Towards Data Spaces for circular economy and green business value networks

Problem description and outline of a solution concept

Lukas Rilling [1], Alexander Schneider [2], Nico Castelli [3]

Abstract: Circular economy (CE) has been identified by several studies as the necessary reformation of the industry to decrease the environmental impact of production in the fight against climate change. Some studies have identified the lack of technological solutions to support the move towards a circular economy where among others the digital networking and data exchange is one of the most pressing and general problems which must be solved cross-industry and cross-country. This paper therefore identifies the most important requirements for a digital infrastructure to support CE and proposes a solution that combines all these factors by using Data Space concepts and technologies as the backbone for collaboratively collecting data in form of Digital Product Passports (DPP).

Keywords: Circular Economy, Value Networks, B2B Platforms, Digital Product Passport, Digitalization, Digital Ecosystems, Data Spaces

1 Introduction

Decreasing the amount of fossil resources needed in the industry and decreasing the amount of waste being burned and eventually dumped in landfill is one of the most striking transformations necessary to decrease global warming. Therefore, in the last years, different concepts, such as cradle-to-cradle and industrial symbiosis (IS) are summarized under the concept of circular economy (CE), aiming at an economy that tries to reuse, repair, refurbish and recycle its products and resources to the greatest extent possible.

As shown in [RS17] there are several barriers that make an adoption of the concept in the industry difficult. Especially financial and technological barriers are identified in the

[1] Fraunhofer FIT, Human-Centered Engineering & Design, lukas.rilling@fit.fraunhofer.de
https://orcid.org/0009-0005-5500-0598
[2] Fraunhofer FIT, Human-Centered Engineering & Design, alexander.schneider@fit.fraunhofer.de
https://orcid.org/0000-0002-5654-9129
[3] Fraunhofer FIT, Human-Centered Engineering & Design, nico.castelli@fit.fraunhofer.de
https://orcid.org/0000-0002-5916-876X

literature review leading to the assumption that some technological aspects need to be resolved to push the transformation of industries towards circularity.

While some of the technological barriers might be connected to missing technologies focusing on optimizing the recycling of materials, one general problem that exists cross-industry is the lack of technologies that connect businesses and help overcome interoperability gaps between companies. This might be due to an actual lack of a sufficient number of companies that provide the services necessary for reusing, repairing and recycling [Ri16], but a major technological barrier is also the lack of information exchange between companies. This leads to information deficits and hinders the search and matchmaking of circularity cooperations, which could close loops in current production chains [GCG15, JM18, RS17].

While this challenge is not exclusive to circular economy (CE) business models, it is a pervasive issue across the manufacturing sector: The crucial task of establishing compatible suppliers and customers to construct a cohesive value chain.

Interestingly the concept of value chain itself is in a state of revolution, since chains build on personal contact and established connections with fixed business partners proved to be vulnerable to crises, very recently demonstrated by the effect crises such as the COVID-19 pandemic or the Russian attack on Ukraine had on supply chains.

Therefore, more flexible, and agile solutions are required to become more adaptive and resilient in case either suppliers or customers can't uphold the established business relationship. The concept behind this is referred to as value networks [Ri20] and has been around since the early 2000s.

One important tool for value networks are digital platforms, especially in the form of B2B marketplaces, which make it easier and more comfortable for companies to find suppliers or customers. But often these marketplaces resemble a digital version of industrial catalogues without actual tools that support matchmaking, quality assurance and smart contracts and therefore lack to offer the full potential available through innovative digital solutions [BW19].

Such aspects are especially crucial when it comes to CE [BW19]. Circularity matchmaking for example needs to connect companies across industries and country borders to find connections that are in a certain sense thought "outside-the-box". Quality standards also need a more trustworthy toolset, since recycled (so called *secondary*) resources still suffer from the prejudice that their quality can't meet the standards set by primary resources. This blocks a movement towards circularity due to an information deficit about the actual quality of secondary materials [BW19].

In that sense CE can be seen as a special case of value networks, where new connections are not only or directly based on short-term economic advantages but where all connections are made based on the idea of decoupling growth and value creation from the usage of fossil resources to achieve economic advantages in the long-term [BW19, EVL22]. In [EVL22] the authors refer to business value networks that apply CE principles in their business model as *Green Business Value Networks* (GBVN).

In the following we argue that Data Spaces, a concept that has been developed since the early 2000s [FHM05], offer a solution for a secure and trustworthy data exchange between businesses and are therefore ideal to be used as a base concept for a digital industry networks that support the circularity and flexibility of GBVN – ultimately leading to a Data Space for CE.

Section 2 will briefly give an overlook of related work.

In Section 3 we describe the technological problems that hinder the adoption of B2B marketplace solutions and the adoption of CE.

In Section 4 we look at the concept of Data Spaces to sketch the advantages of a Data Space solution for CE and marketplaces.

Section 5 identifies further research questions that we see as crucial for the realisation of a Data Space for CE.

2 Related Works

The authors of [BW19] already identified B2B platforms as a technological enabler of CE and therefore, highlighted current problems of such platforms to be solved to further drive the transformation. The authors identify these platforms as a possibility to exchange all information about a product´s value flow which removes information gaps between businesses and makes it possible to further develop and optimize material and product flows by combining Fast Data and Smart Manufacturing with Big Data analysis. But to accomplish this, platform solutions need to provide data exchange models that are secure, standardized and support requirements in regard of data sovereignty and governance, which the authors do not address.

A data model that is seen as crucial in the field of digital tools for CE is the Digital Product Passport (DPP) [ATG21, Ja23, Pl22, WSM21]. DPPs are supposed to provide a data model that is collaboratively filled by companies providing information about a product throughout its production chain and even beyond. It combines information about manufacturing, usage, end-of-life and life-cycle data in general [Ja23].

While DPP is envisioned as a key technology by the German environmental ministry (BMU) and the European Commission in the CE Action Plan [Eu00a] the authors of [Ja23] pointed out that there is a lack of collected requirements that need to be fulfilled by the DPP system. Currently the European Union is focusing on the sectors consumer electronics, apparel, and batteries for the first implementations of DPPs. The *battery passport* is the first one that has been part of an EU legislation and is furthest in its development. According to the Content Guidance [Re21] the underlying Battery

Management System is supposed to use a decentralized storing. The backend structure itself is not necessarily decentralized. The interoperability with other DPPs should be guaranteed.

[Ja23] also mention Data Spaces as a possible solution for security and privacy requirements when it comes to exchanging DPPs between companies. While not going into detail about the integration of DPPs into Data Spaces the article briefly highlights the general properties of Data Spaces.

The role and importance of Life Cycle Assessments (LCA) in the implementation of CE has been discussed and analysed in various publications [NR18, Si22], but considerations on digital technologies that could be used as an enabler for LCA in various industries was so far mainly focused on blockchain technology and big data analysis [Zh20].

3 Technological requirements

We have seen that among other reasons the adoption of CE principles into a company strategy is prevented by technological barriers. While this is not described in great detail in [GCG15, JM18, RS17] there are hints that the most general problem cross-industry is data exchange. The goal of CE is to keep products working for as long as possible and sustaining the material cycle as long as possible. This makes it necessary to identify holes in a products life cycle in each step. While this could be supported to a high degree by modern data and process mining algorithms as well as machine learning and artificial intelligence, these algorithms require a high amount of detailed information. Therefore, details about the materials of a product and its production stages as well as the product's usage data needs to be tracked over the full lifetime to unlock the full potential of these algorithms [Eu00a]. The fact that these production and lifetime stages involve a high number of different companies and consumers makes data exchange a key aspect of tracking and eventually of increasing circularity through information technology.

The main barrier for the actual data exchange lies in the missing adoption of digital solutions and in the under-utilized interoperability between companies across different industries in general. Especially small and medium-sized enterprises (SMEs) in the manufacturing industry struggle with adopting digital solutions, since it poses economic risks and the time and expertise for selecting the right solution are often not available. This is also due to a misconception of the impact of adopting digital solutions and the importance of taking part in digitalization, leaving SMEs more and more behind in the general Industry 4.0 movement [So15].

This also has an impact on the adoption of platform solutions and B2B marketplaces [PM00] especially in the manufacturing industry, as low participation leads to a lower value of such a platform. Consequentially this makes it even less attractive for other companies to join the platform, which has been identified as a barrier for B2B marketplaces as enablers for CE in [BW19].

Therefore, one of the key aspects of developing digital solutions to support CE lies in lowering the barrier to implement and integrate the necessary software tools, while keeping necessary standards in respect of data security, data privacy and usage control. Additionally, it will be necessary to identify possible data models to increase the interoperability between different companies and the respective software tools they integrate and use.

4 Concept Sketch

4.1 Data Space concept

Data spaces were introduced as a concept in 2005 [FHM05]. In the last years that concept is gaining importance both in research projects such as International Data Spaces (IDS) and Gaia-X but also commercially viable Data Spaces are being established e.g., Mobility Data Space. The Data Space concept promotes trusted data exchange and data sharing without the need of central or cloud-based storage nodes while ensuring data sovereignty and support regulation enforcement through governance frameworks [OHW22, chap.1]. These frameworks are especially designed to offer open and digital standards and provide a toolset for all companies, especially SMEs, to become a part of global digital markets, overcoming the monopoly situation of Big Tech, which has overshadowed the digitalization in the last 20 years. Thereby Data Spaces could become a driver of digitalization by lowering the costs of integrating the necessary software into a company’s infrastructure and reducing the risks of integrating software tools that don’t last long due to a lack of interoperability and adoption in the industry.

The main aspects of the *Data Space* concept are [OHW22, chap.3]:

- Security
- Data sovereignty
- Data ecosystems
- Standardized interoperability

The IDS Reference Architecture Model (RAM) [Ot19] as well as the Gaia-X Architecture Document [GA00] define different categories of roles that companies and organizations can take in a Data Space ecosystem: **core participants**, **intermediary**, **software/service provider** and **governance body**, the latter being only part of the IDS RAM and consist of certification and evaluation faculties and IDS itself. Gaia-X tries to further decentralize the concept and avoids such central certification nodes and therefore only relies on the Gaia-X Trust Framework to enforce security, privacy, and transparency. **Core participants** are any company that ***owns***, ***provides***, ***consumes*** or ***uses*** data. These four types define the basic roles in a Data Space. **Intermediary** roles then make the actual connection possible providing ***broker*** services to provide information about the available data, ***clearing houses*** to track data exchange transactions and ***identity providers*** to certify and manage identities. Each data connection in a Data Space is managed by what is called a *Connector*. Connectors are installed on every node of a Data Space providing that node with the capability of communicating with other nodes, regardless of the role, while maintaining security and implementing standards for data sovereignty. Data connectors can either use proprietary implementations of data models and formats to connect a company's internal data model with a common data model, or they are enabled to use a specific data model by using extensions that are provided by third-party extension developers.

Service and **software providers** offer the tools necessary to participate in a Data Space according to the regulations and standards. While **software providers** focus on offering the necessary software to be hosted by a company itself, **service providers** offer companies the usage of the necessary software as a Software-as-a-Service (SaaS) model, making it unnecessary for them to host the connectors themselves. These two providers reduce the barriers for companies to participate in Data Spaces [Ot19].

The concept of Data Spaces in general does not only offer a way of overcoming interoperability gaps between companies but also offers a connection to data marketplaces and data applications that are able to use the provided data in an intelligent way, while keeping the standards of data sovereignty and data usage control [OHW22]. This is important, since it offers a way to introduce technological improvements such as Big Data and AI applications and makes it safer for companies to share data with companies providing such services.

4.2 Data Spaces for CE

Given the basic principles of Data Spaces as summarised in the previous section we will in the following sketch a concept that would use Data Space principles to connect businesses to adapt CE principles and increase the industry circularity.

One of the drivers of Data Spaces following the RAM includes Re-using existing technologies [Ot19] and standardize interoperability, which is crucial for introducing circularity to the industry. Therefore, it is important to state that our proposal for a Data Space for CE would not aim at replacing existing B2B marketplace but rather include them into a federated marketplace, which would combine catalogues and applications combining existing solutions across country and industry borders. This would also help to overcome the participation conundrum that a digital platforms value is highly dependent on the number of participants [BW19], since participants would not need to adopt a new platform but rather their chosen platform would be integrated into a federated Data Space, eventually guiding them towards the necessary digitalization steps necessary to fully take advantage of the Data Space.

In that sense existing marketplace solutions would at first take the role of Data Providers and Data Owner[4], providing information about companies that are registered on their respective platform. Marketplaces would then offer companies to overtake the role of Data Owner by implementing necessary digitalization standards and most importantly installing a *Connector* connecting them to the Data Space. Eventually companies could also take the role of Data Provider leaving marketplaces to focus on providing software solutions (*Data Apps* in RAM), that provide search and matchmaking functionality.

Following the idea of Digital Product Passports (DPP) [Gö00] and Industry 4.0s Asset Administration Shell (AAS) [Pl00] the key data model in the Data Space for CE would consist of digital twins representing products, pre-products or materials. These would include all information about the origin, life cycle and supply chain of the respective asset. Such information could then be used to derive information about the asset's circularity and emissions as we will further describe in Section 4.3. DPPs in general are, as mentioned before, seen as a key technology for CE [Ja23, WSM21] and their implementation in AAS was also discussed as a supporting technology for CE in [ATG21].

Figure 1: Positioning of the 5Rs in production chains to enable circularity

4.3 Solutions for 5R

To identify the advantages of the proposed concept based on Data Space technology for the adoption of CE we can think about the different aspects of CE as defined in [El15,

[4] *Data owner* here is not meant in a legal sense but rather as it is defined in the RAM [Ot19]. The role is defined as having the responsibility of defining meta data and handling usage control rules. Differences between legal data owner and the role of Data Owners in the reference model are also further discussed in [Ot19]

GP18] consisting of a collection of aspects referred to as either 3R, 4R or 5R: Reduce, Reuse, Recycle, (Repair, (Refurbish)) (see Figure 1).

Recycling is the best known and probably most implemented aspect of CE. There are many companies offering recycling services and thereby matching the waste output of production activities with the resource demands of other companies. There is a general movement towards optimizing production chains to recycle by-products also driven by regulations defined in the European Green Deal [Eu00b]. But the implementation is still very limited to specific materials, such as metals or plastics with known and established ways to recycle.

Especially for SMEs it is difficult to introduce recycling into their production chains due to several information deficits [BW19, Ri16] concerning the existence and quality of recycling methods, making it hard for companies to find waste management providers that actually match their needs

While both directions could in theory be solved by B2B marketplaces, since these offer a digital platform for businesses to publish tenders and request products and services the reality shows that these platforms are still too rare or do not adequately offer tools to overcome the mentioned information asymmetries and trust problems [BW19] when it comes to the quality of circular business connections.

Especially the lack of automatic matchmaking blocks the usefulness of B2B platforms, since matchmaking offers a way to identify new synergies based on semantic analyses of inputs and outputs of businesses and could also be used to automate the creation of new connections in value networks while prioritising companies that offer a higher degree of circularity. This has been analysed and broken down to a framework by the authors in [Łę21].

By using matchmaking in a Data Space companies could provide the necessary data to the matchmaking providers in a secure and standardized way without the risk of depending on cloud service providers with opaque data usage regulations. That way the matchmaking providers could also gain access to a higher degree of data delivered in a standardized form and thus also increase their search space and the quality and importance of their results.

Reducing the amount of resources and energy necessary to produce pre-products, products or secondary materials is also part of the 5R CE concept. Reducing is only possible if the current amount of resources and energy is known for every step in production and life span to identify the steps with the biggest impact on the total footprint. Collecting and calculating these values and impacts is often done by performing a Life Cycle Assessment (LCA) on a product type. But LCAs highly depend on secondary data and experts' knowledge on how to define the limits of the calculation and approximate factors according to ISO 14040/14044. The amount of secondary data could be reduced by using standardized data models and DPPs to collaboratively collect data about products and materials and thereby increasing the amount of primary data. This would eventually make automatically generated LCAs with standardized limits and calculation factors possible making LCAs faster and more accessible to both companies (especially SMEs) and customers. An alternative measure focused on circularity can be found in the ITU-T recommendation for a circular scoring assessment method [IT20].

The calculated results of an LCA can be used to identify bottlenecks, which could be avoided by improving a products eco-design. Since the DPP would also break down each company's impact in a product's LCA, enforcing extended producer responsibility (EPR) according to each countries respective law would also be easier. Taking action to avoid unnecessary emissions in a products manufacturing would then not only be beneficial due to the responsibility but also due to the economic advantage of developing a product or pre-product that has lower emissions than comparable products by other companies, which would be an advantage in a circular economy market.

Repairing products to enable reusage of products without the need to fully reassemble relies on expert knowledge about a product. Nowadays manufacturers of consumer products try to reduce the repairability of their products to make customers rely on proprietary repair and customer services or to reduce the motivation to reuse a product leading to more new products being sold. While solving this strategic problem would also rely on legislations the movement towards repairable products could further be driven by providing information about the repairability of a product in its DPP. This would not only open the market for third-party companies focusing on repairment tasks, but the Data Space could further work as a feedback loop providing data to the manufacturing companies about weak points in their products, eventually leading to a collaborative improvement of the product's design.

Refurbishment includes keeping parts of a product while reducing broken, worn-down or outdated parts with new ones, sending the reduced parts into the recycling step of the CE. Refurbishment can partly be seen as a more elaborate version of repairments, but since it offers the option to upgrade products it reduces the waste produced by consumers replacing whole devices only because parts of it are outdated. Using the DPP available in the Data Space could make it possible to identify parts of a product that are easy to replace again introducing several feedback loops about which product parts are most likely to be outdated, which parts are impossible to be replaced and which parts last the longest building the basic grid for a products refurbishment.

Reusing products is the most direct circularity possible in the 5R concept since it does not involve any repair- or refurbishment steps. It therefore also is the step that includes the smallest amount of data necessary and adds the smallest amount of data to the products DPP. Still the data available in the DPP could be used to introduce more transparency about a products life cycle to reselling platforms eventually enabling the consumer to choose the more circular version of a resold product, while having information about what repairments or refurbishments might be necessary in the future.

5 Outlook

In this paper we discussed the main problems that keep businesses and industries from adapting digital solutions for a CE and proposed a platform concept based on Data Space standards that could lead to an improved data exchange and improved interoperability and ultimately to an improved digitalization, especially for SMEs in the manufacturing industry.

While Data Spaces allow connecting businesses independently from data format standards and enable connectivity by using connectors that work as intermediaries it is still crucial to the success of such a Data Space to support well-defined data exchange models and bridge the currently existing interoperability gaps. The Digital Product Passport (DPP) concept enables the collection of necessary life cycle and production data of single products, pre-products or materials. The information gathered in that model would unlock the potential to circulate productions by enabling the application of the 5Rs through information exchange. The Asset Administration Shell provides a standardized way to exchange data about products or materials based on Industry 4.0 tools and platforms [Pl00] and thereby could serve as a possible wrapper for the DPP. But even though the DPP has been identified as crucial to the development of CE industries in Europe in terms of the European Circular Economy Action Plan [Eu00a] the lack of research and design perspectives that go beyond single industries or use cases is a barrier in the development and adaption of digital tools [ATG21, Ja23]. Therefore, we identify the open questions concerning the design of the European or international DPP as crucial for the further design of the proposed Data Space for CE.

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