Data Spaces as Enablers for Sustainability

Christoph Hoppe[1], Robert Schmelzer[2], Frederik Möller[3], Thorsten Schoormann[4]

Abstract: One of our society's most fundamental challenges is promoting sustainable development. Data sharing across organizations is one way to spur innovation and address the Sustainable Development Goals (SDGs) through optimizing resource utilization, fostering circular supply chains, and producing accurate information about CO_2 emissions. However, organizations often hesitate to share data given a range of concerns, including the fear of data misappropriation or the lack of control over what others do with their data. Data spaces as a novel artifact seek to tackle these issues by providing an integrated data management approach upholding data sovereignty. These spaces can boost sustainable development by being a secure and trusted digital infrastructure for organizations to share data for sustainable purposes. To disclose how this digital solution fosters sustainability, we present a set of 65 potentials of data spaces along with the dimensions of ecological, economic, and social sustainability.

Keywords: Data Spaces, Sustainability, Sustainable Development, Circular Economy

1 Introduction

Fighting global warming, reducing greenhouse emissions, improving personal health, and enabling sustainable economic growth are just a few of the most pressing issues our society faces today [Mu21], [Ro21], [Sc21]. To make these ecological, economic, and social concerns more tangible, the United Nations (UN) proposed the 17 Sustainable Development Goals (SDGs), which illustrate a shared vision of how to achieve and preserve sustainability for societies and the planet [Un15]. One promising enabler in this context is digitalization [Ri22], [Sc21], [SL17]. Particularly, novel technologies like cyber-physical systems, the Internet of Things (IoT), and data spaces generate new opportunities for inter-organizational data sharing and pave the way toward more sustainable value creation within ecosystems [AUK18], [Wo15], [De15]. This is also indicated by a review of 550 data sharing cases conducted by the Boston Consulting Group, which concludes that data sharing can contribute significantly to sustainable

---

[1] Fraunhofer Institute for Software and Systems Engineering, Industrial Manufacturing, Speicherstraße 6, 44147 Dortmund, christoph.hoppe@isst.fraunhofer.de

[2] Technische Universität Chemnitz, Business Informatics, Straße der Nationen 62, 09111 Chemnitz, robert.schmelzer@wirtschaft.tu-chemnitz.de

[3] Technische Universität Braunschweig, Institute for Business Informatics, Rebenring 58a, 38106 Braunschweig; Fraunhofer Institute for Software and Systems Engineering, Industrial Manufacturing, Speicherstraße 6, 44147 Dortmund, frederik.moeller@tu-braunschweig.de

[4] Universität Hildesheim, Department for Information Systems, Samelsonplatz, 31141 Hildesheim; Fraunhofer Institute for Software and Systems Engineering, Industrial Manufacturing, Speicherstraße 6, 44147 Dortmund, thorsten.schoormann@uni-hildesheim.de

development. For example, aggregating shared data from various sources can help address climate change by combining and verifying the same data from multiple sources or complementing different data sources, for example, in optimizing energy efficiency or supporting sustainable agricultural farming through data [Ru21]. In this paper, we take the view of one of these technical enablers, namely *data spaces*, and explore how they contribute to sustainable development by acting as a digital infrastructure for multiple participants to share data in ecosystems.

Data spaces offer the promising potential to address various sustainability goals across ecological, economic, and social concerns in practice. However, given that data spaces as technological artifacts are novel and still emerging, these potentials need to be uncovered rigorously to make them tangible for future research and applications. Consequently, we explore this phenomenon and pursue the following research question (*RQ*): *How do data spaces promote sustainability?* To answer this RQ, we report on a systematic literature review and analyze 60 data spaces working as enablers for sustainability.

This paper is structured as follows: First, the theoretical foundations of sustainability and data spaces are introduced (Section 2). Afterward, we illustrate our research approach, which follows a systematic literature review (e.g., [Br09]) as well as a procedure for clustering and conceptualization of the collected insights [Ku22] (Section 3). Following this, we present a map of data space potentials, structured according to their domain and dimensions of sustainability (Section 4). We then discuss selected use cases in detail and illustrate how they promote sustainable value creation in practice (Section 5). Finally, we conclude with our paper and indicate further research opportunities (Section 6).

2 Research Context

2.1 Sustainability and circular economy

Sustainability describes a quasi-stable state in the long term, which is considered a societal goal or paradigm [BK87]. The path to these goals is usually described as sustainable development. Its three pillars are: ecology, economy and social equity [El98]. Due to the increasing ecological challenges, the term is strongly charged with regard to the ecological dimension. Apart from the focus on one dimension, this paradigm is increasingly finding its way into all social considerations and disciplines such as information systems and engineering, but also psychology and education [PMR19]. One model that is being discussed in various places for achieving the SDGs is the circular economy (CE). According to Kirchherr et al.'s [KRH17] analysis of 114 definitions, the following characteristics of the concept were proposed: *1.* “End of life” is avoided by reducing, reusing, recycling and recovering materials along the value and use chain; *2.* It impacts at the micro (products, companies, consumers), meso (eco-industrial parks) and macro (city, region, nation and beyond) levels; *3.* It aims to achieve sustainable development while creating environmental quality, economic prosperity and social equity for the benefit of future generations; *4*. Through responsible consumers and new business models [KRH17]. In order to achieve an operating CE in practice, technical support to enable exchange of data is needed. One promising technology to ensure secure data sharing is data spaces.

2.2 Data spaces

Data spaces were introduced in computer science about 15 years ago. At that time, the term referred mostly to data integration concepts, which integrate data without a physical layer [FHM05], [HFM06]. Moreover, a data space refers to the co-existence of structured, semi-structured, and unstructured data distributed over several sources. They manage an extensive collection of data shared over various sources [Si13], [SJ11]. Nowadays, data spaces can be defined as an enabler of data sharing between organizations (e.g., in larger ecosystems), based on a set of relationships among them [Ot22], [SJ11]. According to Otto [Ot22] a data space is "a distributed data integration concept. Thus, there is no central data store or data vault into which data providers deliver their data and from where it can be accessed and retrieved by data consumers. In contrast, the exchange of the data happens directly between the two participants."

The logic pursued in data spaces is to keep the operational data with the data providers, making common database schemas obsolete [Ot22]. The fundamental traits of data spaces include data integration through a semantic level and vocabularies in accordance with linked data principles, retaining a decentralized data infrastructure and the ability to nest and overlap data [FHM05], [HFM06], [OB21]. The variety of ways data space users can connect and share data leads to the formation of data ecosystems. These data ecosystems are socio-technical systems enabling its participants to (re-)use data, promote collaboration between data providers and consumers, and link data to cutting-edge services [GGO21], [OL18]. The underlying software infrastructure of data spaces and data ecosystems must support interoperability, trust, and data sovereignty. Additionally, data spaces meet the requirements of the Data Governance Act (DGA) of the European Union, which mandates neutrality in data-sharing intermediaries [Eu20], [Ot22]. The implementation of data spaces in practice is supported by concepts such as GAIA-X [Ga19] and the IDS Reference Architecture Model (IDS-RAM) [In23], [Ot22]. The IDS-RAM describes the central software components of data spaces and provides a blueprint of a secure gateway for trusted data exchange [Ot22]. Since GAIA-X includes not only data sharing but also the storage and management of data on cloud platforms, it strives to achieve data sovereignty in a broader sense [Ga19]. In practice, the IDS-RAM and GAIA-X are closely aligned in order to allow seamless integration of architectures and support processes. From a business point of view, the term – data space – led to a common understanding of collaboration on data, driven by the desire to accomplish common business goals [Ot22]. As the centerpiece of multiple European research initiatives and industry projects, data spaces have recently received huge attention [Gi23]. Especially in the scope of sustainability and CE, data spaces are seen as a key enabler for a data-driven, sustainable value creation. A leading example in this regard is the Green Deal Data Space (GDDS) [Ad23], which is the first cross-domain data space for projects and services related to resilience and sustainability. Moreover, many other industrial data spaces address this context, such as Catena-X, an initiative launched by parts of the German automotive industry and government. Catena-X focuses on building trusted data chains in the automotive supply chain and implementing various use cases towards more sustainable value creation, such as CO_2 monitoring or material traceability [Ca22]. Both examples illustrate the potential of data spaces as enablers for sustainability, making a closer examination of them of major interest.

3 Research Design

In this paper, we report on a systematic literature review uncovering the potential of data spaces regarding sustainability. Although data spaces are a novel technological phenomenon, we observe a variety of data space initiatives entering the market. In consequence, from our perspective, the field has matured and collected a body of objects to study meriting a deeper investigation. Next, orientated at Kundisch et al. [Ku22], we describe our approach to building a potential map of data spaces enabling sustainability. We adapted a taxonomy-based approach because this allows us to make use of both empirical objects (real data spaces) and conceptual knowledge (captured in literature).

Data spaces and their application for sustainability is a field yet largely untapped in IS research. As there is a growing interest in such spaces, our review predominantly draws from the analysis of publically available data spaces and describes how contribute to sustainable development. In total, our review passed three iterations consisting of one conceptual-to-empirical iteration of investigating the literature and two empirical-to-conceptual iterations of examining real-world data spaces to disclose their potential towards sustainably (see Table 1). Below, each iteration is described in greater detail.

Iteration	Source	Sample
Iteration 1	Systematic literature review in Scopus, IEEE Xplore, Science Direct	n=9
Iteration 2	Empirical analysis of International Data Spaces Association (IDSA), EuPro Gigant	n=22 n=16
Iteration 3	Internet Research	n=13

Tab. 1: Overview of data sources

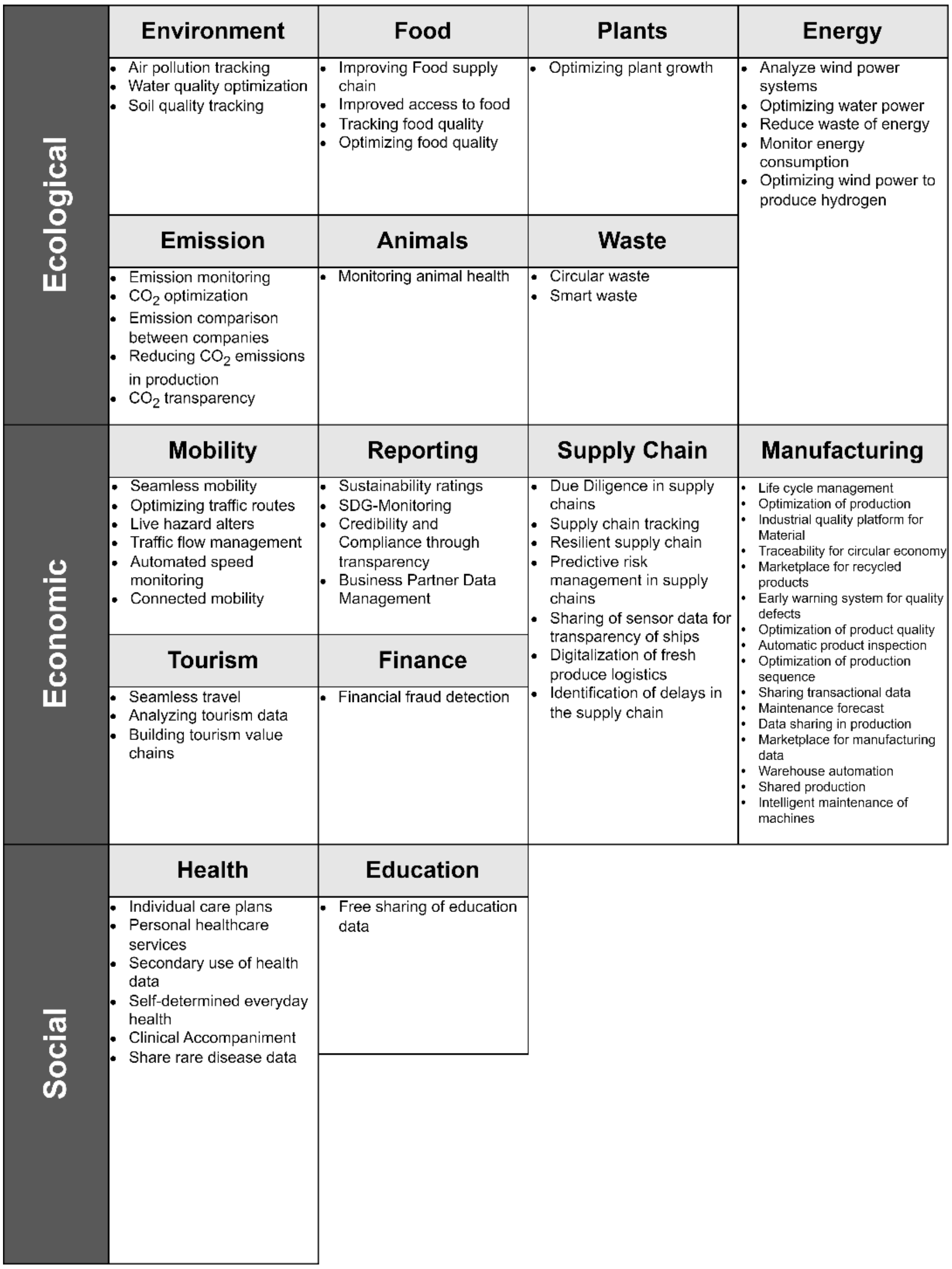
Within the *first iteration (conceptual),* we conducted a literature review with the scope to find scientific papers regarding data spaces and sustainability, published in common scientific databases, including Scopus, Science Direct, and IEEE Xplore. Therefore, we adapted the established methods of Webster and Watson [WW02] and vom Brocke et al. [Br09]. In order to perform the review, vom Brocke et al. [Br09] proposed a framework that consists of five steps. In the first step, a definition of the review scope must be given. The second step focuses on the conceptualization of the topic to be researched. In step three, the current literature search took place. Within the fourth step, the literature found is analyzed and synthesized. Subsequently, the research agenda will be defined [Br09]. To conceptualize the topic (step 2), key concepts and terms with attention to real-world data spaces regarding sustainability were identified. For the literature review conducted (step 3), we used the search string 'data space*' AND 'sustainability' OR 'circular economy' among different scientific databases and received an initial amount of 178 papers. During the literature analysis and synthesis phase (step 4), the papers found were subjected to title and abstract analysis and our exclusion criteria were applied. Moreover, all duplicates, papers that could not be accessed and not peer-reviewed papers were excluded. Furthermore, quality aspects proposed in vom Brocke et al. [Br09] and [Co88] like a consistent methodological approach were applied to the papers to be analyzed. This resulted in a total number of 29 remaining papers. Those were taken into account for an introduction and conclusion analysis, which resulted in ten papers that made it to the final corpus for the full-text analysis. After the full-text analysis, we identified nine relevant papers addressing data spaces in the context of sustainability.

Our *second iteration (empirical)* focused on the investigation of real-world data spaces enabling sustainability. In doing so, we aimed to enrich the results of the first iteration with practical initiatives and insights. Hereby, we identified 22 data spaces from the data space radar published by the International Data Spaces Association (IDSA) [In23]. Moreover, we collected 16 real-world data spaces out of the EuPro Gigant repository [Eu23]. The project aims to create a cross-site, digitally networked manufacturing ecosystem through data spaces [Gi23], [Eu23]. Finally, our *third iteration (empirical)* focused on an Internet research, which allowed us to derive additional 13 data spaces. Following our three iteration-based approach, we examined 60 real-world data spaces from the scientific literature and practice during our iterations.

Based on the systematic literature review and an empirical analysis of real-world data spaces, an overview of data space potentials regarding sustainability was derived. In line with the approach informed by [Ku22], we organized and structured our findings and present them in the form of a map. This map provides a description of the identified dimensions and data spaces potential towards sustainability.

4 Data Spaces for Sustainability

To answer the RQ, we formed dimensions and potentials of data spaces regarding sustainability and conceptualize them in a map. The map itself consists of 15 dimensions, derived from the systematic literature review. The lowest level of the map is formed by 65 specific potentials of data spaces enabling sustainability. Following the recommendations of the literature and to structure the potentials more clearly, we grouped our findings into meta-dimensions. Here, the three pillars of sustainability, ecology, economic and social were chosen as meta-dimensions (see Figure 1).



Ecological

Environment
- Air pollution tracking
- Water quality optimization
- Soil quality tracking

Food
- Improving Food supply chain
- Improved access to food
- Tracking food quality
- Optimizing food quality

Plants
- Optimizing plant growth

Energy
- Analyze wind power systems
- Optimizing water power
- Reduce waste of energy
- Monitor energy consumption
- Optimizing wind power to produce hydrogen

Emission
- Emission monitoring
- CO_2 optimization
- Emission comparison between companies
- Reducing CO_2 emissions in production
- CO_2 transparency

Animals
- Monitoring animal health

Waste
- Circular waste
- Smart waste

Economic

Mobility
- Seamless mobility
- Optimizing traffic routes
- Live hazard alters
- Traffic flow management
- Automated speed monitoring
- Connected mobility

Reporting
- Sustainability ratings
- SDG-Monitoring
- Credibility and Compliance through transparency
- Business Partner Data Management

Supply Chain
- Due Diligence in supply chains
- Supply chain tracking
- Resilient supply chain
- Predictive risk management in supply chains
- Sharing of sensor data for transparency of ships
- Digitalization of fresh produce logistics
- Identification of delays in the supply chain

Manufacturing
- Life cycle management
- Optimization of production
- Industrial quality platform for Material
- Traceability for circular economy
- Marketplace for recycled products
- Early warning system for quality defects
- Optimization of product quality
- Automatic product inspection
- Optimization of production sequence
- Sharing transactional data
- Maintenance forecast
- Data sharing in production
- Marketplace for manufacturing data
- Warehouse automation
- Shared production
- Intelligent maintenance of machines

Tourism
- Seamless travel
- Analyzing tourism data
- Building tourism value chains

Finance
- Financial fraud detection

Social

Health
- Individual care plans
- Personal healthcare services
- Secondary use of health data
- Self-determined everyday health
- Clinical Accompaniment
- Share rare disease data

Education
- Free sharing of education data

Fig. 1: Conceptualization of data space potentials enabling sustainability

4.1 Meta-dimension: Ecological sustainability

The first meta-dimension summarizes dimensions relevant to *ecological* potentials of data spaces. As a first observation, it can be stated, that the meta-dimension contains dimensions from various domains such as *emissions*, *environment* and *energy*. Moreover, the specific potentials cover a wide range from *air pollution tracking* to *emission comparison between companies* or the *optimization of water power systems*. In doing so, the most addressed SDGs in the meta-dimension of ecology are *zero hunger* (SDG 2) and *climate action* (SDG 13). Overall, the number of potentials in this meta-dimension account for 32 % of the total potentials observed, which indicates a great interest in this pillar of sustainability. One possible reason for the high level of interest could be the requirements of the legislator, who have passed various laws relating to the ecological sustainability of companies in the EU. For example, the European Corporate Sustainability Due Diligence Directive (CSDDD) [Eu22] can be considered as a leading law, that establishes comprehensive rules for companies operating in the EU to respect human rights and the environment along their operations.

4.2 Meta-dimension: Economic sustainability

In the second meta-dimension, we examined potentials of data spaces regarding sustainability purposes in the context of *economy*. As a first observation, it can be stated that most of the potentials in our sample are concerned with this meta-dimension (58 %). It is reasonable to assume that most potentials are involved here, as companies in our sample believe that sustainability from an economic point of view has the most immediate impact on their day-to-day business. Similar to the *ecological* meta-dimension, a wide range of dimensions and potentials can be observed. For instance, the domains of *mobility* as well as *manufacturing* and *supply chain* are represented with a variety of specific potentials like the *optimization of traffic routes*, *material traceability* or *predictive risk management in supply chains*. Another observation shows that most of the potentials inside the meta-dimension of *economic* are located in the dimension of *manufacturing*. Based on these findings, we anticipate that there is a huge interest to create data spaces for manufacturing purposes in practice. As the majority of the data spaces examined in this study are located in Europe, where the sector of industrial manufacturing is very important, we assume that enough funding can be provided in this area to carry out research and industrial projects in the field of data spaces. Furthermore, there are laws like the German Due Diligence Supply Chain Act [Fe21] that demand a sustainable manufacturing and supply chain, considering various sustainability aspects. The SDGs addressed the most in this meta-dimension are *decent work and economic growth* (SDG 8), *industry, innovation and infrastructure* (SDG 9) and *responsible consumption and production* (SDG 12).

4.3 Meta-dimension: Social sustainability

The third meta-dimension deals with *social* potentials of data spaces in terms of sustainability. Compared to the other meta-dimensions, it can be stated that there are significant fewer potentials (10 %) located in this meta-dimension. We assume that the meta-dimension is smaller compared to the others, as the social sector has fewer financial resources to build and operate data spaces in practice. The meta-dimension itself is divided into the dimensions *health* and *education*. While in the dimension of *health* different potentials like *individual care plans* and the *sharing of rare disease data* are located, there is only the potential of *free sharing of education data* in our sample placed in the dimension of *education*. The SDG mentioned the most in the *social* meta-dimension was *good health and well-being* (SDG 3).

5 Illustration of Selected Data Space Potentials

This section gives a deeper insight into selected potentials from our potentials map and demonstrates their applicability and relevance to sustainability. For this purpose, we choose the *traceability* use case from the German data space Catena-X [Ca23] as well as the *predictive risk management in supply chains* case from the PAIRS project [PA22]. Following, both use cases are described in detail based on public data.

The manufacturing of a vehicle is a complex process, involving multiple steps from production over usage to recycling. In order to coordinate all the processes inside the life-cycle of a vehicle, materials used must be traced. The use case *traceability* aims to trace hardware and software applications ranging from production to recycling in the near future [Ca23]. In doing so, information on each work step are recorded and material as well as part lists are developed. This gives rise to continuous data chains that show when and where which materials, components, or software were used in the value creation process of a vehicle. Through data spaces, those continuous data chains can be shared with other participants inside the value chain, in compliance with rules and their respective data sovereignty. All participants use a common ecosystem, through which they document their hardware and software deployments and exchange information. Thereby, Catena-X also explicitly addresses small and medium-sized enterprises (SMEs), providing compatible, interoperable solutions from an Excel upload via standardized interfaces to open-source and manufacturer-specific traceability solutions [Ca23], [Ca22]. As a result, the consistent *traceability* of materials leads to multiple positive impacts on sustainability. For example, the CO_2 footprint calculation of a product across the entire life-cycle, a simpler recall of materials and a successful CE can be realized through continuous data chains, leading to accomplish the SDGs of *decent work and economic growth* (SDG 8), *industry, innovation and infrastructure* (SDG 9), and *responsible consumption and production* (SGD 12).

The collapse of supply chains has now reached global proportions. Behind a final supply chain are numerous other supply chains. If just one of these chains collapses, the entire process comes to a standstill. The resulting sensitivity extends from raw material extraction to material procurement and includes all logistical imponderables such as the closure of ports and lack of transport options due to staff shortages [PA22]. To solve this, the use case *predictive risk management in supply chains* is developing a service-oriented, open data infrastructure to predict the emergence and impact of crisis situations to create transparency and initiate precautionary measures for risk minimization. The technology will incorporate both the initial crisis event and the reactions of various actors in a cross-domain data space in order to generate targeted recommendations for action [PA22]. In doing so, they aim to support the SDGs of *decent work and economic growth* (SDG 8), *Industry, innovation and infrastructure* (SDG 9), as well as *responsible consumption and production* (SGD 12).

6 Conclusion and Future Work

In this paper, we have developed a map to collect, group and organize real-world sustainability potentials enabled by data spaces. To the best of our knowledge, there is currently no other study that examines the field of data spaces as an enabler for sustainability-related potentials from both a scientific and practical point of view. Therefore, several implications for science and practice can be derived from our findings.

In terms of *scientific contributions*, our paper advances knowledge of data spaces in the context of sustainable development. Our map presents a big picture of the sustainability landscape enabled through data spaces, which is one of the most important and future-oriented research fields for the industrial value creation and society in the 21st century.

Also, our findings have *implications to practice*. As mentioned, various regulations, such as the Due Diligence Supply Chain Act or CSDDD, require companies to act with regard to the three pillars of sustainability, which requires secure cross-company data sharing [Fe21], [Eu22]. As a result, industry needs knowledge of data space potentials related to sustainability in order to support their strategic decisions towards more sustainable value creation. Our paper contributes to solving these problems by providing a conceptualization of the data space potentials in terms of sustainability. In this way, our findings support companies to implement the regulations of the legislators. In particular, the map presented helps practitioners to gain and classify knowledge in this area.

Naturally, the interpretation of results also includes the discussion of *limitations* that affect this study. Data spaces in general, and particularly in the context of sustainable development, are a rapidly evolving field that remains relatively unexplored, even at this point in time. As a result, our study is a time-limited contribution. Therefore, the data sources and potentials map need to be updated regularly to remain relevant. Furthermore, our findings are based on literature derived from common scientific databases and practical data space initiatives. Despite a strict methodical approach, the selection of the underlying data can be subjective and biased. It is unlikely that the scientific literature and data spaces analyzed in this paper cover all sustainability potentials where data spaces might develop in the future.

However, the aforementioned limitations lead to possibilities for *future research* directions. As a next step, we want to conduct a series of interviews with experts from science and industry to find out how data spaces can support companies in reaching sustainability goals and act as an enabler of a CE. In doing so, we aim to derive transition patterns for companies moving towards a CE and point out how data spaces can support this process. Based on the transition patterns found, the development of archetypical patterns for data spaces enabling a CE could be a common next step.

Acknowledgement

This work was partially funded by the “Digital ecosystem for a sustainable circular economy in the automotive industry” (DIONA) project. The project DIONA is funded by the German Federal Ministry of Education and Research.

Bibliography

[Ad23] Advaneo GmbH: Green Deal Dataspace - Resilience & Sustainability. https://green-deal-dataspace.eu/de/, accessed: 11/04/2023.

[AUK18] Antikainen, M.; Uusitalo, T.; Kivikytö-Reponen, P.: Digitalisation as an Enabler of Circular Economy. In (Sakao, T. et al. ed.): Proceedings of the 10th CIRP Conference on Industrial Product-Service Systems (IPS2). Elsevier B.V., Amsterdam, pp. 45–49, 2018.

[BK87] Brundtland, H.; Khalid, M.: Our Common Future: Report of the World Commission on Environment and Development. Oxford University Press, USA, 1987.

[Br09] vom Brocke, J. et al.: Reconstructing the Giant - On the Importance of Rigour in Documenting the Literature Search Process. In (Newell, S. et al. ed.): Proceedings of the 17th European Conference on Information Systems (ECIS), Verona, Italy, 2009.

[Ca22] Catena-X Automotive Network e.V.: Catena-X Automotive Network. https://catena-x.net/de/, accessed: 11/04/2023.

[Ca23] Catena-X Automotive Network Consortium: Traceability as the backbone of Catena-X. https://catena-x.net/en/mehrwerte/traceability, accessed: 11/04/2023.

[Co88] Cooper, H. M.: Organizing knowledge syntheses: A taxonomy of literature reviews. Knowledge in Society 1/1, pp. 104–126, 1988.

[De15] Deloitte: The more things change: Value creation, value capture, and the Internet of Things. https://www2.deloitte.com/us/en/insights/deloitte-review/issue-17/value-creation-value-capture-internet-of-things.html, accessed: 30/03/2023.

[El98] Elkington, J.: Partnerships from cannibals with forks: The triple bottom line of 21st-century business. Enviromental Quality Management 8/1, pp. 37–51, 1998.

[Eu20] European Commission: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A European strategy for data. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0066, accessed: 30/03/2023.

[Eu22] European Commission: Corporate sustainability due diligence directive. Fostering sustainability in corporate governance and management systems. https://commission.europa.eu/business-economy-euro/doing-business-eu/corporate-sustainability-due-diligence_en#what-are-the-next-steps, accessed: 07/04/2023.

[Eu23] EuProGigant: Internationale Datenräume. https://euprogigant.com/wissens-hub/internationale-datenraeume/, accessed: 05/04/2023.

[Fe21] Federal Ministry of Labour and Social Affairs: Act on Corporate Due Diligence Obligations in Supply Chains. https://www.bmas.de/DE/Service/Gesetze-und-Gesetzesvorhaben/Gesetz-Unternehmerische-Sorgfaltspflichten-Lieferketten/gesetz-unternehmerische-sorgfaltspflichten-lieferketten.html, accessed: 07/04/2023.

[FHM05] Franklin, M.; Halevy, A.; Maier, D.: From databases to dataspaces. ACM SIGMOD Record 4/34, pp. 27–33, 2005.

[Ga19] Gaia-X European Association for Data and Cloud AISBL: Gaia-X: A Federated Secure Data Infrastructure. https://gaia-x.eu/, accessed: 11/04/2023.

[GGO21] Gelhaar, J.; Groß, T.; Otto, B.: A Taxonomy for Data Ecosystems. In (Bui, T. ed.): Proceedings of the 54th Hawaii International Conference on System Sciences (HICSS), Hawaii, USA, 2021.

[Gi23] Gieß, A.; Möller, F.; Schoormann, T.; Otto, B.: Design Options for Data Spaces. In: Proceedings of the 31st European Conference on Information Systems (ECIS), Kristiansand, Norway, 2023.

[GV95] Glass, R. L.; Vessey, I.: Contemporary application-domain taxonomies. IEEE Software 4/12, pp. 63–76, 1995.

[HFM06] Halevy, A.; Franklin, M.; Maier, D.: Principles of dataspace systems. In: Proceedings of the twenty-fifth ACM SIGMOD-SIGACT-SIGART symposium on Principles of database systems. ACM, New York, NY, USA, pp. 1–9, 2006.

[In23] International Data Spaces Association: IDS Reference Architecture Model 4.0. https://docs.internationaldataspaces.org/knowledge-base/ids-ram-4.0, accessed: 11/04/2023.

[KRH17] Kirchherr, J.; Reike, D.; Hekkert, M.: Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling 127, pp. 221–232, 2017.

[Ku22] Kundisch, D. et al.: An Update for Taxonomy Designers. Business & Information Systems Engineering 4/64, pp. 421–439, 2022.

[Mu21] Mulhern, O.: 2020: A Climate Change Perspective. https://earth.org/data_visualization/2020-a-climate-change-perspective/, accessed: 30/03/2023.

[OB21] Otto, B.; Burmann, A.: Europäische Dateninfrastrukturen. Informatik Spektrum 4/44, pp. 283–291, 2021.

[OL18] Oliveira, M. I. S.; Lóscio, B. F.: What is a data ecosystem? In (Janssen, M. et al. ed.): Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age. ACM, New York, NY, USA, pp. 1–9, 2018.

[Ot22] Otto, B.: Designing Data Spaces. The Ecosystem Approach to Competitive Advantage. Springer International Publishing; Springer, Cham, 2022.

[PA22] PAIRS-Project: Predictive risk management in supply chains. PAIRS, 2022.

[PMR19] Purvis, B.; Mao, Y.; Robinson, D.: Three pillars of sustainability: in search of conceptual origins. Sustainability Science 3/14, pp. 681–695, 2019.

[Ri22] Rickmann, H.: Digitalization: Enabler for a sustainable future, https://www.telekom.com/en/company/management-unplugged/details/digitalization-enabler-for-a-sustainable-future-1010186, accessed: 30/03/2023.

[Ro21] Robinson, D.: 14 Biggest Environmental Problems of 2021, https://earth.org/the-biggest-environmental-problems-of-our-lifetime/, accessed: 30/03/2023.

[Ru21] Russo, M.; Young, D.; Feng, T.; Gerard, M.: Sharing Data to Address Our Biggest Societal Challenges. https://www.bcg.com/publications/2021/data-sharing-will-be-vital-to-societal-changes, accessed: 11/04/2023.

[Sc21] Schoormann, T. et al.: Achieving Sustainability with Artificial Intelligence. A Survey of Information Systems Research. In: Proceedings of the 42nd International Conference on Information Systems (ICIS), Austin, USA, 2021.

[Si13] Singh, M.: A Framework for Data Modeling and Querying Dataspace Systems. In: Proceedings of the 2013 Conference on Data Mining and Warehousing (ICDMW), pp. 17–25, 2013.

[SJ11] Singh, M.; Jain, S. K.: A Survey on Dataspace: Proceedings of the Fourth International Conference on Network Security & Applications (CSNA), pp. 608–621, 2011.

[SL17] Seele, P.; Lock, I.: The game-changing potential of digitalization for sustainability: possibilities, perils, and pathways. Sustainability Science 2/12, pp. 183–185, 2017.

[SMS22] Schoormann, T.; Möller, F.; Szopinski, D.: Exploring Purposes of Using Taxonomies. In: Proceedings of the Wirtschaftsinformatik, Nürnberg, Germany, 2022.

[Un15] United Nations: Transforming our world: The 2030 agenda for sustainable development, https://sdgs.un.org/2030agenda, accessed: 02/02/2023.

[Wo15] World Economic Forum: Intelligent Assets Unlocking the Circular Economy Potential. Industry Agenda 2015, 2015.

[WW02] Webster, J.; Watson, R. T.: Analyzing the Past to Prepare for the Future: Writing a Literature Review. MIS Quarterly 26, pp. 13–23, 2002.