustainability worldview (light green, 3%, $n = 1580$)—are both relatively underrepresented in the sustainability reports. Most reports contains worldviews in the central spectrum ranging between a weak (yellow, 45%, $n = 1580$) and intermediate (dark green, 41%, $n = 1580$) sustainability worldview. According to the assigned codes, the

FIGURE 4 Document portrait of sustainability worldviews on digitalisation of DAX 30 companies (four companies excluded due to lack of codes)

average digitalisation level found in the company's sustainability reports is located among the middle level, relating to production processes or strategies (light blue, 45% of $n = 764$ [only digitalisation code]). In 16 of 20 reports, text passages can be found dealing with digital business models and pre-stages of Industry 4.0 (dark blue, 21%, $n = 764$). The colour purple stands for 'digitalisation only mentioned' (15%, $n = 764$), while light pink represents the 'digitalisation of single measures/products (19%, $n = 764$). The brown colour was assigned to the 'observed relation' code, characterising those text passages where a relation between digitalisation and sustainability is (rhetorically) established without giving further explanation.

3.9 | RQ 2: How are different sustainability types of digitalisation characterised?

The first identification of sustainability types of digitalisation is based on the importance of digitalisation to companies as measured by the frequency of digitalisation codes, the dominant worldview as illustrated by the visualizations (sum of very weak and weak sustainability worldviews versus sum of intermediate and strong sustainability worldviews), and whether the top-level codes Instruments (What), Assumed Benefits (Why), Challenges and, Approaches and Participation (How) are equally addressed with a dominant intermediate or even strong sustainability worldview, indicating a more holistic approach to digitalisation. The different levels of digitalisation (codes ranging from 'only mentioned' to 'prestages of Industry 4.0') were also consulted as a distinguishing criterion for the groups, but the results show that no homogeneous group based on similar levels of digitalisation can be established. These initial distinguishing criteria are complemented by further qualitative commonalities in the reports, for example, the proactive approach in certain fields of digitalisation as shown by the 'Pioneers'. Following this approach, five groups can be distinguished: 1. Pioneer, 2. Medium Bad, 3. Indecisive, 4. Unsustainable and 5. Laggards.

3.9.1 | Pioneer company—On the way of aligning transformations?

There are two companies in the DAX sample that can be described as 'pioneers' in terms of their sustainability worldviews on digitalisation. The first company comes close to being a role model for aligning progressive sustainability worldviews and digitalisation. Even this company is strongly anchored in the systemic (intermediate) worldview (see Figure 5), which is consistent with the findings of Landrum (2018) where the companies considered as sustainability leaders were also anchored in the systemic sustainability worldview (Landrum, 2018). In the company's report, digitalisation is an important topic with 67 coded text passages (Table 3). From a sustainability perspective, the balance is comparably positive for all top-level codes of digital instruments (What), the assumed benefits of digitalisation (Why), challenges mentioned and the approach and participation (How). Based on the more quantitative criteria, the second company is more on the way to becoming a pioneer compared to the first company and is not quite there yet. Digitalisation appears with 26 coded text passages. Regarding the proportion of very weak and weak versus intermediate and strong sustainability worldviews, the second company performs slightly worse overall and in the top-level codes. The unifying qualitative element of both companies is the proactive approach to a particular area of digitalisation and sustainability. For the first company, this approach is characterised by dedicating its own resources to the field of data-ethics and democracy challenges to proactively and participative defining normative standards together with external and internal

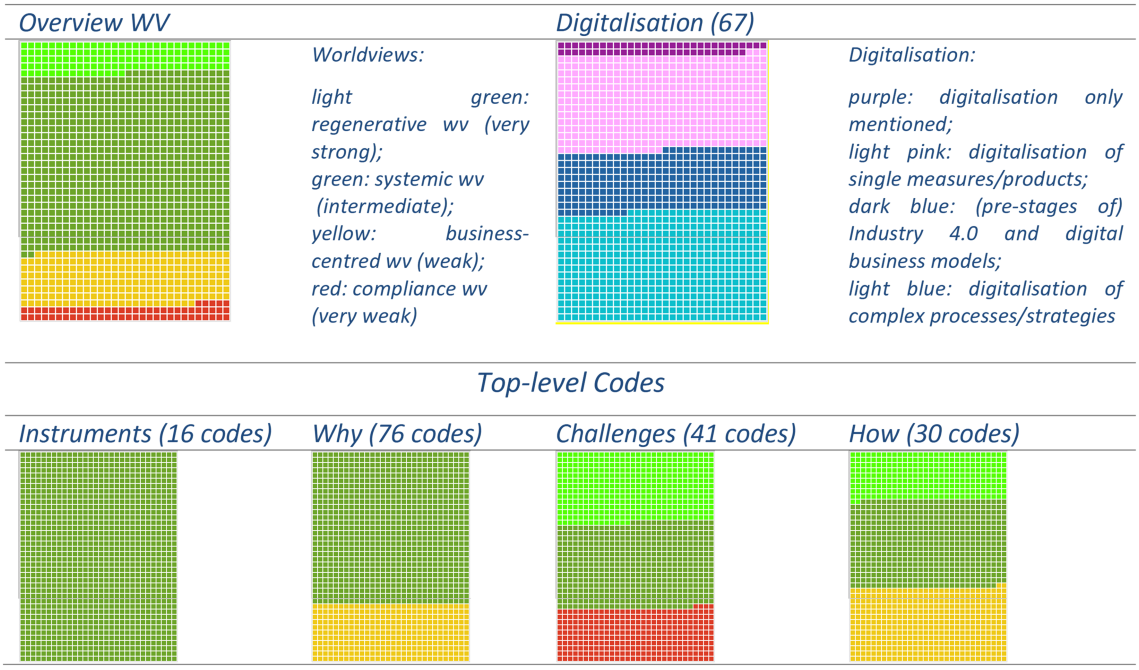

FIGURE 5 Exemplary document portrait of pioneer company

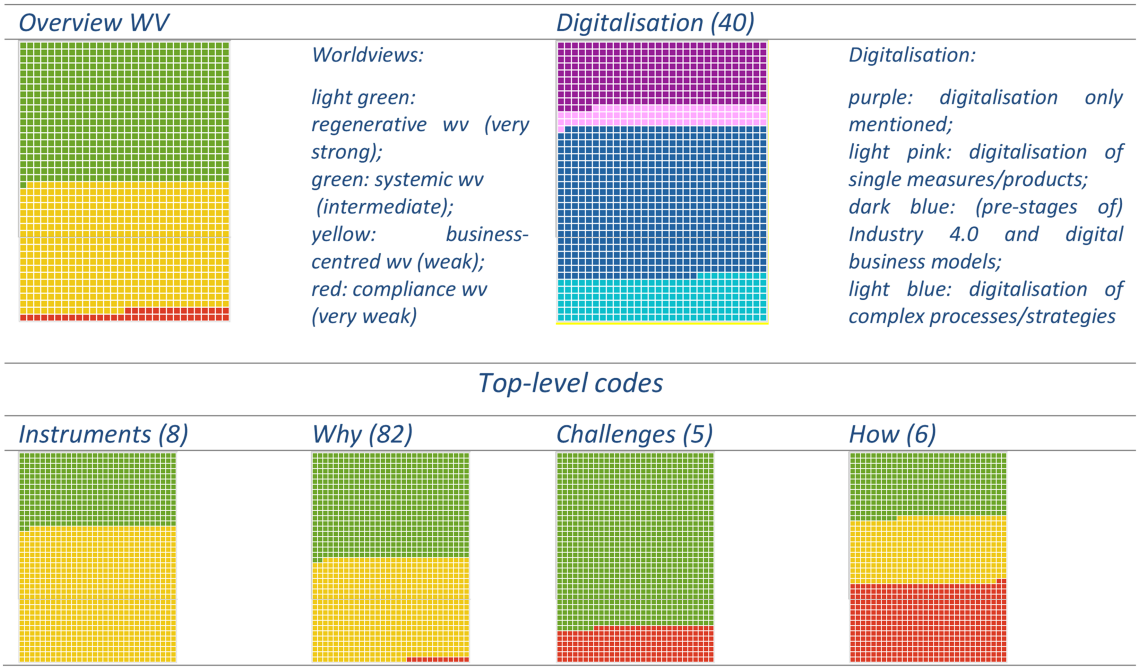

FIGURE 6 Exemplary document portraits of medium bad

stakeholders. The second company uses digitalisation to support its sustainability management by having created a platform that digitally connects different company sites and enables environmental data such as energy consumption to be collected, integrated and analysed, and optimisation potential to be identified.

3.9.2 | Medium bad: Room but also potential for improvement

For the three Medium Bad companies, a business-oriented (weak sustainability) and a systemic (intermediate sustainability) worldview

dominate regarding digitalisation in a ratio of around 60:40%. This picture is mirrored for most top-level codes, which have at most one top-level category dominated by a significantly weaker sustainability worldview. Figure 6 shows an exemplary document portrait for the 'medium bad' companies. The number of text passages dealing with digitalisation varies between the companies in this group. While two of the companies address digitalisation with 32 and 40 digitalisation codes, digitalisation is not (yet) a main focus for the third company with 17 coded text passages (Table 3). The assumed benefit of 'satisfying customer demands' is the most frequently occurring code in the respective top-level category 'Assumed Benefits (Why)' in all reports, which supports the impression that the worldview on digitalisation revolves around the economic dimension of sustainability for the companies in this group. However, another unifying element of this group is that starting points for implementing and spreading a more sustainable worldview can be identified, such as supporting the circular economy through digital technologies, existing small bottom-up initiatives by employees in the digital context that could support a more participatory approach in the long term or business-models in development which could contribute to more sustainable smart cities.

3.9.3 | Indecisive—No equal relevance in all top-level codes

For this group of three companies, the dominating sustainability worldview on digitalisation is overall systemic (intermediate sustainability) with a share of 50 up to 60%. The main characteristic is an unequal distribution among top-level codes in terms of frequency of codes but also in terms of the dominating worldview. In all cases, there are significantly fewer text passages in the report that refer to the top-level code 'Challenges' and 'Approaches and Participation (How)' than to the other top-level codes. In addition, the dominating worldview is weak or very weak with a share of at least 75% in all examples, while the dominating worldview related to the other top-level codes 'Assumed Benefits' and 'Digital Instruments' is a systemic one (intermediate sustainability). Figure 7 shows an exemplary document portrait for the 'indecisive' companies. With an average of 18 digitalisation codes, digitalisation is not yet a focal topic in the companies in this group. The presence of starting points for the alignment of sustainability and digitalisation while at the same time neglecting the challenges associated with digital transformation and the lack of an approach on how digitalisation can be implemented in a sustainable (participatory) manner leads to the impression of indecisiveness that gives this group its name. In this context, it is also fitting that the frequency of statements suggesting a positive relationship or proximity of sustainability and digitalisation without explaining this relationship in more detail (see Section 3.2) is higher than for the other groups.

3.9.4 | Unsustainable—Digitalised business-as-usual

The group of 'Unsustainable' is the largest in the DAX-sample and consists of seven companies. Digitalisation appears with over 40 coded text-passages in six of the reports and 29 codes in the seventh report (see also Table 3). At least in three out of four top-level codes, a business-centred (weak sustainability) worldview on digitalisation is predominant. Figure 8 shows an exemplary document portrait for the 'unsustainable' companies. Across all top-level codes,

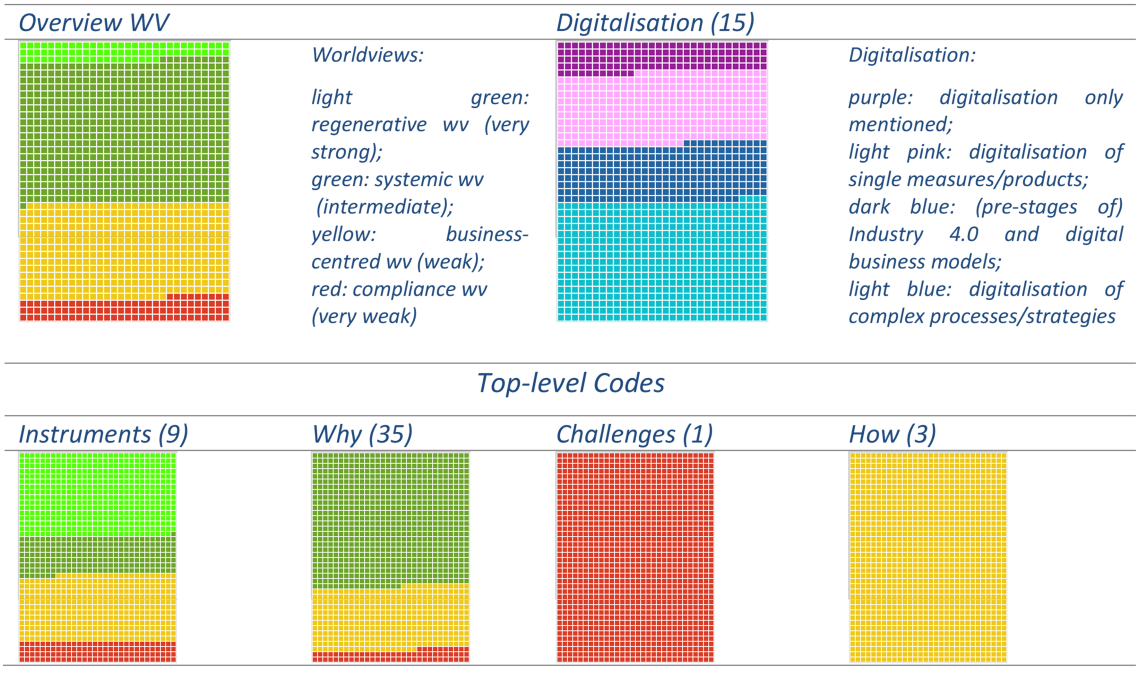

FIGURE 7 Exemplary document portraits of indecisive

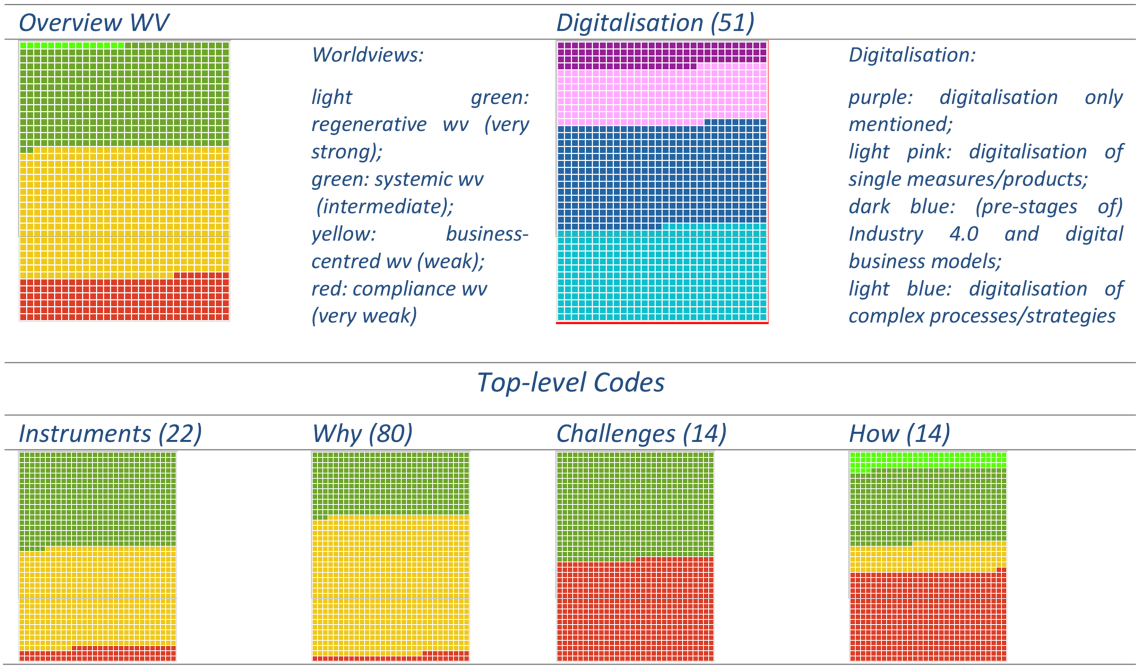

FIGURE 8 Exemplary document portraits of unsustainable

text passages with a compliance or very weak sustainability worldview can be identified, averaging 16 codes per report (other groups: averaging 5 to 7). Similar to the other groups, most coded text passages deal with the assumed benefits of digitalisation, but unlike the other groups, the business-centred worldview also predominates in this top-level code. In addition, satisfying customer-demands and creating new business models are the most frequent applied codes under the top-level code 'Assumed benefits', followed by the expectations of more efficient and less time-consuming production processes as the second frequently used codes. The picture of a purely weak sustainability view on digitalisation is contrasted by a small number of text passages (12 codes) with an underlying strong sustainability worldview in six out of seven reports. These include single measures such as a bottom-up initiative for innovation aimed at a participatory approach and data-analyses to reduce environmental impacts.

On a more qualitative note, the coded text-passages in the 'Unsustainable' group are characterised by a certain vagueness. While concrete examples of what has been done or will be done can be found in the reports of other groups, especially among the 'Pioneers', this is not often the case among the 'Unsustainable' group. Here very general, marketing-like statements predominate, such as praising the innovative strength without describing the innovation or offering a digital solution without explaining what the concrete effects of this solution are.

3.9.5 | Laggards—What is the relevance?

The unifying element of the Laggard group is the small number of codes dedicated to digitalisation in the company's sustainability reports (see also Table 3). Given that digitalisation is only a random topic at most, it is not possible to distinguish between different worldviews on a meta-level.

3.9.6 | Unusual profile—Greenwashing?

One company stood out in the sample because it could not be clearly assigned to one of the sustainability types of digitalisation. The company's overview profile was characterised by a predominant systemic (intermediate sustainability) worldview but when evaluating the various top-level codes, it became clear that this was due to the top-level code 'Assumed benefits', while all other top-level codes (Challenges, Approach and Participation and digital Instruments) consisted only of none to a maximum of three codes. The report stood out primarily because it promised sustainability benefits through using the company's products. This one-dimensional view on sustainability, also reflected in the low number of codes in all but one top-level code, could possibly indicate greenwashing.

4 | DISCUSSION

The main objective of this study was to assess whether the industrial implementation of digitalisation in its current manifestation tends to support a more sustainable economy or reinforces unsustainable growth patterns. The description of the presented relationship between digitalisation and sustainability in the sustainability reports of companies and their underlying sustainability worldviews provide results in this regard which are discussed below. In the second part,

the identified sustainability types of digitalisation are discussed as a starting point for possible sustainable interventions.

4.1 | RQ1: How sustainable are the companies' digitalisation processes currently based on their sustainability reports?

In most of the sustainability reports, digitalisation is presented as a topic with relevance for the social, ecological and economic dimensions of the companies' sustainable management. But—as described by the 'observed relation' code—this relevance is often not specified in more detail, instead, the impression that digitalisation will lead to more sustainability by default is created. This contradicts the clear mandate given by expert panels like the 'German Advisory Council on Global Change' (WBGU) to view digitalisation as a process which must be actively aligned with sustainability to avoid the acceleration of unsustainable growth patterns (WBGU, 2019).

Based on the companies' presentation of digitalisation and the underlying worldviews found in the sample, digitalisation in its current implementation is more likely to accelerate unsustainable growth patterns than support sustainable development in the DAX 30 companies.

This is particularly indicated through the worldview on assumed benefits of digitalisation (see Section 3.3), which actually reproduce unsustainable growth patterns like the focus on customer demands, while at the same time the overall participation of other societal stakeholders is not ensured by most of the companies. Additionally, the problematic combination of codes expecting efficiency gains (without further explaining what kind of efficiency), more productivity, reduced costs at a higher pace are indicating worldviews which contradict a sustainable economic development (Carroll, 1991; Dyllick & Muff, 2016; Landrum & Ohsowski, 2018; Steurer, 2001). Moreover, the pattern of 'doing the same thing but more efficiently and faster 'suggests an acceleration of unsustainable growth patterns, although the extent of the acceleration cannot be assessed in this way. Considering the correlation between a weak sustainability worldview and weak sustainability performance (Landrum, 2018), it can be concluded that this worldview on digitalisation will not lead to the necessary transformation of companies to a more sustainable economy.

Even when assumed benefits also include societal or environmental benefits (systemic worldview), this is often based on the realisation of win-win-situations like resource-efficiency and reducing costs or the distribution of the companies' own products which will only benefit society when used (like intelligent cars reducing accidents for everyone). It is highly controversial whether realising win-win situation and the identification of the 'business case of sustainability' is sufficient for a truly sustainable transformation (Dyllick & Muff, 2016).

In this context, the companies' presentation of digitalisation as 'a problem-solver' characterised by more than 50 codes in 14 documents can potentially contribute to an unsustainable development, if the adoption of resource-intensive digital technologies serves as an end in itself or in other words digital technologies are applied to solve a problem which yet has to be created ('solutionism').

The section on challenges (Section 3.4) indicates that risks for the environment such as an increased resource consumption of and for digital technologies are almost non-existent in the reports. Given that problems not acknowledged will not be tackled, this also poses a risk to the goal of aligning sustainability and digitalisation.

On the other hand, societal challenges like securing future jobs are not only frequently mentioned in the reports, but most of the companies also have taken measures and made plans to support their staff in the transformation. This is indicated by the frequency of the code of preparing and training of employees (top-level code 'How: Approach and Participation in digital transformation'). Still, only a few companies involve their employees actively by participation or cooperation in the digital transformation. This matches the impression, that digitalisation is mostly not viewed as a topic to be discussed with stakeholders with the exception of four out of 20 companies debating ethical questions with societal actors in varying degrees of participation (see Section 3.5).

The digital instruments discussed in the reports show the potential to support the sustainability management of companies (see Section 3.6). Creating transparency through digital technologies and applications by collecting data, integrating and analysing them for reasons of better environmental or social performance is one of the possibilities already used in the companies. Coming from a systemic worldview (intermediate sustainability), this means mostly identifying new efficiency potentials by monitoring and analysing production processes in a more holistic and comprehensive way. Eco-efficiency alone is not believed sufficient to realize the transformations to an economy operating within the limits set by planetary boundaries (Dyllick & Hockerts, 2002; Hauschild, 2015; Hoffrén & Apajalahti, 2009; Rockström et al., 2009). Nevertheless, a digital-supported transparency could also lead to the identification of neglected sustainability challenges when companies are willing to use technologies accordingly. This transparency does not only include internal processes but is also mentioned in the reports and interviews for managing collaborations with stakeholders. While currently, the most reported solutions are digital platforms with the purpose of sharing documents to ensure supplier compliance with regulations, the exchange of data along the supply chain could potentially be used for tackling sustainability challenges like problem-shifting along supply chains (Clarke & Boersma, 2017). Transparency along the supply chain also has the potential to support a circular economy if conditions such as early stakeholder engagement are met (Awan et al., 2021).

The digital instruments appearing in the reports also have the potential to foster employee participation. Companies have implemented social intranets or feedback tools to facilitate the exchange among employees as well as between employees and management. Again, the worldview of the purpose of these technologies, or the context in which these technologies are used, is critical to their sustainability potential. When used in an open participatory culture they can be of value for employee participation or the culture can be a hindrance to their success (Chelte et al., 1989). In all cases, the

reports do not provide details about the purposes of introducing digital communication tools or the actual impacts it has had on employees so far.

4.2 | RQ2: Characteristics of sustainability types of digitalisation—How can they be addressed?

Based on the sustainability types of digitalisation, ideas can be developed on how to support the alignment of digitalisation and sustainability by specifically addressing each type.

The Pioneers could serve as a role model, at least in the area(s) which they proactively approached. This would mean improving the visibility of company efforts, for example by best practice guides, conferences or supporting flagship initiatives together with researchers. Given that digitalisation is a complex transformation with a high likelihood of unintended side effects (for sustainable development), Renn et al. (2021) propose a systemic risk–benefit approach to policy-making that is interdisciplinary and supported by scientists, regulators, and stakeholders. The detected 'Pioneers' seem well suited to engage in such a process.

For all other types, corporate awareness of digitalisation needs to be promoted as a task to be proactively addressed and shaped by corporate sustainability managers to counteract the damaging narrative that digitalisation automatically promotes sustainability. As a first step, this can be done through an exchange between sustainability managers, digitalisation experts, policy makers and researchers to identify areas of relevance and best-practice approaches.

The 'Medium Bad' type brings a certain awareness for the linkages of sustainability and digitalisation and delivers starting points for development in all categories. These companies should be supported to develop pioneer solutions in areas of their expertise. In the group of 'Indecisive' the significance of digitalisation for certain areas is not clear. This mostly concerns the approach and participation in digital transformation and the addressed challenges. These companies might benefit from best-practice exchange with pioneer companies. Such an approach must be moderated by for example industrial associations, governmental agencies or in the context of transdisciplinary research projects because barriers of exchange such as data confidentiality must be addressed. While the 'Laggards' could possibly still be addressed by information campaigns, the 'Unsustainable' group underlines the need to additionally implement regulations to support a sustainable path of digitalisation. This relates, for example, to the ecological dimension of sustainable development, since according to the results none of the companies surveyed is ready or perhaps even willing to address the ecological challenges associated with digitalisation.

5 | CONCLUSION AND OUTLOOK

The contribution of this paper is twofold: First, the sustainability of the current companies' digitalisation processes was assessed based on their sustainability reports of 2019. For this, the relationship between digitalisation and sustainable development in sustainability reports was described and an approach to sustainability views on digitalisation was developed based on the concept of sustainability worldviews by Landrum (2018). Second, the results were analysed to define different sustainability types of digitalisation.

According to the results, the current worldview on digitalisation is predominantly business-centred (weak sustainability) which could potentially lead to the acceleration of unsustainable growth patterns and thus harm the goals of sustainable development. Particularly, the focus on customer demands and the understanding of digital instruments to do business-as-usual from a sustainability perspective but faster and more efficient seems to pose a risk on sustainable development. This worldview was found in all companies but to different degrees.

Different sustainability types of digitalisation can be distinguished in the sample. While pioneer companies can inform policy-making, the other types could be addressed by information exchange, support and regulation to foster a more sustainable take on digitalisation by companies. The unsustainable digitalisation type would be the most difficult one to address with soft policy instruments. One outlier was identified in the sample whose profile was likely pointing to greenwashing.

The study has certain limitations which must be considered. It is based on a qualitative case study of 20 cases, so the results are limited regarding their generalisability. Moreover, the reports analysed refer to only one point in time, namely, the reporting year 2019, and can therefore only describe the situation based on this current presentation. Certain measures were taken to ensure the validity of results such as intercoder reliability, discussion of the code-system and the approach of several rounds of refining the code-system. Nevertheless, it is not possible to avoid assigning of wrong codes in single cases. Given that the results were discussed in terms of tendencies and not absolute statements, this is not expected to influence the overall picture. It was also not the purpose of the study to rate single companies according to their results. Further, it is only possible in the context of this study to deliver first ideas on how to address the sustainability types of digitalisation, while it is not possible to suggest how to change certain worldviews based on the results.

To assess the direction in which industrial digitalisation is developing and test the approach of applying corporate worldviews to analyse developments, a broader empirical basis is needed, which should include different countries, sectors and longitudinal studies. Further research could also elaborate more on the preconditions for addressing and maybe even influencing worldviews on a corporate level building on research such as Stubbs and Cocklin (2008), which shows that the shift in worldviews toward a holistic perspective of ecological modernisation is constrained by the prevailing worldviews of the surrounding neoclassical socioeconomic system.

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APPENDIX A: SEARCH TERMS

Table A1 gives an overview of the applied search terms to identify text passages about digitalisation in the sustainability reports.

TABLE A1 Search terms for reports (German)

Search terms			
Digi*	additiv	Cyber	ICT
Industrie	smart	Autonom*	Cloud
Vernetz*	Intelligen*	data	
Virtu*	Künst*	Compu*	
Automatisier*	Internet	3D	

APPENDIX B: FULL CODE-SYSTEM INCLUDING NUMBER OF CODES

1 Digitalisation	0
1.1 Digital BM/Industry 4.0 and pre-stages	160
1.2 Complex Processes/Strategy	343
1.3 Products/single measures	147
1.4 Digi, only mentioned	114
2 observed relation	0
2.1 Sustainable Digi/Digi for Susta.	28
2.1.1 word creations	11
2.2 stands next to/with sustainability	97
3 What: Digital Instruments and Sustainability	0
3.1 Compliance Instruments	0
3.1.1 environmental compliance	6
3.1.2 risk management	13
3.2 BC Instruments economic	0
3.2.1 attracting employees/HR management	15
3.2.2 quality control	2
3.2.3 improve customer experience	14
3.2.3.1 assistance systems for customers	16
3.2.4 Maintenance/Service	11
3.2.5 Information, data collection and decision making	41
3.2.6 improve efficiency	14
3.3 Systemic Instruments	0
3.3.1 social/society	0
3.3.1.1 digital supported external collaboration/transparency	10
3.3.1.2 Philanthropy: school projects, etc.	11
3.3.1.3 Health/Safety	16
3.3.1.4 Employee support/benefits/training in general	48
3.3.1.5 digital supported internal communication/collaboration	18
3.3.2 environmental	0
3.3.2.1 environmental protection (Apps, Platform, Games, …)	5
3.3.2.2 Measure/Control/Analysis environmental data for optimization	25
3.3.2.3 Resource efficiency/circular economy	9

3.4 Systemic/Regenerative Instrument	0
3.4.1 Transparency already implemented	5
3.4.2 Digital Data Monitoring/Analysis/for Transformation	16
4 Why: Assumed Benefits of Digitalisation	0
4.1 Compliance Motivation	0
4.1.1 Helps to identify/avoid compliance risks	21
4.2 business-centred Motivation	0
4.2.1 improves competitiveness	12
4.2.1.1 solves a business problem	21
4.2.1.2 Company is innovative	42
4.2.1.3 supports/secures growth	24
4.2.1.4 Satisfy customer demands	138
4.2.1.5 Company creates new business models	64
4.2.2 optimize processes	22
4.2.2.1 Optimize for employees	21
4.2.2.2 Recruitment processes	7
4.2.2.3 more control	5
4.2.2.4 transparency of business processes	30
4.2.2.5 reduces errors/more security	28
4.2.2.6 more efficiency	55
4.2.2.7 Meets ecological/social requirements	12
4.2.2.8 supports maintenance	14
4.2.2.9 reduces costs	21
4.2.2.10 reduces complexity	11
4.2.2.11 improves quality	16
4.2.2.12 makes faster	39
4.2.2.13 more productivity	8
4.2.2.14 more flexibility	11
4.3 Systemic Motivation	0
4.3.1 improves resilience/safety/reliability	39
4.3.2 Transparency/Communication/Exchange	31
4.3.2.1 Data analysis for sustainability	28
4.3.3 Resource conservation/efficiency	67
4.3.4 environmentally friendly	17
4.3.5 solves an environmental/societal problem	38
4.3.6 support the SDG…	15
4.3.7 Benefits for the Global South	5
4.3.8 Climate Protection	39
4.3.9 Benefits for Society	53
4.3.9.1 Product/BuMo are supporting	49
4.3.10 provides more sustainability	39
5 Challenges of Digi	0
5.1 Compliance challenge	1
5.1.1 Business risks of technology	18
5.1.2 Cybersecurity/Data Protection	64
5.2 business-centred challenge	0
5.2.1 integrating old and new systems/coordination	11
5.2.2 recruiting digi experts	27
5.2.3 time and money-consuming	9
5.3 systemic challenge	0
5.3.1 Future of work	0
5.3.1.1 Acceptance Employees	10
5.3.1.2 Digi as a factor of job insecurity	27
5.3.1.3 health risks due to digi	12
5.3.2 Digital and Ethics of BM	20
5.3.3 increased resource use/negative impacts on natural environment	7
5.4 Regenerative	0
5.4.1 Challenges for Democracy/digi competence	12
6 How: Approach and Participation in dig. Transf.	0
6.1 Compliance/shareholder	0
6.1.1 Without Participation/top down	22
6.1.2 Buy start-Ups/'techn.' Cooperation	30
6.2 BC/Cooperation	0
6.2.1 Public/private Partnerships	6
6.2.2 Information for dig trans society	12
6.2.3 Preparing and training employees for dig trans	66
6.3 Systemic/Participatory	0
6.3.1 Creating new Apprenticeships, Study courses	11
6.3.2 Participation Society	22
6.3.3 Participation/bottom up Employees	25
6.4 Regenerative	0
6.4.1 Cooperation with Society/Ethics	10

APPENDIX C: INTERVIEW GUIDE

Excerpt of Interview guide for expert interviews used for data-triangulation (created by Simon Haddenhorst), translated from German.

1. Demographic data
   - Number of employees of the company
   - Sector of the company
   - Core business of the company
2. Part on Digitalisation
   - Are operational processes (especially in production) already digitalised?
   - If yes: What was the original reason for introducing digital technologies? What is the greatest added value for your company? Were you able to achieve potential savings in comparison to previous, non-digitalised solutions? What was the nature of these savings?
   - If no: Have you considered implementation to date? What were the arguments for or against it? Do you plan to digitize individual processes? Which ones and with what expectations?

- Are you facing specific challenges in the area of digitalisation in your company?
- Do digital technologies play a role in the implementation of sustainability management? (e.g., in the collection and analysis of relevant data for performance measurement or reporting [environmental, social and economic]).
- If yes: What are currently the biggest challenges in using them?
- If no: In your opinion, what speaks for or against their use in the medium term? How will the data be collected instead?
- Will data generated by machines be used to measure success?
- If machine data is not used: How will performance be captured/measured within production?
- Are digital technologies used to ensure compliance with your company's standards along the entire value chain?
- If yes: What are the current biggest challenges?
- Is data also transmitted from external partners?
- If yes: Is this done digitally?
- If no: In your opinion, what speaks for or against their use in the medium term?